Witness The
ARCTIC
Chronicles of the NSF Arctic Sciences Program

Spring 2002, Volume 9 Number 2

Ancient Ice, Cool Science Brings the Public Face to Face With Climate Change Research in the North

Genevieve LeMoine and Susan A. Kaplan

In November 2001, *Ancient Ice, Cool Science: Climate Change in the North* opened at the Peary-MacMillan Arctic Museum at Bowdoin College in Brunswick, Maine. On view until fall 2003, the new exhibit, designed for the general public, presents a broad array of information about contemporary research on climate change in the Arctic. The Arctic Museum's Russell and Janet Doubleday endowment funded the development and production of *Ancient Ice*.

The idea for an exhibit on climate change grew in part from visitors' reactions to previous exhibits and programs addressing the relationship of various northern groups to the environment. Local elementary school students, Bowdoin College undergraduates, tourists, and other visitors were often surprised to learn, for example, the extent of past climatic and environmental changes and that not all changes were caused by humans. Museum staff noted that, while media presentations of topics in climate change may oversimplify and sensationalize the issues, more detailed scholarly presentations are less accessible to general audiences. As the staff perceived a need to disseminate information about climate change research, they also recognized the increasing number of Bowdoin faculty teaching and investigating topics related to climatic and environmental change. They saw an opportunity to engage and challenge visitors with a wide array of information about climate change by using three-dimensional objects, supported by photographs and other graphics, to tell stories.

Ancient Ice tells its complex stories through case studies based on particular issues or specific research projects. Drawing on contributions from museum staff, college faculty, and other colleagues, the exhibit explores how:

- weather and climate are related,
- past and current climates are studied,
- arctic climates have changed in the past and are changing now,
- arctic people have adapted to past climate change, and
- present and future change may affect northern residents.

continued on next page

For thousands of years, Inuit have used sea ice, an integral part of the arctic marine ecosystem, as a hunting platform and a highway. Employing Inuit techniques, explorers such as Robert E. Peary traveled with dog-drawn sleds over the sea ice of the Arctic Ocean in hopes of reaching the North Pole. On his 1906 and 1908 expeditions, Peary, his crews, and Inuit companions ferried dogs, men, and supplies across numerous leads—cracks that open in the ice—using blocks of ice as barges. Ultimately, Peary's path to the North Pole in April 1906 was blocked by a large expanse of open water and moving ice. Today, travel over sea ice is increasingly difficult and dangerous, as the ice cover is thinning (hand-tinted glass lantern slide by Donald B. MacMillan, 1908–09. Gift of Donald and Miriam MacMillan, © Bowdoin College).

Published by the Arctic Research Consortium of the United States • 3535 College Road • Suite 101 • Fairbanks, AK 99709

Setting the Context: Weather and Climate

Because most visitors have little background in climate studies, *Ancient Ice* introduces basic concepts of weather and climate. For the exhibit, Bowdoin College faculty Peter Lea (Geology), Carey Phillips (Biology), and programmer Randall Downer expanded their meteorological study from the college's Coastal Studies Center on nearby Orr's Island to the town of Brunswick and prepared a web site so that visitors can observe real-time data from the two locations. They can also explore historic weather trends and, through access to the Weather Underground web site (www.wunderground.com), view weather conditions across the Arctic and Antarctica. Other information that helps visitors connect weather in the short term with climate in the long term includes:

- snowfall data from recent decades in Maine (courtesy of Mark Zielinski, University of Maine, Orono);
- a comparison of instrumental records and proxy data from England over the past millennium, including information derived from ice cores, coral, lake sediments, and tree rings (prepared by Philip Jones and colleagues, University of East Anglia); and
- lake sediment core sections (courtesy of Mike Retelle, Bates College, and Marianne Douglas, University of Toronto).

The exhibit uses tree rings to illustrate the links among weather, growth rate, and climate. Even young children frequently are familiar with the concept of annual growth rings and can grasp how this information can be used to reconstruct climate. Visitors are struck by the obvious disparities in growth rates in various species of trees and in specimens from different climatic areas. The exhibit contrasts:

- small (15–25 cm diameter) tree cookies taken from Labrador trees that were about 200 years old; the material is from a dendrochronology project run by Susan Kaplan (director of the Arctic Museum) and Rosanne D'Arrigo and Brendan Buckley (Lamont-Doherty Earth Observatory); with
- slabs of wood two feet in diameter from two trees from the Bowdoin campus. One tree, an oak, was about 200 years old when it died, while a similar-sized pine tree was only half that age.

Long-term Climate Change

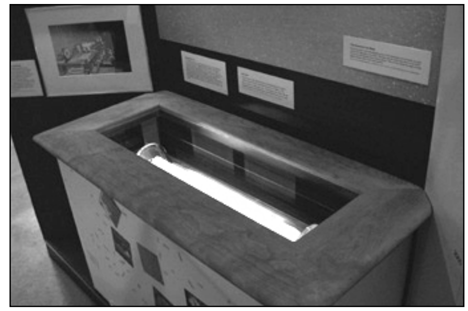
Most people are familiar with climate change in the form of ice ages—tokens of Pleistocene ice sheets abound in Maine—but in *Ancient Ice*, visitors come face to face with prehistoric indicators of tropical climate in the High Arctic. Fossil wood, 45 million years old, from the Eocene forests of Axel Heiburg Island (lent by James Basinger, University of Saskatchewan) and casts of dinosaur bones and footprints from Bylot Island and the North Slope of Alaska (courtesy of Roland Gangloff and Kevin May, University of Alaska Museum) show visitors that the Arctic was once a much warmer place.

The records from cores extracted from the Greenland ice sheet in 1992 and 1993 (see *Witness* Spring 1997) describe 110,000 years of climatic and environmental change in unprecedented detail. In October 1999, as researchers finished collecting and cataloging data from the cores, the National Ice Core Laboratory began making the deaccessioned ice cores available for educational purposes. With the assistance of Mark Twickler (University of New Hampshire), a one-meter section of the 3,029-meter ice core obtained by the Greenland Ice Sheet Project Two (GISP2) became one of the anchor pieces of the *Ancient Ice* exhibit (see photo). Visitors drawn to its jewel-like quality are soon engaged in displays that add depth to the exhibit, including:

- photographs of researchers at the drill site (courtesy of the Paleoclimatology Program of the National Oceanic and Atmospheric Administration; www.ngdc.noaa.gov/paleo/education.html);
- a drill bit used in coring glacial ice in Antarctica (loaned by Mark Battle, Bowdoin College); and
- a 2.4 m graph of changes in oxygen isotope (^{18}O) ratios, a proxy indicator of temperature, throughout the record provided by the GISP2 ice core, illustrated with images and captions highlighting significant geological and historical events.[2]

Climate Change and Wildlife

Case studies of the effects of climate change on arctic wildlife explore the effects of rapidly warming and cooling temperatures on animals, the importance of both sea ice and polynyas to marine ecosystems,



A section of the Greenland Ice Sheet Project Two (GISP2) ice core (113–114 m, dating to the 17th century) is one of the stars of the Ancient Ice *show. Lit with fiber optics against a background of black velvet, the section is displayed in a customized household freezer with a thermoplane top framed in cherry[1]. (photo by David Maschino, © Bowdoin College).*

and the dynamics of the North Atlantic Oscillation. Grant Gilchrist and Ian Stirling (Canadian Wildlife Service) and Mike Hammill (Department of Fisheries and Oceans, Canada) are among the biologists who supplied recent data on arctic species, including eider ducks, ringed seals, polar bears, and reindeer. Animal mounts, carvings, Inuit implements and clothing, photographs, and other graphics help communicate these complex stories and their significance for arctic residents.

Climate Change and Human History

Other *Ancient Ice* case studies examine how climate change has affected human societies and demonstrate how paleoclimatic research, archaeology, history, and other paleoscience disciplines can be used to understand cultural responses to climate change. Thomas McGovern (City University of New York-Hunter College) and his colleagues investigated the Greenland Norse, whose cultural inflexibility doomed them to extinction around AD 1350 (see *Witness* Autumn 1994). This story is illustrated with Greenlandic Norse objects on loan from the National Museum of Denmark.

The Norse case study contrasts with that of the Thule people—ancestors of present-day Greenlandic and North American Inuit—who successfully adapted to the Medieval Warm Period and the Little Ice Age. This story is told with decorative clothing, elaborate weapons used to hunt terrestrial and marine mammals in a variety of environments, and ethnohistoric photographs from the museum's collections. The case study illustrates how the

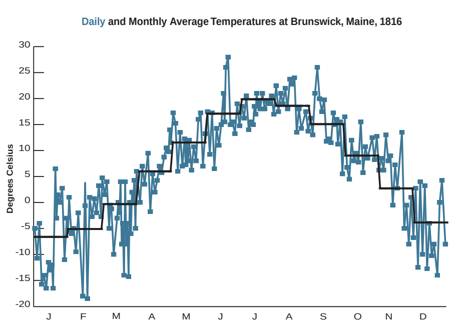
Inuit flourished in conditions that devastated the Norse.

Ancient Ice also explores the ramifications of rapid change by focusing on volcanic eruptions. Geological specimens, photographs of eruptions and of cars covered in ash generated by Mount St. Helens, and a canister of tephra from that eruption bring this unit to life.

Scientists are not the only people observing and cultivating an in-depth understanding of how northern environments have been changing. Anne Henshaw (director of Bowdoin's Coastal Studies Center) interviewed Inuit from Baffin Island concerning changing environmental conditions they have witnessed in their lifetimes. Visitors can watch videos of some of these interviews at an *Ancient Ice* kiosk. Another display devoted to 1816, known as "the year without a summer," includes the original notebook in which Parker Cleaveland, then president of Bowdoin College, recorded weather conditions three times a day, documenting the unusually cold summer that doomed Maine's agricultural industry (see figure).

Ancient Ice also explores the effects that humans can have on Earth's environment, using the toxic element lead as an example. This display includes:

- a Roman cup and piece of pipe made of lead (on loan from the Museum of Art, Bowdoin College, and Professor James Higginbotham, Classics);
- lead ore from the Polaris Mine in Nunavut, Canada (donated by Cominco, Ltd.);



In Maine, the summer of 1816 was both colder and drier than usual. Frosts hit inland farms in every month of the year, and southern Maine experienced the shortest growing season ever recorded—just 68 days. The figure shows daily and monthly mean temperatures for 1816 at Brunswick, on southern Maine's coast. William R. Baron, Historic Climate Records Office. In: Year Without a Summer? World Climate in 1816*, C. R. Harrington, ed., 1992 (figure courtesy of the author).*

To adapt successfully to changing conditions in different regions of the Arctic, Thule people and their present-day Inuit descendants have developed a complex array of tools and techniques to hunt a variety of species, depending on availability. In this July 1922 photo, a Baffin Island man holds a fish lure. In his other hand, he grasps a spear to impale fish drawn to the lure (gelatin print by Donald B. MacMillan. Kavavan and Nipatchee fishing, Goding Lake. Gift of Donald and Miriam MacMillan, © Bowdoin College).

- advertisements for "ethyl," a lead-based additive for gasoline; and
- data from the GISP2 ice core[3] that document the use of lead by the Romans, the rapid rise in atmospheric lead with the introduction of leaded gasoline, and its precipitous drop since the enactment of the 1970 Clean Air Act.

Beyond Museum Walls

Ancient Ice is not confined to its display cases. A year before the exhibit opened, the museum collaborated with Mark Battle and the Bowdoin College Physics Department to host a conference, "Unraveling Climate Change." In April 2002, the museum hosted a second symposium, "Coastal Communities and Climate Change in the North Atlantic," in collaboration with the Coastal Studies Center and the Environmental Studies Program. The museum also sponsored "Weather Whys," a morning of family activities about weather, ice, and northern peoples that attracted approximately 250 visitors in April 2002.

Dozens of climate researchers around the world contributed to the development and production of *Ancient Ice*. Individual researchers, archives, and governmental agencies were very generous, helping museum staff obtain, interpret, and customize massive datasets and extensive photographic files. On the strength of this unprecedented generosity, we have been able to increase the public's understanding of this important research and the role of the Arctic in the Earth's dynamic history.

For more information, see the Arctic Museum web site (http://academic.bowdoin.edu/arcticmuseum), or contact Susan A. Kaplan (207/725-3289; fax 207/725-3499; skaplan@bowdoin.edu). ■

Notes

1. The case was designed and developed by David Maschino, exhibit coordinator at the Arctic Museum. For information on case plans and the challenges of exhibiting ice, please contact the authors.
2. The graph was produced using data from the "Greenland Summit Ice Cores CD-ROM, GISP2/GRIP," 1997, produced by the International Ice Core Data Cooperative and the National Snow and Ice Data Center, University of Colorado, and the World Data Center for Paleoclimatology, National Geophysical Data Center.
3. Hong, S., J. P. Candelone, C. C. Patterson, and C. F. Boutron. 1994. Greenland ice evidence of hemispheric lead pollution two millennia ago by Greek and Roman civilizations. *Science* 265:1841–43; Legrand, M. and R. J. Delmas. 1998. Trends recorded in Greenland in relation with Northern Hemisphere anthropogenic pollution. *Global Change Newsletter* 36:14–17.

Genevieve LeMoine is curator/registrar, and Susan A. Kaplan is director of the Peary-MacMillan Arctic Museum and Arctic Studies Center, Bowdoin College.

Noctilucent Clouds Connected to Greenhouse Gases

This article continues a series on current topics in arctic upper atmospheric research. Studies of noctilucent clouds, their connection to two major greenhouse gases, and the detectable changes expected in the upper atmosphere due to these gases, are highly relevant to climate-change research and to atmospheric science in general.

Because noctilucent clouds are optically thin, they can be observed only when the sun is 6–12° below the horizon. Under these conditions, the Earth's shadow darkens the troposphere, while the sun continues to illuminate the upper mesosphere. In this August 2000 photo taken in Valkeakoski, Finland (24° E, 61° N), the tropospheric clouds are dark bands on the horizon, and the noctilucent clouds are the white clouds above (photo by Tom Eklund).

In 1885, observers in northern Germany first reported the appearance of high, thin clouds that seemed to glow at dusk. By 1887, numerous observers had reported night luminous clouds over northern Europe. Data from the past 30 years indicate that the number of noctilucent cloud (NLC) occurrences has nearly doubled, and in the past few years, NLC have been seen over the central United States near 40° N—the lowest latitudes yet recorded.

The highest clouds in the Earth's atmosphere, noctilucent clouds form in the upper mesosphere at an average altitude of 82 km. At most a few kilometers thick, NLC form in both polar regions during their respective summer months—typically from about 3–5 weeks before summer solstice to 7–9 weeks afterward.

The general circulation of the global mesosphere is characterized by upward winds in the summer hemisphere that cycle latitudinally to downward winds in the winter hemisphere. The expansion of gases caused by the upward winds results in summer temperatures at high latitudes in the upper mesosphere that are typically below 140 K (-133 °C). NLC form as mesospheric water vapor freezes on condensation nuclei in this pool of extreme cold as it spreads from the "summer" pole to 50° latitude by late May and retracts again by late August. The nature of the nuclei is an active research topic; the most likely candidates are meteoric dust particles and proton hydrate ions. The radius of a cloud particle is typically less than 100 nanometers. Particle size distribution and shape are still under investigation.

Connections to Global Change

The two main factors leading to NLC formation are an increase in water vapor and/or a decrease in the local temperature. Atmospheric methane and carbon dioxide levels directly affect NLC formation through these two factors. Methane is an important source of mesospheric water vapor. While tropospheric water vapor is prevented from dispersing into the mesosphere by the cold trap of the tropopause, methane escapes. Once transported into the upper atmosphere, methane can form water vapor by interacting with atomic oxygen and hydroxyl radicals. Roughly speaking, each methane molecule leads to two water molecules. The two-fold increase in methane concentrations over the Industrial era may, therefore, partly explain the increase in NLC observations.

The fact that NLC were first reported in 1885—only 117 years ago, a relatively short time, considering that the aurora has been observed for centuries—may also be connected to the massive 1883 eruption of Krakatau. It is possible that a great deal of the water vapor injected into the stratosphere by the volcano was transported to the polar upper mesosphere within two years, rapidly introducing enough new material to bring the developing, but not yet detectable, NLC into visibility.

Models indicate that the expected doubling of carbon dioxide in the next 100 years will lead to a 10 K decrease in mesospheric temperature. This will increase the altitudinal region supporting NLC formation and extend the pool of low temperatures in which the clouds form to middle latitudes. Predictions of global change also include increased tropospheric storm activity and the associated buoyancy or gravity waves that transport energy into the mesosphere region. These waves break at mesosphere altitudes, transferring momentum to the wind system that generates the cold temperatures of the summer upper mesosphere. An increase in gravity wave activity could further decrease upper mesosphere temperatures.

Science Support

A network of ground observers from North America to Asia has recorded NLC behavior on an organized basis for decades, providing invaluable information on NLC occurrence and structure (www.nlcnet.co.uk). Since 1970, satellite-borne optical instrumentation has allowed unobstructed views of NLC, improving knowledge of their global distribution and migration during the summer months.

The NSF Upper Atmospheric Research Section (www.geo.nsf.gov/atm/upper.htm) and NASA rocket and satellite programs (http://spacescience.nasa.gov) fund U.S. research on NLC, including novel remote-sensing approaches and sophisticated rocket payloads. Ground stations, such as ALOMAR in Norway (www.rocketrange.no/alomar) and Søndrestrøm in Greenland (http://isr.sri.com), use radars, lidars, and other optical instruments to study NLCs. Instrumentation on a NASA satellite known as TIMED, launched in 2001 (www.timed.jhuapl.edu), will provide new insights into NLC and the mesosphere.

For more information, see http://lasp.colorado.edu/noctilucent_clouds/, or contact Jeff Thayer in Menlo Park, CA (650/859-3557; fax 650/322-2318; thayer@sri.com).

Biocomplexity Awards Fund Arctic Research Topics

The Biocomplexity in the Environment (BE) initiative, which NSF began in FY 1999 (see *Witness* Spring/Autumn 1999) is a multiyear, agency-wide effort in environmental science, engineering, and education. Biocomplexity refers to phenomena that arise from dynamic interactions within biological systems and between these systems and the physical environment.

In the 2000 BE competition, NSF awarded $52.5 million to 16 full-scale projects and 57 incubation activities. In 2001, NSF funded 32 research projects and 41 exploratory projects for a total of $55 million. For the 2002 BE initiative, NSF expects to have $37.5 million available to fund 40–50 projects. Proposals were due earlier this year; awards will be announced this autumn in five interdisciplinary areas:

- Dynamics of Coupled Natural and Human Systems (CNH),
- Coupled Biogeochemical Cycles (CBC),
- Materials Use: Science, Engineering, and Society (MUSES),
- Genome-Enabled Environmental Science and Engineering (GENEN), and
- Instrumentation Development for Environmental Activities (IDEA).

In her keynote address to the 2002 Arctic Forum, held in May in Arlington, VA, NSF Director Rita Colwell noted that three of the 2002 BE areas—CNH, CBC, and IDEA—have “direct applications in the Arctic.”

Arctic Topics Funded in 2000 and 2001

In 2000 and 2001, the BE initiative awarded five years of funding to two arctic research projects:

- investigations of arctic frost-boil ecosystems—Donald (Skip) Walker (University of Alaska Fairbanks); and
- the bio-feedback basis of self-organization in planktonic ecosystems —Peter Verity (Skidaway Institute of Oceanography).

BE incubation awards relevant to the Arctic include:

- assembling resources for studies on the effects of oceanographic variability on marine mammal populations and Native subsistence hunting—Carin Ashjian (Woods Hole Oceanographic Institute);
- multidisciplinary investigations of human-salmon-ecosystem interactions in the Bering Sea—Herbert Maschner (Idaho State University);
- reviewing factors known to regulate dimethyl sulfide concentrations in seawater with the goal of developing a comprehensive understanding of biogenic sulfur dynamics and their links to global climate—Patricia Matrai (Bigelow Laboratory for Ocean Sciences);
- workshops to develop research partnerships and stimulate proposals to investigate the Human Dimensions of the Arctic System (HARC; see *Witness* Autumn 2001 and page 11)—Henry Huntington (ARCUS); and
- workshops to plan research on the impact of arctic environmental change on ecosystems and society (see *Witness* Autumn 2001 and page 8)—James Morison (University of Washington).

For more information, including the complete list of Biocomplexity awards, see www.geo.nsf.gov/ere/ere_be-competitions.html.

Funds Available to Study Arctic Freshwater Cycle and Land/Ocean Linkages

In February 2002, NSF announced that $30 million is expected to be available over five years to fund 20–30 awards that address the physical, chemical, and/or biogeochemical character of the arctic freshwater system and interactions with the subpolar oceans. The program solicitation emphasizes particularly the research planning of three programs:

- Arctic/SubArctic Ocean Fluxes (ASOF; see *Witness* Winter 2000/2001),
- Pan-Arctic Community-wide Hydrological Analysis and Monitoring Program (Arctic-CHAMP; see page 9), and
- the Study of Environmental Arctic Change (SEARCH; see *Witness* Autumn 2001 and page 8).

The solicitation does not seek proposals for the full ASOF, CHAMP, or SEARCH projects but instead will focus on the following topics:

- implementation of internationally coordinated observation systems that take advantage of innovative technological advances and can serve as prototypes for sustained, long-term efforts to document and understand variability in key freshwater, ice, and chemical tracer fluxes and/or processes within the arctic land, atmosphere, and upper-ocean systems and the teleconnection to the subarctic oceans;
- synthesis and integration of available data and modeling studies to reveal processes, linkages, and causes of variability in the arctic terrestrial, atmosphere, and upper-ocean hydrologic cycle; and
- documentation and assessment on the decade-to-century timescale of the variability of the arctic hydrologic freshwater cycle and associated changes in oceanic water-mass properties in the Arctic Ocean.

The proposed research must contribute to:

- a pan-arctic understanding of the freshwater land/ocean system and its influence on regional or global-scale processes, and
- the goals of SEARCH.

Proposals were due in early June 2002. For more information, contact Neil Swanberg (703/292-8029; fax 703/292-9082; nswanber@nsf.gov) or Robin Muench (703/292-7436; fax 703/292-9082; rmuench@nsf.gov) in Arlington, VA, or see www.nsf.gov/pubs/2002/nsf02071/nsf02071.html for the complete solicitation.

ARCSS All-Hands Workshop Shapes Future Directions

The Arctic System Science (ARCSS) Program held its second All-Hands Workshop in Seattle, Washington 20–23 February 2002. More than 300 members of the arctic research community came together to share information and help plan the future of the ARCSS Program.

In the weeks before the workshop, investigators considered specific research topics and initiatives in several online discussions. This virtual discussion process allowed participants to reflect on ARCSS priorities before the workshop itself.

The opening plenary presentations emphasized the primary goal of the All-Hands Workshop—articulating future directions of the ARCSS Program. Jack Kruse, outgoing ARCSS Committee (AC) chair, outlined the program's structure and objectives for future research. Mike Ledbetter, ARCSS Program director, stressed the integrative, coordinated, and thematic approach to arctic system science that characterizes ARCSS.

On behalf of the AC, Amanda Lynch introduced a process for moving from current ARCSS knowledge to future ARCSS research, stressing major discoveries, key uncertainties and readiness for reducing those uncertainties, and priorities for integrative research. The same guidelines structured reviews of each existing ARCSS component:

- Paleoenvironmental Arctic Sciences (PARCS; see page 11),
- Ocean-Atmosphere-Ice Interactions (OAII; see page 9),
- Land-Atmosphere-Ice Interactions (LAII; see page 9),
- Russian-American Initiative on Shelf-Land Environments in the Arctic (RAISE; see page 10), and
- Human Dimensions of the Arctic System (HARC; see page 11);

and of emerging arctic research initiatives:

- Pan-Arctic Community-wide Hydrological Analysis and Monitoring Program (Arctic-CHAMP; see page 9), and
- Study of Environmental Arctic Change (SEARCH; see page 8).

A moderated panel evaluated progress on the broad thematic questions outlined in the 1998 ARCSS science plan (see *Witness* Spring 1998). Four working groups discussed future directions of the emerging ARCSS Program:

At the 2002 ARCSS All-Hands Workshop, more than 45 undergraduate and graduate students formed a young investigators' working group to identify common concerns and share information (photo by Ben Wade).

- Modes of Variability in the Arctic System (see page 8),
- The Hydrologic Cycle and its Role in Arctic and Global Environmental Change (Arctic-CHAMP; see page 9),
- Land-Shelf Interactions (LSI) initiative (see page 10), and
- Pan-Arctic Cycles, Transitions, and Sustainability: Changes in Biophysical, Biogeochemical, and Social Systems (PACTS; see page 10).

In addition, an ad hoc working group of students discussed young investigators' perspectives on the program (see page 8). Each working group identified numerous opportunities for integration and collaboration (see following pages for summaries of the working group discussions). Plenary discussions revealed a broad consensus to continue the deliberately integrated approach to ARCSS research and to coordinate future efforts around science-driven thematic questions and research initiatives, rather than disciplinary components. In the final session, Jack Kruse introduced Jonathan Overpeck of the University of Arizona as the incoming AC chair.

For more information on the ARCSS All-Hands Workshop and online discussions, see the ARCUS web site (www.arcus.org/ARCSS/allhands2002), or contact Acting ARCSS Program Director Neil Swanberg or Associate Program Director Luis Tupas in Arlington, VA (703/292-8030; fax 703/292-9082; nswanber@nsf.gov; ltupas@nsf.gov), or AC Chair Jonathan Overpeck in Tucson, AZ (520/622-9065; fax 520/792-8795; jto@u.arizona.edu).

Ledbetter Passes the Torch

In May 2002, ARCSS Program Director Mike Ledbetter announced that he will leave NSF in mid-2002 to join the University of Arkansas at Little Rock as dean of the College of Science and Mathematics. Ledbetter began working with the ARCSS research community as the associate program director in 1994 and has been the director of the ARCSS Program since 1995.

Neil Swanberg, who has been a program manager in the NSF Arctic Natural Sciences Program since 2000, becomes acting program director for ARCSS beginning 17 June 2002. A biological oceanographer by training, Swanberg served as deputy executive director of the International Geosphere-Biosphere Program from 1992–2000 before joining the OPP staff (see *Witness* Spring 2000).

Luis Tupas joined OPP as ARCSS associate program director in November 2001 on an Intergovernmental Personnel Act (IPA) rotation. Tupas is on leave from the Department of Oceanography at the University of Hawaii.

In announcing his departure from NSF, Ledbetter praised the ARCSS community, saying, "The researchers, steering committees, data managers, and logistics providers have all worked in concert to produce a truly interdisciplinary research program that has continually increased its profile in arctic research."

For more information, see the ARCSS Program web site (www.nsf.gov/od/opp/arctic/system.htm). For more information on the NSF IPA program, see www.nsf.gov/oirm/hrm/jobs/rotators/start.htm.

ARCSS Focuses on Sustainability, Predictability, Feedbacks

Following the All-Hands Workshop, the ARCSS Committee (AC) met with ARCSS science management office directors and science steering committee chairs to further develop the workshop's recommendations in the context of the future ARCSS Program. The group revised and refined the five broad thematic questions from the 1998 ARCSS science plan (see previous page), based on the accomplishments and new priorities identified during the workshop. This summary introduces:

- the new ARCSS thematic questions,
- a tentative plan for the revised organization of the ARCSS Program, and
- the currently active or planned ARCSS research initiatives.

Thematic Questions

The AC recommended that ARCSS Program research be organized according to three thematic questions, which have developed from:

- the questions presented in the 1998 ARCSS science plan,
- ongoing research and new findings, and
- planning discussions within the research community.

The revised questions emphasize three interrelated concepts fundamental to an improved understanding of the arctic system as a whole:

- sustainability,
- predictability, and
- feedbacks.

An important assumption underlying these questions is that many changes in the global climate system affect the arctic system. Changes in the Arctic may, in turn, feed back on the globe.

Sustainability

How do human activities interact with changes in the Arctic to affect the sustainability of ecosystems and societies? Since human activities in the Arctic depend closely upon the environment, arctic residents and resource developers are susceptible to arctic change and capable of contributing significantly to it. For example, both human development and a warming climate can thaw permafrost, with implications for arctic engineering and development and for global biogeochemistry and hydrology. Research addressing this question includes:

- the emerging Land-Shelf Interactions (LSI; see page 10) and Pan-Arctic Cycles, Transitions, and Sustainability (PACTS; see page 10) initiatives,
- the Human Dimensions of the Arctic System (HARC; see page 11), and
- research relevant to ARCSS supported by the NSF-wide Biocomplexity in the Environment program (see page 5).

Predictability

What are the limits of arctic system predictability? Recent data indicate changes to the arctic climate over the past half-century that are without precedent over at least the previous three centuries. Although these changes have important repercussions for science and society, their causes, extent, and probable outcomes remain unclear and difficult to predict. For example, observational data suggest that warmer Atlantic waters are penetrating farther into the Arctic Ocean, affecting global weather and climate. Can we develop enough of a predictive understanding of this and many other phenomena to be able to formulate policy responses to these changes? Research related to this question includes:

- aspects of long-term observational programs, such as Paleoenvironmental Arctic Sciences (PARCS; see page 11) and the International Tundra Experiment (ITEX; see *Witness* Winter 2000/2001);
- planned programs such as the Study of Environmental Arctic Change (SEARCH; see page 8);
- the modeling components of every aspect of ARCSS research; and
- a possible initiative concerning modes of variability in the arctic system (see page 8).

Feedbacks

How will changes in arctic cycles and feedbacks affect arctic and global systems? The arctic system is linked to the global system through complex, dynamic physical and biogeochemical mechanisms, which will respond to changes in the arctic system and feed back to the global system. For example, global climate models suggest that CO_2-induced warming is amplified by declining sea ice in the Arctic, but models return widely variable results on the degree of the amplification. This question, particularly concerning feedbacks within the arctic system, has been the focus of much of the research funded by ARCSS to date, including:

- the Western Arctic Shelf-Basin Interactions Project (SBI; see page 18),
- the Russian-American Initiative on Shelf-Land Environments in the Arctic (RAISE; see page 10),
- Arctic Transitions in the Land-Atmosphere System (ATLAS; see *Witness* Autumn 2001), and
- Surface Heat Budget of the Arctic Ocean (SHEBA; see *Witness* Autumn 2001).

The new Community-wide Hydrological Analysis and Monitoring Program (Arctic-CHAMP; see page 9) initiative also addresses this question.

Program Organization

As the ARCSS Program continues to develop its integrative structure, each of the current and emerging ARCSS research initiatives will contribute primarily to one of the three thematic questions described above. The thematically driven ARCSS Program, however, will not be a restrictive structure; a project or initiative may well address multiple research questions.

While science steering committees and science management offices will continue to guide focused research efforts, existing component science steering committees may be replaced gradually by more integrative theme-based oversight committees. The ARCSS Committee, which will rotate and expand its membership, will continue to represent the community of ARCSS researchers and provide oversight and direction to the program.

Developing Research Initiatives

The initiatives discussed by the working groups at the All-Hands Workshop represent current or potential research efforts that will develop further over the next few years (see previous page and following pages for more details).

For more information, see the sources listed on page 6.

Working Group Discusses Arctic System Variability

Distinguishing natural variability from anthropogenic change in the arctic climate system is challenging because of limitations in:
- observational data series,
- temporal resolution and spatial extent of many paleoenvironmental datasets, and
- theoretical and mechanistic understanding of the structure and evolution of interannual and decadal variability.

The issue is further complicated by the increasing evidence that the arctic system, like any system, manifests preferred states that are both persistent and recurrent, referred to as modes of variability. The search for and analysis of such states is fundamental to understanding both natural variability and responses to forcing.

At the 2002 All-Hands Workshop, the Modes of Variability working group discussed the relevance of this important new research area to the arctic system and identified some key uncertainties, including:
- What is known about thresholds, abrupt changes, high rates of change, and extreme events?
- How do we define the extreme states of the arctic system?
- How do we produce useful scenarios of future change?
- What are the interactions between global and arctic modes of variability? How might arctic environmental changes affect environments and societies at lower latitudes?

Addressing these uncertainties will require improved conceptual models of variability as well as enhanced observational time series and paleoenvironmental data. The working group also identified specific opportunities for collaboration with other research efforts, including:
- NSF programs such as Long-Term Ecological Research (see page 15) and Long-Term Observatories (see *Witness* Spring 2000), as well as programs in other NSF Directorates; and
- International programs such as Arctic/Subarctic Ocean Fluxes (see page 5) and Climate Variability and Predictability (see *Witness* Winter 2000/2001).

For more information, see the ARCUS web site (www.arcus.org/ARCSS/allhands2002/modes_discussion.html).

Modes of Variability and SEARCH

The interagency Study of Environmental Arctic Change (SEARCH; see *Witness* Autumn 2001) is a major emerging research initiative, which, like the ARCSS Program, seeks to understand environmental change in the Arctic.

Because boundaries between ARCSS and SEARCH are sometimes difficult to define, discussions in the ARCSS Modes of Variability working group encompassed several issues related to SEARCH. Topics related to the developing SEARCH implementation plan included:
- establishing the dominant modes of variability of the Arctic Ocean and arctic marine and terrestrial ecosystems;
- understanding the interactions of these modes; and
- developing a modeling and observation system that will allow predictive understanding of these modes.

SEARCH Workshop Report Available

In November 2001, 68 investigators met in Seattle for the SEARCH Workshop on Large-Scale Atmosphere/Cryosphere Observations. Participants reviewed existing land, sea ice, and atmospheric observations to determine how current observation systems can best be used and enhanced to understand and anticipate the course of the ongoing changes in the Arctic.

The workshop report is available on the NOAA Arctic Theme web site (www.arctic.noaa.gov). For more information, contact Jim Overland in Seattle, WA (206/526-6795; fax 206/526-6485; overland@pmel.noaa.gov).

For more information about SEARCH, see the SEARCH web site (http://psc.apl.washington.edu/search), or contact Jamie Morison in Seattle, WA (206/543-1394; fax 206/616-3142; morison@apl.washington.edu).

Young Investigators Share Perspectives

Approximately 80 students participated in the ARCSS All-Hands Workshop. An ad hoc student working group formed on the last day of the workshop and developed recommendations in the following categories. They presented their ideas to the ARCSS community in plenary session.

Interdisciplinary Science
- Networking is especially important in the ARCSS Program, where large interdisciplinary projects are the norm.
- Specialists are vital to interdisciplinary projects; they should not be disregarded in the quest for greater integration.
- Students must be trained to work effectively with colleagues in other fields.

Collaboration
- Competition for limited funds cannot override important science questions.
- Because of the enormous size of the Arctic, data is sparse. International collaborations could help fill some of these gaps.
- Industries with experience working in the Arctic may have useful information for arctic logistics planning.

Human Impacts in the Arctic
- Arctic residents must have a voice in arctic science as stakeholders and as bearers of accumulated knowledge of the Arctic.
- Important issues related to human impacts on the Arctic that are complex or politically charged (*e.g.,* contaminants, bioaccumulation) are relevant to understanding the arctic system and should be explored by ARCSS researchers.

Spatial and Temporal Scale in ARCSS Organization
- Structure the ARCSS Program in such a way that the global, regional, and local scales are all accounted for, since the scaling issue has the potential to confound many pan-arctic studies.

Hydrological Analysis and Monitoring Work Advances

Following a 1998 recommendation of the ARCSS Committee, the ARCSS Program sponsored a community workshop on pan-arctic hydrologic studies in September 2000 at the National Center for Ecological Analysis and Synthesis in Santa Barbara, California. More than 30 investigators gathered at the workshop to:

- assess the state of the art in arctic systems hydrology, and
- identify research priorities for achieving predictive understanding of the role of the arctic water cycle in global change.

A major product of the workshop is *The Hydrological Cycle and its Role in Arctic and Global Environmental Change*, published by ARCUS in 2001. This report:

- defines major research and synthesis challenges in arctic systems hydrology,
- provides recommendations for investments in arctic systems hydrology, and
- outlines the development of a new pan-Arctic Community-wide Hydrological Analysis and Monitoring Program (Arctic-CHAMP).

The Arctic-CHAMP program aims to catalyze and coordinate interdisciplinary research and to construct a holistic understanding of arctic hydrology, through:

- integration of routine observations,
- process-based field studies, and
- integrative modeling.

Four major goals guide the Arctic-CHAMP effort:

- to assess and better understand the stocks and fluxes that constitute the arctic hydrologic cycle;
- by documenting changes to the arctic water cycle, to contribute a hydrological component to the multiagency Study of Environmental Arctic Change (SEARCH; see page 8);
- to understand the causes of changes in the arctic water cycle and assess their direct impacts on biological and biogeochemical systems; and
- to develop predictive simulations of global and human social responses to feedbacks arising from progressive changes to arctic hydrological systems.

All-Hands Workshop Discussions

During the working group discussions at the ARCSS All-Hands Workshop, participants repeatedly articulated:

- the urgent need to maintain long-term hydrological data series, and
- the importance of biogeochemical cycling and hydrological process studies in the Arctic-CHAMP effort.

Key uncertainties identified during the discussions included:

- What is the role of lakes in arctic water, energy, and biogeochemical cycles?
- What are the mechanisms for cloud formation and dissipation, and what role do arctic clouds play in the system?
- What are the controls on the timing, magnitude, and quality of river inputs into the Arctic Ocean, and what is the fate of this input?
- What are the impacts of changes in the hydrological cycle on humans?

Addressing these uncertainties will require improvements in the length and quality of data records. Aspects of the system that influence these uncertainties, such as permafrost dynamics, aerosols, snow, and vegetation, also will need study. Further, changes in these cycles will affect not just humans but also vegetation, microbial processes, and macrofauna.

The Arctic-CHAMP Science Steering Committee (SSC) is developing a detailed interdisciplinary implementation plan, and some funding has been made available to support research efforts contributing to the objectives of Arctic-CHAMP (see page 5). An online workshop in April 2002 focused on developing a human dimensions component to the Arctic-CHAMP effort (see page 11 and 28).

For more information, see www.arcus.org/ARCSS/hydro/index.html, or contact Arctic-CHAMP co-chairs Larry Hinzman in Fairbanks, AK (907/474-7331; fax 907/474-7979; ffldh@uaf.edu) or Charles Vörösmarty in Durham, NH (603/862-0850; fax 603/862-0587; charles.vorosmarty@unh.edu).

ARCSS Components Share Results and Plans

In November 2001, more than 200 researchers funded by the ARCSS Land-Atmosphere-Ice Interactions (LAII) and Ocean-Atmosphere-Ice Interactions (OAII) components gathered for their respective All-Hands meetings in Salt Lake City, Utah (see *Witness* Autumn 2001), as well as for joint sessions that included representatives of Paleoenvironmental Arctic Sciences (PARCS; see page 11) and the Russian-American Initiative on Shelf-Land Environments in the Arctic (RAISE; see page 10). The group endorsed a developing initiative to address crucial environmental research problems related to the arctic land-sea boundary (see page 10).

LAII Update

The record of the November LAII meeting is available on the LAII web site. Matthew Sturm of the Cold Regions Research and Engineering Lab replaces Terry Chapin as the chair of the LAII Science Steering Committee (SSC); the SSC is drafting a major new science plan based on discussions at the November 2001 and February 2002 All-Hands meetings (see page 10). The LAII Science Management Office will remain at the University of Alaska Center for Global Change. For more information, see the LAII web site (www.laii.uaf.edu), or contact Patricia Anderson in Fairbanks, AK (907/474-5415; fax 907/474-6722; patricia@iarc.uaf.edu).

OAII Update

Don Perovich of the Cold Regions Research and Engineering Lab replaces Lou Codispoti as the chair of the OAII Science Steering Committee. The OAII Science Management Office will remain at the University of Maryland Center for Environmental Science. For more information, see the OAII web site (http://arcss-oaii.hpl.umces.edu), or contact Jane Hawkey in Cambridge, MD (410/221-8416; fax 410/221-8490; hawkey@hpl.umces.edu).

Initiative Plans for New Nearshore and Coastal Studies

Following the November 2001 Land-Atmosphere-Ice Interactions (LAII) and Ocean-Atmosphere-Ice Interactions (OAII) sessions (see box page 9), a group of researchers serving on the science steering committees of LAII, OAII, and the Russian-American Initiative on Shelf-Land Environments in the Arctic (RAISE; see *Witness* Autumn 2001) began formulating a Land-Shelf Interactions (LSI) initiative, focused on environmental change in human and biological communities, and related physical and chemical systems, at the arctic land-sea margin.

The Land-Shelf Interactions (LSI) initiative's primary goal is to improve understanding of the biogeochemical, physical, and hydrological processes that occur in the nearshore zone of the arctic shelf, with respect to changes in:

- the global climate system,
- marine ecosystems, and
- resource use by humans.

The initiative's zone of interest lies seaward of the hydrological studies developing under the Pan-Arctic Community-wide Hydrological Analysis and Monitoring Program (Arctic-CHAMP; see page 9) and landward of the research at the shelf-basin boundary under the Western Arctic Shelf-Basins Interactions (SBI; see page 18) project, serving to effectively integrate land and sea studies without ignoring the complexity of processes that occur uniquely in this zone.

All-Hands Workshop Discussions

At the ARCSS All-Hands Workshop, additional discussions of scientific research needs at the land-sea boundary in the Arctic from a broad community perspective included the following key uncertainties:

- What are the bidirectional impacts of society and coastal environments?
- Can we determine the evolution and landscape dynamics of the shelves and nearshore zone?
- What are the mechanisms important to transport of materials in and through the coastal zone?
- What is the importance of the structural and functional patchiness of the ecosystem in this zone?
- How do processes in the coastal zone feed back with changes in the global system?

Related to these key uncertainties are various sub-themes, which include:

- biogeochemistry as a linking feature between land and sea,
- permafrost dynamics,
- atmospheric circulation and meteorological events,
- the effects of changes in the annual cycle of sea ice cover,
- the vulnerability of gas hydrates, and
- the types of information coastal communities need to adapt to rapid change.

The leaders of the LSI initiative have posted a draft science plan (see http://arctic.bio.utk.edu), developed with help from interested members of the arctic research community. An online workshop in April 2002 focused on developing a human dimensions component as part of the LSI initiative (see page 28).

For more information, see the RAISE web site (www.raise.uaf.edu), or contact Lee Cooper in Knoxville, TN (865/974-2990; fax 865/974-3067; lcooper@utkux.utk.edu) or Ken Dunton in Port Aransas, TX (361/749-6744; fax 361/749-6777; dunton@utmsi.zo.utexas.edu).

Biological Understanding is Key to Predicting Transitions

Discussions at the 2001 Land-Atmosphere-Ice Interactions (LAII) meeting and the 2002 ARCSS All-Hands Workshop (see pages 6 and 9) identified the need for a broadly integrative research initiative addressing the complexity of arctic biophysical and biogeochemical cycles and transitions. An understanding of how arctic biota, including humans, not only respond to change but also feed back and induce change is key to predicting future states of a system that can undergo rapid changes, pass through irreversible transitions in state, and show nonlinear and emergent behavior.

Although this developing initiative began in the LAII community, Pan-Arctic Cycles, Transitions, and Sustainability: Changes in Biophysical, Biogeochemical, and Social Systems (PACTS) spans the various domains of the arctic system, recognizing that investigations in and across terrestrial, marine, and atmospheric cycles will be needed. Because a major way humans interact with the Arctic is through their use of biological and environmental resources, the PACTS initiative is directly relevant to human society and plans to develop strong collaborations with the Human Dimensions of the Arctic System (HARC) initiative (see page 11).

At the All-Hands Workshop, the PACTS working group discussed ways to build on the results of previous ARCSS research to develop an understanding of the Arctic as a complex regional system. The working group addressed four interrelated topics:

- biophysical and biogeochemical cycling,
- temporal state changes (transitions) in biophysical systems,
- vulnerability and sustainability of biological systems, and
- heterogeneity, patchiness, and pattern.

These four topics are directly relevant to other ARCSS efforts. The PACTS initiative also is likely to make major contributions to two science issues that the ARCSS Program is starting to address:

- thresholds in the arctic system that seem to lead to distinct changes in system state, and
- heterogeneity in spatial and temporal extrapolation and scaling.

Members of the working group are revising the draft science plan (www.laii.uaf.edu/pubs/smo-pubs/draftplan.pdf) based on the outcomes of the working group discussions. For more information, contact Matthew Sturm (907/353-5183; fax 907/353-5142; msturm@crrel.usace.army.mil) or Terry Chapin (907/474-7922; 907/474-6967; terry.chapin@uaf.edu) in Fairbanks, AK.

Workshops Explore Human Dimensions Issues

The Human Dimensions of the Arctic System (HARC) is a broadly defined research initiative on human-arctic system interactions (see *Witness* Autumn 2001). The ARCSS All-Hands Workshop was one of the first opportunities for HARC investigators to share their findings with other ARCSS researchers. Human dimensions issues were integral to the All-Hands working group discussions. The working groups identified specific HARC research opportunities associated with the emerging ARCSS initiatives, including:

- Modes of Variability (see page 8): examine long-term records of human activity to establish connections to environmental and social changes;
- Arctic-CHAMP (see page 9): identify and characterize the interactions of people and the arctic hydrological cycle, including human influences on and responses to change;
- LSI (see page 10): examine the feedbacks in this key area for human activities, such as hunting, settlement, development, and transportation; and
- PACTS (see page 10): include human influences in shaping ecosystems, particularly at local and regional levels.

As a first step in developing project-level ideas for HARC contributions to two of these themes, in April 2002 the HARC Science Management Office (SMO) sponsored online workshops on:

- Humans and Arctic Hydrology (see page 28); and
- Humans and the Arctic Nearshore Zone.

Previous HARC online workshops covered:

- Arctic Weather: how weather is changing and affecting arctic residents;
- Northern Treeline: the relationships between humans and the location of the treeline; and
- Sea Ice: the effects of changes in sea ice on coastal communities.

The discussions from all the workshops are available on the HARC web site (www.arcus.org/harc). For more information, contact SMO Director Henry Huntington in Eagle River, AK (907/696-3564; fax 907/696-3565; hph@alaska.net).

Paleosciences Provide Temporal Depth to Initiatives

All the emerging ARCSS initiatives will require inclusion of the temporal perspective provided by paleodata. Working group discussions at the 2002 All-Hands Workshop identified specific contributions from the arctic paleoscience community needed to achieve the goals of each initiative. These contributions will rely on expanding and improving the Paleoenvironmental Arctic Science (PARCS) network of sites that record the spatial variability of the arctic system over long timescales.

Modes of Variability

Paleorecords can characterize climatic, oceanographic, hydrological, and biogeophysical variability, rates of change, and the timing and magnitude of abrupt changes in the past. An expanded network of accurately dated, high-resolution proxy records is needed to:

- place the prominent 20th Century warming and the shift in the mode of the Arctic Oscillation in the context of longer term variability, and
- identify the environmental consequences of this change in climate.

Land-Shelf Interactions

An improved understanding of the recent geologic history of coastal zones is needed to better predict the environmental consequences of changes taking place on- and offshore. For example, the rate of sea-level rise during the Holocene controls the rate at which sub-sea permafrost warms and the consequent threat of methane and carbon dioxide release. Records of changing sea-ice conditions, coastal-plain hydrology, and the history of deltas and estuaries are all preserved in coastal areas. Ancient beach deposits record oceanographic conditions of earlier warm periods, and coastal geomorphic features preserve evidence of the dynamics of beach processes and the human cultures that inhabited them.

Pan-Arctic Cycles, Transitions, and Sustainability (PACTS)

Of particular interest in predicting future states of arctic biophysical and biogeochemical systems are factors that may cause rapid changes of state and thus make nonlinear trajectories likely. For example, invasion of woody plants and thawing of permafrost are both thresholds that seem to induce rapid changes, such as shifts in biogeochemical feedbacks and energy exchange processes. Combined efforts must employ techniques over a range of temporal scales, including long-term experiments and observational studies (0–10 year time frame), use of traditional ecological knowledge (10–50 year time frame), and high-resolution paleorecords (10–1000 year time frame).

Arctic-CHAMP

An improved understanding of modern hydrological processes is needed to better interpret and calibrate the proxy records used to infer past hydrospheric changes. In turn, long-term records of all aspects of the hydrological cycle (*e.g.,* lakes, rivers, glaciers, permafrost) are needed to understand the causes and consequences of these systems' natural variability. For example, lake sediments integrate a variety of hydrologic and biogeophysical processes on the watershed scale. The synergy between modern processes and paleorecords of arctic hydrological systems provides strong motivation for research efforts linking PARCS and Arctic-CHAMP.

For more information, see the PARCS web site (www.ngdc.noaa.gov/paleo/parcs/), or contact PARCS co-chairs Glen MacDonald in Los Angeles, CA (310/825-2568; fax 310/206-5976; macdonal@geog.ucla.edu) or Darrell Kaufman in Flagstaff, AZ (928/523-7192; fax 928/523-9220; darrell.kaufman@nau.edu).

Research Documents Chronic Impacts of 1989 Oil Spill

On 24 March 1989, the supertanker *Exxon Valdez* ran aground on Bligh Reef in Prince William Sound, Alaska, spilling almost 11 million gallons of crude oil. The spill oiled more than 1,300 miles of Alaska coastline and 10,000 square miles of coastal seas. The ecological damage has had severe impacts on human communities, especially those dependent on renewable natural resources.

With funding from NSF, the NSF-sponsored Natural Hazards Research and Applications Information Center at the University of Colorado, and the Prince William Sound Regional Citizens' Advisory Council, Steve Picou (University of South Alabama) and Duane Gill (Mississippi State University) have been investigating community impacts of the *Exxon Valdez* oil spill (EVOS) since 1989.

Their initial project focused on Cordova and used Petersburg, in southeast Alaska, as a control community. Both communities depend on renewable natural resources such as fish. Findings demonstrated significantly elevated levels of psychological stress and social disruption in Cordova, associated with commercial fishing occupational roles and subsistence cultural traditions—two social structural components that were directly threatened by the EVOS (Picou and Gill 1997).

Based on these findings, Picou and Gill developed, implemented, and evaluated an alternative community mental health program designed to help the community mitigate chronic social impacts of the EVOS. Results from this project are described in "Coping With Technological Disasters" (www.pwsrcac.org/oldsite/CWTD/CWTDmenu.html).

When victims of technological disasters seek compensation through litigation, the litigation can become a "secondary disaster," a continuous reminder of the original event that may last for years and further delay community recovery. This has been the case for Cordova residents who were part of class-action litigation against Exxon. Although a 1994 jury awarded plaintiffs almost $300 million in actual damages and $5 billion in punitive damages, to date no settlement money has been paid.

This situation provides the foundation for the most recent research. In 2000, the NSF Arctic Social Sciences Program awarded Picou and Gill a two-year grant to study long-term community change resulting from both resource loss associated with the EVOS and the litigation outcome.

Very little previous research had addressed how litigation decisions affect community recovery from technological disasters. The present study affords an opportunity to document consequences resulting from final resolution. The project goal is to further understand the chronic nature of social impacts resulting from technological disasters. The objectives are:

- to build on and continue previous research on community impacts of the EVOS by monitoring social disruption, psychological stress, threats to resources, and community change; and
- to examine effects of the litigation decision by collecting data before and after a decision is finalized.

Data from community residents, commercial fishermen, and Alaska Natives will be combined with data collected from 1989–92 and 1995–97 to form a unique longitudinal dataset on chronic impacts of technological disaster. In the fall of 2000, researchers collected community data from 200 residents of Cordova and 200 residents of Petersburg. In 2001, they collected data in Cordova from 143 commercial fishermen and 65 Alaska Natives. Preliminary results indicated that:

- Cordova continues to experience elevated levels of psychological stress and social disruption, and
- these impacts are most pronounced among commercial fishermen and Alaska Natives.

Contrary to the "spillionaire" scenario popularized in the media, most litigants do not expect to receive a large amount of money, and the majority indicate that they will use compensation money to pay debts and save for retirement. As expected, Cordova respondents anticipate positive outcomes on community, family, work, and future plans if the jury decision is upheld, and negative consequences for the community if Exxon successfully appeals the decision.

The researchers are awaiting final resolution of the litigation before starting phase two of their current project. This phase will include another cross-sectional survey of Cordova and Petersburg and a follow-up survey of commercial fishermen and Alaska Natives who participated in the first phase of the project.

For more information, contact Duane Gill in Mississippi State, MS (662/325-1570; fax 662/325-7966; duane.gill@ssrc.msstate.edu) or J. Steven Picou in Mobile, AL (251/460-6347; fax 251/460-7925; spicou@usouthal.edu).

References

Picou, J. S. and D. A. Gill. 1997. Commercial fishers and stress: Psychological impacts of the *Exxon Valdez* oil spill. In J. S. Picou, D. A. Gill and M. J. Cohen (eds.). *The* Exxon Valdez *Disaster: Readings on a Modern Social Problem.* Kendall-Hunt, Dubuque, IA. pp. 211–35.

The Arctic Social Sciences Program

Robin Muench is acting program manager for the Arctic Social Sciences Program (ASSP). Muench, who is on leave from the Office of Naval Research, replaces Fae Korsmo, who is now a program director in the NSF Experimental Program to Stimulate Competitive Research (EPSCoR). NSF expects to name a permanent Arctic Social Sciences program manager in the near future.

ASSP welcomes proposals in February and August of each year to fund research in any social science discipline in the Arctic. For more information, see www.nsf.gov/od/opp/arctic/social.htm, or contact Muench in Arlington, VA (703/292-8030; fax 703/292-9082; rmuench@nsf.gov)

Major Survey Examines Why People Live in the Arctic

Why do people continue to live in the Arctic? A 1994 Greenland Homerule Government survey indicated that many residents remained in remote settlements despite limited economic opportunities. Intrigued by these results, Birger Poppel and Thomas Andersen (Statistics Greenland) suspected that standard measures of living conditions, such as income and employment, do not include factors that appear to be important to arctic residents, including the natural environment and established social relationships. Poppel and Andersen contacted researchers in the eight arctic nations with the idea of conducting a larger scale survey designed to develop a better understanding of:

- living conditions in the Arctic,
- people's choices about places to live, and
- the effects of different national policies on arctic living conditions.

The resulting partnership of researchers and indigenous organizations in Canada, Denmark, Finland, Greenland, Norway, Russia, Sweden, and the United States is conducting the *Survey of Living Conditions in the Arctic: Inuit, Saami, and Indigenous Peoples of Chukotka*.

In structured 90-minute personal interviews, researchers ask arctic residents about family, household production, language, formal and traditional education, mobility, employment, subsistence, health, housing, income, community activities, religion and spirituality, environment, and their subjective sense of well-being.

Respondents are selected using probability sampling methods. The information from 18,000 individual interviews will be processed to protect the confidentiality of respondents and combined into an international database. Researchers have completed more than 12,000 interviews in Canada and the Northwest Arctic region of Alaska. Interviews in the other six countries and the remaining Alaskan communities—in the North Slope and Bering Straits regions—will be completed in January and February 2003.

The U.S. portion of the study is funded by the NSF Arctic Social Sciences Program through grants to the University of Alaska Institute of Social and Economic Research. The Alaska Native Management Board (ANMB), established specifically to direct the study, includes representatives from the Alaska Native Science Commission and major Iñupiat organizations—Maniilaq, Kawerak, the Northwest Arctic Borough, the North Slope Borough, NANA (the Northwest Alaska Native Association), the Bering Straits Foundation, Ukpeagvik Iñupiat Corporation, and the Inuit Circumpolar Conference. The ANMB has taken an active role in the decision to participate in the study as well as in the design of the questionnaire. Ed Ward, a representative of Maniilaq on the ANMB, has also contributed to study decisions at international team workshops.

Jack Kruse, director of the Alaska portion of the study, notes that the survey cannot, by itself, conclusively distinguish how the many forces for change, including governmental policies and climate variability, have contributed separately to changing living conditions in the Arctic. "We see the *Survey of Living Conditions in the Arctic* as a major first step in understanding changes in arctic human systems. We hope that it serves to raise many questions among policy leaders, researchers, and community residents. Active debate and research on these questions can serve as a sound basis for improving public policies and individual choices."

For more information, see the project's web site (www.arcticlivingconditions.org), or contact Jack Kruse in Leverett, MA (413/367-2240; fax 413/367-0092; afjak@uaa.alaska.edu).

The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change

With funding from the NSF Arctic Social Sciences Program, ARCUS has published a collection of 10 papers describing contemporary efforts to document indigenous knowledge of environmental change in the Arctic, with an emphasis on the ways arctic peoples perceive, influence, and are influenced by their surroundings. *The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change* reviews major individual studies on indigenous knowledge and climate change undertaken during the past few years, primarily in North America. The volume offers:

- a comparative survey of research practices and paradigms used in current documentation studies of indigenous knowledge, and
- a general assessment of the field and of the data collected.

The text is accompanied by local observations, quotations from interviews, personal observations, illustrations, and photographs. Contributors include well known academic researchers and Native people from Canada, Finland, and the United States. The publication is designed to be useful to both researchers and communities as a tool for networking and communication.

The volume was compiled and edited by Igor Krupnik and Dyanna Jolly. Igor Krupnik (Arctic Studies Center, Smithsonian Institution) is currently working on a project in collaboration with St. Lawrence Island Yupik. Dyanna Jolly was affiliated with the University of Manitoba and the Inuit Observations on Climate Change project in Sachs Harbour, Canada in 1999–2000. She is now working on co-management issues in New Zealand at the Center for Maori and Indigenous Planning and Development at Lincoln University, New Zealand.

The Earth is Faster Now is available from ARCUS for $20 (U.S.), including shipping and handling. For more information or to request a copy, see the ARCUS web site (www.arcus.org), or contact Sue Mitchell (907/474-1600; fax 907/474-1604; sue@arcus.org).

Collaboration Probes Genetic History of Siberia

Siberia occupies the greatest part of northern Asia, extending from the Arctic Ocean south to Kazakhstan, Mongolia, and China, and from the Ural Mountains east to the Pacific watershed. An important geographic link between northern Asia and the Japanese Archipelago, and between the Asian and North American continents, Siberia has been the homeland of Native peoples adapted to boreal climates for more than 30,000 years. Siberia's economic and cultural patterns are linked to Paleolithic and Neolithic subsistence strategies, and traditional Siberian lifeways reflect features common to hunter-gatherer existence throughout much of the arctic and sub-arctic region.

Today, 31 different ethnohistoric/linguistic groups are indigenous to Siberia. Although differing in their origin, language, and culture, most Native Siberian populations share common types of economic activities, such as hunting, fishing, reindeer breeding, and cattle herding, which are closely linked to their nomadic and seminomadic ways of life. In addition, most Siberian indigenous groups are characterized by a number of common sociocultural features, such as clan structure, polygamous marriages, the compulsory marriage of a widow to a younger brother of her deceased husband (levirate), high levels of endogamy, and low rates of intermarriage with non-Native peoples.

Economically dependent on reindeer herding, the Nentsi people live in scattered groups in western Siberia (photo by Ludmila Osipova, April 1999).

The discovery of giant deposits of Siberian oil and natural gas, construction of the Baikal-Amur pipeline, and intense industrialization of Siberia in the 1970s have forced major changes on the Native peoples of Siberia. Small, isolated ethnic groups are under strong pressure to adopt the technological lifeways of non-indigenous immigrants from the former Soviet Union, leading to higher rates of intermarriage and the breakdown of the traditional Native Siberian way of life.

As Native Siberians are assimilated into other populations, their genetic relationships become obscured. Information from Siberian indigenous populations is key to testing several hypotheses regarding:

- the chronology of the initial peopling of northern Asia,
- the origins and migrational patterns of local prehistoric cultures, and
- the early peopling of the New World and Japan.

Joint U.S.-Russian research, funded by the NSF Arctic Social Sciences Program, is contributing to assessments of the genetic structure of Siberian Native populations and reconstruction of the historical events leading to the peopling of Siberia. Principal investigators Michael Hammer and Tatiana Karafet (Laboratory of Molecular Systematics and Evolution, University of Arizona) are collaborating with the Laboratory of Human Molecular and Evolutionary Genetics at the Institute of Cytology and Genetics in Novosibirsk, and Native populations from many parts of Siberia. Hammer and Karafet are working with more than 1,000 DNA samples from 17 Siberian ethnic groups. NSF funding enabled Karafet to collect genetic material and associated demographic and genealogical information from five Siberian groups in 1999 and 2000. This material supplements a major archive of samples from other Siberian populations collected over the past 20 years by investigators in Novosibirsk. The samples will allow Hammer and Karafet to:

- survey DNA sequence and microsatellite variation in Native Siberian populations;
- reconstruct the genetic relationships among these populations from the perspective of multiple genomic regions;
- assess the genetic impact of geographic and linguistic boundaries; and
- infer the relative role of different evolutionary forces shaping patterns of variation in Siberia.

Hammer and Karafet's initial analyses, focused on studies of paternally inherited Y-chromosomes, reveal unusual patterns of genetic variation in Siberia:

- a relatively strong correlation between genetic and linguistic variation,
- rather low levels of genetic variation within many Siberian populations, and
- high levels of variation between the sampled populations.

Levels of variation in Siberia as a whole are quite high relative to other regions of the world. These results appear to reflect a complex history involving multiple range expansions, low population densities, and isolation over time—patterns that may represent a typical signature of hunter-gatherer populations.

Hammer and Karafet are continuing their analyses by surveying genetic variation in other compartments of the human genome and by comparing the Siberian populations with groups from central Asia, northern China, and Mongolia. They hope to be able to:

- reconstruct the settlement of Siberia in the context of the history of northern Asia;
- identify the sources of population expansions to the Americas and Japan;
- infer the evolutionary forces operating on a set of quickly disappearing hunter-gatherer populations.

For more information, contact Michael Hammer (520/621-9828; fax 520/626-8050; mhammer@u.arizona.edu) and Tatiana Karafet (520/621-9791; fax 520/626-8050; tkarafet@u.arizona.edu) in Tucson, AZ.

New Technique Reveals Nitrogen Cycles in Arctic Streams

The NSF Office of Polar Programs has supported aquatic research at the Toolik Field Station (see *Witness* Autumn 2001) on the North Slope of Alaska since 1975. The Arctic Long-Term Ecological Research (LTER) program began at the same site in 1987. This ongoing complementary funding has allowed investigators to combine experimental manipulations, environmental surveys and monitoring, and synthesis and predictive modeling efforts to develop a broad understanding of tundra ecosystem structure and function.

As part of this sustained research effort, the Arctic Natural Sciences Program funded a number of scientists, led by John Hobbie and Bruce Peterson (The Ecosystems Center at the Marine Biological Laboratory), to investigate the responses of aquatic ecosystems to anticipated future changes in parameters such as climate, thickness of the active layer, and atmospheric deposition of nitrogen.

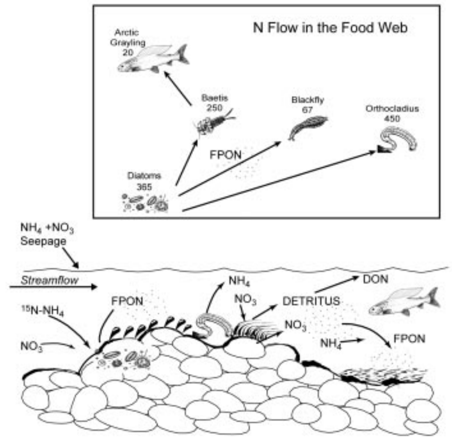
A major focus of the research is on the movement of nitrogen across the tundra landscape. Monitoring the amount of nitrogen, in the form of ammonium and nitrate molecules, transported by the Upper Kuparuk River indicates how much of this key element moves down the river to lakes and the ocean. This watershed-level monitoring is complemented by experimental work in the river to develop process-level understanding of nitrogen movement through soils, streams, and lakes that will eventually allow predictions of the ecological effect of changes.

The investigators studied the processes responsible for nitrogen movement in the river using nitrogen-15 (^{15}N), a harmless stable isotope, as a tracer. They dripped ^{15}N-ammonium slowly into the Kuparuk River for six weeks and then measured the ^{15}N in various organisms (see figure).

The ^{15}N-ammonium was incorporated into the diatoms that live attached to surfaces in the river. Mayflies (*Baetis* sp.) ate the algae and were, in turn, eaten by arctic grayling, the only species of fish in the river. A different food chain began with the sloughing of diatoms into the river current where they were captured by the filters of black fly larvae (*Prosimulium*) attached to rocks in the stream. Another pathway included *Orthocladius,* a midge larva, which, in a form of gardening, consumed the diatoms growing upon its tube-like case.

The amount of ^{15}N taken up over time gives an estimate of the N incorporation rate, which can be used to indicate how fast an organism grows. The attached diatoms, which are primary producers, contain 120 mg N/m^2 of stream bottom; their daily uptake rate was 30 mg N/m^2, and their N turnover time was four days. The mayfly *Baetis* had a mass of 5 mg N/m^2 and a daily uptake of 0.7 mg N/m^2. This surprisingly rapid turnover of seven days is little different from that occurring in warmer temperate streams with a high primary production. In contrast, the top predator, the grayling, contained 29 mg N/m^2 and had a daily uptake rate of 0.2 mg N/m^2—the turnover of N would be 145 days if conditions were always as optimal as they were during this summer period.

These results indicate that atoms of nitrogen are not just passively transported downstream to the ocean but are continually taken up by stream organisms. In this section of the Kuparuk River, an average molecule of ammonium moved 800 m before it was taken up by an organism. Despite this rapid uptake, nitrogen concentrations in the water changed little as the water moved downstream. Although organisms continually took up nitrogen from the water, an equal amount was continually added from seepage from stream banks and from release back to the water as organisms metabolized, excreted, died, and were decomposed by microbes.



^{15}N is added to the Kuparuk River in Alaska as ammonium (NH_4) at the upstream (left) side of the diagram. Some of the organisms of the stream food chain are shown in the upper box; numbers next to the names are given in "the delta" notation in which ^{15}N contents are written as parts per thousand deviation from the atmospheric standard. DON = Dissolved Organic Nitrogen; FPON = Fine Particulate Organic Nitrogen. Details are given in Wollheim et al. *(1999).*

These results are the first measures anywhere of the cycling distance of nitrogen in a stream, and the ^{15}N-addition method is now being used to investigate nitrogen processing in streams all over the world. Early conclusions from this comparative approach are that:

- processes of nitrogen cycling are similar throughout the world, and
- nitrogen uptake distances are controlled more by the depth and velocity of streamflow than by the rate of biotic uptake, indicating that the ecology of arctic streams is much more similar to streams worldwide than expected.

For more information, contact John Hobbie in Woods Hole, MA (508/289-7470; fax 508/457-1548; jhobbie@mbl.edu).

Reference

Wollheim, W. M., B. J. Peterson, L. A. Deegan, M. Bahr, J. E. Hobbie, D. Jones, W. B. Bowden, A. E. Hershey, G. W. Kling, and M. C. Miller. 1999. A coupled field and modeling approach for the analysis of nitrogen cycling in streams. *Journal of the North American Benthological Society* 18:199–219.

The Arctic Natural Sciences Program

The Arctic Natural Sciences Program provides core support for basic disciplinary research in the atmospheric, biological, and Earth sciences. For more information, contact Program Managers Jane Dionne or Robin Muench in Arlington, VA (703/292-8030; fax 703/292-9082; jdionne@nsf.gov; rmuench@nsf.gov; www.nsf.gov/od/opp/arctic/natural.htm).

Svalbard's Geology Holds Clues to Ancient Climates

The geological record indicates that the latter half of the Neoproterozoic period (approximately 750–543 million years ago) was a tumultuous time. Glaciers shed debris on every continent, even on vast tropical shelves where warm-water carbonates had been more common. Several features associated with the Neoproterozoic glacial deposits are notable:

- In places, the glacial debris is interbedded with iron formation, which forms only after oceans have been deficient in oxygen. Iron formation is absent from the geological record during the preceding billion years.
- Worldwide, the glacial deposits are sharply overlain by warm-water carbonates, signaling a rapid end to the glaciations.
- The negative carbon isotope anomalies (low $^{12}C/^{13}C$ ratios) in the carbonates indicate a major decrease in the global burial of organic matter.

The many unusual characteristics of the Neoproterozoic geological record have led several investigators to advance the controversial "Snowball Earth" hypothesis, which postulates that the Neoproterozoic glaciations were so severe that the entire ocean froze over. Such a global deep freeze would occur if the ice line reached about 30° latitude, at which point the ice-albedo feedback would cross the critical threshold of "runaway" glaciation. The "snowball" would have persisted for up to tens of millions of years, until carbon dioxide (CO_2) from volcanic sources built up sufficiently to warm the lower atmosphere to the melting point of ice. At that point, the ice-albedo feedback would have reversed, transforming the Earth into a transient ultra-greenhouse until continental weathering could scour much of the CO_2 from the atmosphere. These apocalyptic climate swings may have occurred as many as four times during the Neoproterozoic, with the final episode just preceding the first appearance of animals in the fossil record.

The NSF Arctic Natural Sciences Program has funded Paul Hoffman (Harvard University), a major proponent of the Snowball Earth hypothesis, to investigate the stratigraphy and geochemistry of the upper Hecla Hoek succession in northeastern Svalbard. The upper part of the Hecla Hoek, known as the Polarisbreen Group, contains two distinct glacial horizons. Preliminary results from these glacial formations suggest very different conditions preceding each glaciation. The older glaciation is presaged by a negative carbon isotope anomaly that is variably truncated beneath an erosional disconformity. The younger glaciation, on the other hand, is preceded by a positive anomaly and appears abruptly in the stratigraphic record, without evidence for erosion.

The dramatic carbon isotope anomalies found in the Akademikerbreen Group of the Hecla Hoek succession present an enigma: what environmental conditions drove the apparently abrupt oscillations between extremely high and extremely low rates of organic matter burial in the Neoproterozoic oceans? (photo © Galen Halverson).

Below the Polarisbreen Group lies the Akadmikerbreen Group, 2000 m of nearly continuous marine carbonates devoid of glacial deposits. Radiometric dates constrain their approximate age to less than 950 million years old, so they may have been deposited entirely during nonglacial times. Earlier work on these rocks, however, revealed large swings in carbon isotope ratios, which may indicate the changes in biological productivity associated with ice ages.

Hoffman and graduate student Galen Halverson reasoned that, if these rocks spanned a snowball event, an erosional disconformity overlain by a distinctive cap carbonate sequence would be evident. If the cap carbonate also preserved a negative carbon isotope anomaly, they would have at least circumstantial evidence for glaciation. In 1999, Halverson and fellow graduate student Adam Maloof found a possible cap carbonate in the Grusdievbreen Formation, the lowermost unit in the Akademikerbreen Group. The base of this 30 m thick sequence consists of green, then red, shales overlying a conspicuous erosional surface. The sequence stands out against a background stratigraphy of continuous shallow-water carbonates. Geochemical analyses revealed a large negative carbon isotope anomaly at the exposure surface, confirming a major perturbation to the global carbon cycle.

Halverson and Maloof identified this sequence of rocks and documented the carbon isotope anomaly in two other locations. Paleomagnetic analyses show that:

- these rocks were deposited in low latitudes, and
- the exposure surface represents a long hiatus in sedimentation.

Without associated glacial deposits or radiometric dates to link this sequence to other cap carbonates, its relation to glaciation remains speculative. Hoffman's group is pursuing further analytical work to reconstruct other changes in ocean chemistry across this boundary, testing the hypothesis that they have uncovered a cryptic glaciation.

Several hundred meters above the Grusdievbreen cap carbonate is another major sequence boundary overlain by organic-rich shales, which pass upward into mid-shelf limestones. In contrast to the Grusdievbreen surface, this one corresponds to a positive carbon isotope anomaly, indicating environmental conditions that promoted high biological productivity.

By identifying differences between successive glaciations, Hoffman's group hopes to be able to make correlations with other glacial deposits worldwide and to uncover clues to what actually triggered the glaciations. Ultimately, they also hope to understand what paleogeographical and biogeochemical conditions were responsible for this prolonged period of climatic instability at the close of the Precambrian.

For more information, contact Paul Hoffman in Cambridge, MA (617/495-3636; fax 617/496-0434; hoffman@eps.harvard.edu), or see www.sciam.com/2000/0100issue/0100hoffman.html.

Atlantic Meets Pacific at an Arctic Crossroads

The most important subsurface Arctic Ocean transport system is an anti-clockwise boundary current running along the continental slopes and major transarctic ridges. This current distributes waters, contaminants, and tracers from the Atlantic (via Fram Strait and the Barents Sea) and the Pacific (via Bering Strait) around and into the deep arctic basins. On its circumarctic pathway, parts of the topographically steered current are diverted away from the continental margin, generally along oceanic ridges.

The most complex obstacle encountered by the boundary current is the Mendeleev Ridge/Chukchi Borderland complex, north of the Pacific entrance to the Arctic. This region is the crossroads for Pacific waters from the south and Atlantic waters carried from the west with the boundary current (see figure). The area's tortuous bathymetry offers many routes for a topographically steered current. The sparse existing data on the current show:

- high spatial variability, reflecting the bathymetric complexity of the region;
- significant interannual variability, consistent with the changes observed in the past decade throughout the Arctic; and
- possible evidence that the region may divert significant amounts of water into the deep basins.

The Chukchi/Mendeleev region is important to shelf-basin exchange, deep basin ventilation, and circum- and transarctic circulation (with the associated implications for feedbacks to the world ocean). Because of a lack of sufficiently concentrated observations, however, the pathways and exchanges in this area remain unclear, both qualitatively and quantitatively. Under a three-year grant from the NSF Arctic Natural Sciences Program, a team of U.S. and Canadian scientists will investigate the physical and chemical oceanography of this region. The project's objectives are to:

- delineate the pathways of the boundary current carrying the Atlantic water past the Mendeleev Ridge and through the Chukchi Borderland;
- ascertain the input from the boundary current and the shelves to the deep Arctic Ocean in the vicinity of the Mendeleev Ridge and the Chukchi Borderland;
- understand and quantify the pathways and transformations of the Pacific waters through this region;
- describe the horizontal and vertical structure of the boundary current and estimate its transport; and
- quantify recent temporal changes in this region by combining the spatially sparse data extending through most of the past decade with new detailed synoptic measurements.

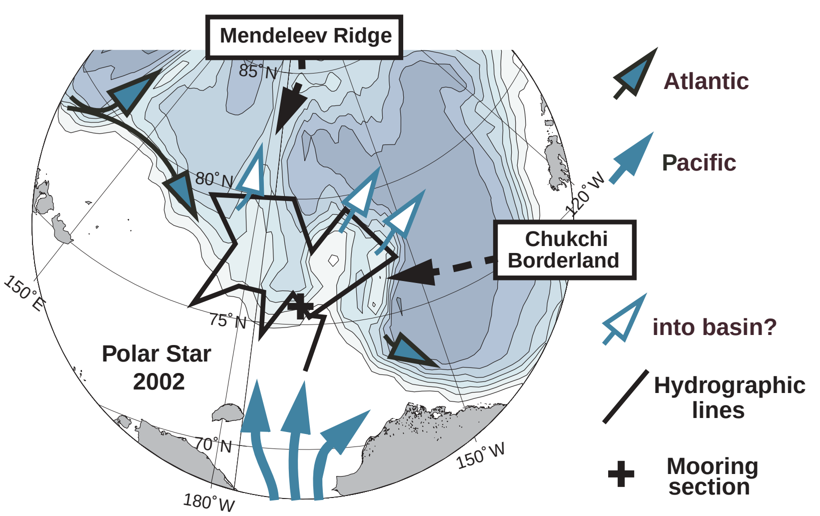
In late summer 2002, the USCG icebreaker *Polar Star* will mount a six-week expedition into the ice-covered Chukchi Borderland and Mendeleev Ridge region (see figure). A high-spatial-resolution hydrographic and tracer survey will be complemented by short-term moored current and CTD measurements. Temperature, salinity, dissolved oxygen, nutrients, chlorofluorocarbons, barium, and ^{18}O will be measured on 12 sections that cross both the boundary flow and the Pacific inputs to the region before and after topographic junctions and hypothesized regions of flow diversion. This tracer suite will:

- identify the pathways of the boundary current and the Pacific-origin waters;
- quantify the different Atlantic and Pacific influences; and
- estimate freshwater input from ice melt and different rivers.

In addition, three moorings, deployed across the boundary current for the duration of the cruise, will allow quantification of the properties and variability of the boundary current. The entire dataset will be analyzed collectively and in tandem with hydrographic, tracer, and moored time-series data from the past decade. Since the transit time of signals through this region is two to four years, the older data provide a temporal background for the high-spatial-resolution data, while the newer data will supply an essential spatial framework for interpreting the variability of the older surveys. These studies will:

- fill a hiatus in hydrographic surveys in the Canadian Basin at a time when the most dramatic changes ever observed in the Arctic are propagating through the Chukchi Borderland region;
- provide important background and mechanistic information to the Study of Environmental Arctic Change (SEARCH; see page 8), Arctic-Subarctic Ocean Fluxes (ASOF; see *Witness* Winter 2000/2001), and Western Arctic Shelf-Basin Interactions (SBI; see page 18) programs; and
- contribute to validating and improving high-resolution computer and conceptual models of the Arctic.

For more information, contact Rebecca Woodgate in Seattle, WA (206/221-3268; fax 206/616-3142; woodgate@apl.washington.edu), or see http://psc.apl.washington.edu/HLD/CBL/CBL.html.



A schematic representation of the hypothesized circulation in the Chukchi Borderland/Mendeleev Ridge complex, showing the proposed cruise track and mooring positions (figure courtesy of Rebecca Woodgate).

Healy Supports Tests of Autonomous Underwater Vehicle

The new U.S. Coast Guard (USCG) Cutter *Healy* successfully completed a challenging first year of funded science in the eastern Arctic. On her first cruise (July–October 2001), *Healy* worked with the German icebreaker *Polarstern* to complete a series of stations in the vicinity of the ultra-slow-spreading Gakkel Ridge (see *Witness* Autumn 2001) in support of the Arctic Mid-Ocean Ridge Expedition (AMORE; see www.earthscape.org/frames/news2frame.html).

A joint U.S.-German effort, the AMORE project mapped and sampled the deepest and most remote part of the global mid-ocean ridge system. The AMORE project, the U.S. portion of which was funded by NSF, received extensive press coverage for a series of striking results, including:

- discovery of 12 new volcanoes,
- abundant evidence of hydrothermal vent activity,
- unexpectedly successful dredging operations in arctic conditions, and
- development of a very detailed map of the ridge using data collected by *Healy*'s multibeam sonar system.

In addition, *Healy* and *Polarstern* visited the North Pole and rendezvoused with the Swedish icebreaker *Oden* to transfer surplus fuel and exchange scientific information. The three vessels took advantage of their meeting to share an ice picnic and international soccer tourney. More than 250 researchers and crew from 17 nations took part in the festivities at 85°N, 15°E.

A teacher supported by the NSF Teachers Experiencing Antarctica and the Arctic (TEA) Program (see Witness *Winter 2000/2001) accompanied the AMORE cruise. Michele Adams, a seventh-grade science teacher from Bunker Hill, West Virginia, posted an online journal of her experiences, which included packing mud from the North Pole into vials (see http://tea.rice.edu/tea_adamsfrontpage.html; photo courtesy of TEA).*

Healy's second cruise (October–November 2001) tested a new autonomous underwater vehicle (AUV) developed at the Monterey Bay Aquarium Research Institute (MBARI) for the Atlantic Layer Tracking Experiment (ALTEX):

- to help determine what happens to Atlantic water as it enters the Arctic Ocean, and
- to demonstrate a safe and economical platform capable of basin-scale surveys.

In late 2001, Healy *supported testing of a new autonomous underwater vehicle (AUV) being developed at the Monterey Bay Aquarium Research Institute for the Atlantic Layer Tracking Experiment to help scientists determine what happens to Atlantic water as it enters the Arctic Ocean (photo by T. Walsh © MBARI 2001).*

While AUVs have been used for arctic science since the 1970s, their ranges have been limited to approximately 1 km and depths of a few hundred meters. In contrast, the ALTEX AUV is designed to range 1,000 km and to depths of 4,500 meters, navigating and deploying ice-penetrating buoys to relay data via satellite. In waters north of Svalbard, the MBARI team tested sensors, ice-buoy operation, high-latitude navigation, and operational techniques (see www.mbari.org/education/cruises/Altex/logbook.htm).

The ALTEX science experiment is funded through the NSF Office of Polar Programs; the AUV's development is funded through a National Ocean Partnership Program grant and managed by the Office of Naval Research. Jim Bellingham (MBARI) leads the group developing the ALTEX AUV; collaborators include Fuel Cell Technologies, the Massachusetts Institute of Technology, the National Oceanic and Atmospheric Administration Pacific Marine Environmental Laboratory, and Scientific Solutions, Inc.

2002 Cruises

In the summer of 2002, *Healy* will support two main science projects in the western Arctic Ocean:

- the first year of fieldwork for the Shelf-Basin Interactions project (see http://utk-biogw.bio.utk.edu/sbi.nsf, and *Witness* Autumn 2001); and
- coring surveys in the Bering and Chukchi seas to develop high-resolution records of the history of sea levels and conditions in the region since the Last Glacial Maximum; this research is led by Lloyd Keigwin (Woods Hole Oceanographic Institution), Julie Brigham-Grette (University of Massachusetts, Amherst), and Neal Driscoll (Scripps Institute of Oceanography, University of California, San Diego).

The USCG Cutter *Polar Star* also will support a series of SBI cruises and a physical oceanography cruise in the western Arctic.

AICC Post-Cruise Assessments

The Arctic Icebreaker Coordinating Committee (AICC; see *Witness* Autumn 2001) continues its commitment to science facilitation for the three USCG icebreakers. The AICC has developed an assessment procedure for recently completed science missions that includes post-cruise debriefings. These discussions engage representatives from:

- the funding agency,
- the USCG,
- the ship's crew,
- the chief scientist, and
- the AICC itself.

The debriefing covers some 20 topics ranging from precruise communications and logistics to technical science services, the performance of the crew, and the quality of food on board. This information exchange has generated several valuable suggestions for continued improvement of science operations on USCG icebreakers.

For more information on the AICC, see the University-National Oceanographic Laboratory System web site (www. unols.org), or contact AICC Chair Lisa Clough in Greenville, NC (252/328-1834; fax 252/328-4178; cloughl@mail.ecu.edu).

New DGPS Infrastructure Supports Research in Barrow

In May 2002, survey-grade (dual-frequency) Differential GPS (DGPS) became available to researchers in the Barrow area through the Barrow Arctic Science Consortium (BASC). The Trimble 5700 system consists of:

- a base station at BASC, and
- a rover system for science-survey use.

DGPS post-processing software is available on a dedicated computer, and real-time kinematic (RTK) capability is possible within approximately 10 km of BASC, including the 7,466-acre Barrow Environmental Observatory (BEO; see *Witness* Winter 2000/2001). Accuracy is on the scale of centimeters.

The University NAVSTAR Consortium (UNAVCO) installed the system as part of its polar support services to OPP. An international organization of more than 90 universities and research institutions using GPS, UNAVCO provides technical support and training to investigators. Researchers intending to use the Barrow system should arrange for training at UNAVCO in Boulder, CO before heading to Barrow, since on-site technical support is often not available.

As part of the long-term improvements to research infrastructure on Alaska's North Slope, DGPS is now available in the Barrow area (photo by Bjorn Johns).

In addition, the University of Alaska Fairbanks and UNAVCO have installed a permanent GPS station for atmospheric and geodetic applications at the National Oceanic and Atmospheric Administration/Climate Monitoring and Diagnostics Laboratory (NOAA/CMDL) facility in Barrow. This system is part of the University Corporation for Atmospheric Research (UCAR) SuomiNet project. SuomiNet is an international network of GPS receivers configured and managed to generate near real-time measurements of atmospheric precipitable water vapor and other meterological and geodetic information. The Barrow station uses dual-frequency GPS, and the GPS antenna is on a stable, geodetic-quality monument. Daily RINEX (Receiver Independent Exchange Format) files will be available from the UNAVCO data archive.

For more information about the Barrow area DGPS system or SuomiNet, see the UNAVCO web site (www.unavco.ucar.edu), or contact Bjorn Johns in Boulder, CO (303/497-8034; fax 303/497-8028; bjorn@unavco.ucar.edu). For more information about BASC support for science, see the BASC web site (www.arcticscience.org), or contact Executive Director Glenn Sheehan in Barrow, AK (907/852-4881; fax 907/852-4882; basc@nuvuk.net).

VPR Equipping and Training Safer Field Researchers

Greater attention to safety issues was a central recommendation to NSF in *Logistics Recommendations for an Improved U.S. Arctic Research Capability*, the 1997 report published by ARCUS (see *Witness* Autumn 1997). To implement this recommendation, VECO Polar Resources (VPR) has made major efforts to ensure that investigators can conduct research safely in the Arctic. VPR has been the NSF Arctic Research Logistics Support Services contractor since November 1999 (see *Witness* Autumn 2001), supplying safety equipment and services to NSF-funded arctic researchers, including:

- satellite telephones, which can support both voice and data communications from the field;
- access to a 24/7 medical care hotline for emergency and nonemergency situations;
- an online field manual;
- extensive medical kits; and
- field-safety courses.

Free courses in field safety, facilitated by Learn to Return Training Systems (www.survivaltraining.com), are available periodically in various locations. Courses are tailored to meet specific needs and to be relevant to particular areas of the Arctic. Travel assistance is available if the course location is not within driving distance of the participants.

In February 2001, VPR offered its first field-training course for arctic researchers in Fairbanks, AK; topics included training in field skills and wilderness medical emergencies. In the spring of 2002, four-day courses in Monterey, CA and Amherst, MA also included coverage of helicopter, bear, and gun safety. An on-site course specifically for Toolik Field Station researchers was offered in June 2002. VPR plans to expand safety course content and offerings further in 2003.

In addition to safety equipment and training, VPR offers arctic researchers an array of research support and logistics services, including an extensive inventory of field equipment and supplies, transportation assistance, and construction services.

For more information, see the VPR web site (www.vecopolar.com), or contact Project Manager Jill Ferris in Englewood, CO (720/344-5619; fax 720/344-6514; jill.ferris@veco.com).

Brian Horner of Learn to Return helps a safety course participant escape from an airframe during a crash simulation (photo by Diana Garcia-Novick).

Agency Budgets Reflect Shifting Federal Priorities

The demands of additional defense and homeland-security funding are constraining the federal budget, including funding for research. In September 2001, Congress passed, and the Administration signed into law, a $40-billion emergency supplemental appropriation for anti-terrorism efforts; at least one more large supplemental bill is likely to follow before the end of FY 2002 (30 September 2002).

FY 2002 Budget

By the end of the FY 2002 budget process in January 2002, the federal budget stood at $718 billion, compared with the $661 billion request submitted by President Bush. This total included a 6.8% increase in discretionary funding, and a 12.7% increase in federal research and development spending—the largest dollar increase in history. Once Congress had completed its budget process, most federal agencies had received budget increases, not the decreases that the President's budget had proposed. The FY 2002 NSF budget is $4.8 billion, an 8.4% increase over FY 2001, although the President had proposed an increase of only 1.3%. The NSF Office of Polar Programs (OPP) received a 9% increase to $229.7 million.

FY 2003 Budget

The President's proposed FY 2003 budget submitted in February 2002 offers decreased or static budgets for nondefense spending, including basic research, in most federal agencies.

For NSF, the President has requested an increase of 5% to just over $5 billion. Almost one third of the 5% increase in the FY 2003 NSF budget is actually due to the President's proposal to move several programs from other agencies to NSF, including:

- the National Oceanic and Atmospheric Administration (NOAA) National Sea Grant program,
- the U.S. Geological Survey (USGS) toxic substances hydrology research program, and
- the Environmental Protection Agency (EPA) Office of Environmental Education.

Few additional funds are included to support these relocated programs, resulting in net losses to the departments tasked with these new responsibilities. Congress may, however, opt to leave these programs in their original agencies before it returns its revised budget to the President's desk in late 2002 or early 2003.

Within NSF, the proposed budget:

- increases the Research and Related Activities budget by 5.1%, to $3.78 billion;
- increases the Education and Human Resources budget by 3.8%, to $908 million; and
- decreases the Major Research Equipment budget by 9%, to $126 million.

President Bush continues to emphasize education in the NSF budget, with a proposed 25% increase for Math and Science Partnerships to $200 million, and a 27% increase in a new NSF initiative called Learning for the 21st Century Workforce. Other priorities in the proposed NSF budget include:

- Biocomplexity in the Environment, up 36.3% to $79 million;
- continuing increases in numbers and amounts of graduate student stipends, up 21% to $175.8 million; and
- establishment of two prototype sites of the National Ecological Observatory Network (NEON; see *Witness* Spring 2000), for a total of $12 million.

In early June 2002, the House passed HR 4664, the NSF Authorization Act. The bill, which passed 397–25, authorizes 15% increases in the NSF budgets for FY 2003, 2004, and 2005. This plan puts the agency on track for a doubling of its budget over the course of the next five years. The bill has been referred to the Senate for consideration by the Health, Education, Labor, and Pensions Committee.

The NSF OPP Budget

The President's FY 2003 budget request for OPP totals $303.81 million, a 2% ($6 million) increase over FY 2002. Within the OPP budget, Arctic Program funding would increase 2.9% ($1.06 million) to $37.84 million. The Arctic Research Support and Logistics budget would remain the same ($26 million). The budget for the U.S. Arctic Research Commission increases 5.9% to $1.08 million.

In FY 2002, NSF designated $30 million to be allocated over five years for the Study of Environmental Arctic Change (SEARCH) and related programs (see page 8). In addition, NSF has requested $1 million per year to support SEARCH beginning in FY 2003.

Barrow Arctic Research Center

Senator Ted Stevens (R-AK) offered an amendment to the Senate version of the Energy Policy Act of 2002 (HR 4), appropriating funds to establish a research center in Barrow, Alaska. Specifically, the amendment would require the Secretary of Commerce, in consultation with the Secretaries of Energy and the Interior, the Director of NSF, and the Administrator of the EPA, to establish a joint research facility to support climate-change and other scientific research activities in the Arctic. The amendment appropriates $35 million for the planning, design, construction, and support of the center. A conference committee has been named to resolve differences, including Stevens' amendment, in the House and Senate versions of the bill.

Climate Change Research Initiative

In a February 2002 address at NOAA headquarters, President Bush outlined the Administration's new multiagency Global Climate Change Research Initiative, which includes funding for SEARCH and has the potential to fund other arctic-based research. As of press time (June 2002), no legislation has been introduced in Congress that would fund or direct agencies to take the actions put forth in the initiative. For a copy, see the White House web site (www.whitehouse.gov/news/releases/2002/02/climatechange.html).

For more information about the NSF budget, see the NSF web site (www.nsf.gov/od/lpa/congress/start.htm). For information about the President's proposed budget, see the White House web site (www.whitehouse.gov). For information about the Barrow Arctic Research Center, see the NOAA web site (www.legislative.noaa.gov/informermay1402.html).

Federal Agencies Face Review, Earmarking Issues

The Bush administration is seeking to improve government efficiency and control federal spending related to academic research funding by:

- developing new performance-review criteria for federally funded basic research and development (R&D), and
- discouraging congressional "earmarking" of funds for specific research programs.

Performance Criteria for Basic Research

In keeping with President Bush's charge to "improve the management, performance, and results of the federal government," the White House Office of Management and Budget (OMB) is developing performance criteria for all federally funded R&D.

OMB has drafted a set of performance criteria for federal R&D based on:

- results from an FY 2001 pilot program focused on the performance of some applied R&D programs at the Department of Energy (DOE);
- contributions from the White House Office of Science and Technology Policy (OSTP); and
- discussions at a February 2002 workshop sponsored by the National Academy of Sciences (NAS) Committee on Science, Engineering, and Public Policy (COSEPUP).

The OMB intends for all federal agencies to use these criteria to evaluate their R&D efforts at the program or portfolio level. These criteria would be based on three principles:

- quality, ensured primarily through peer-review mechanisms;
- relevance, including defining program direction, priorities, and links to identified national and agency goals; and
- performance, including demonstrating effective use of resources and progress toward objectives.

The OMB envisions that these assessments will involve both:

- prospective reviews of the planning, design, and justification of R&D programs; and
- retrospective reviews of program quality, relevance, and outcomes, conducted periodically (approximately every three to five years).

According to David Trinkle of OMB, issues still to be resolved about this evaluation process include:

- how to fit all federal R&D efforts into a similar assessment framework;
- how to define the differences among types of R&D programs and selectively use the evaluation criteria;
- which agencies will begin using the criteria in 2004;
- how the criteria will be implemented at each agency;
- which programs at those agencies will use the criteria; and
- at what level the criteria will be applied.

COSEPUP noted in its report that applying performance metrics to basic research will require an approach tailored to the work of each agency. Jeffrey Kieft, the Roger Revelle Fellow in Global Stewardship at OSTP, spoke at the May 2002 ARCUS Annual Meeting in Arlington, VA on these issues; he noted that it is likely that a set of basic criteria will be developed, to which additional criteria appropriate to each agency will be added.

In late May 2002, OMB announced that it will create a six-member Performance Measurement Advisory Council to:

- provide independent expert advice to OMB regarding measures of program performance, and
- make recommendations regarding management and budget decisions.

The council, which will exist for nine months unless renewed, will advise OMB on specific processes and means to be used in assessing federal programs and initiatives. Council members will be tasked with:

- creating, implementing, and evaluating performance-measurement standards; and
- making recommendations on the types and measures of benchmarking systems that departments and agencies can employ most effectively to track program performance.

The OMB hopes to name the council by late June 2002. For more information on the proposed basic research performance metrics, see the National Academy of Sciences web site (www7.nationalacademies.org/gpra/Basic%20Research.html) or the Association of American Universities web site (www.aau.edu/research/funding.html).

Growing Congressional Earmarks

According to the *Chronicle of Higher Education,* in 2001 Congress directed federal agencies to award a record amount of "earmarked" funds to projects involving specific universities. Earmarking—the practice of designating funds in an appropriations bill for a particular project—has long been used by legislators to "bring home" funding for their constituents.

Academic earmarks have grown steadily in recent years from $296 million in 1996 to an estimated $1.67 billion in 2001. For example, earmarks in the Department of Commerce (DOC) budget for FY 2000 were $92 million; in FY 2002, DOC earmarks increased to $202 million. Almost every agency budget includes similar increases in earmarked funds, with the exception of the NSF. The earmarks are also an increasing share of total federal funding to colleges and universities—9.4% in 2001. The 25 states with the largest shares of federal research dollars received 74% of earmarked funds in that funding year. Alaska and West Virginia headed the list.

The American Association for the Advancement of Science, the Association of American Universities, the National Association of State Universities and Land Grant Colleges, and NAS sponsored a workshop on Earmarking of Science in October 2001. At the workshop, Sarah Horrigan of OMB made a strong appeal to colleges and universities—and their lobbyists—to stop encouraging congressional earmarks. Administration officials, including OMB director Mitch Daniels, contend that the increase in earmarking reduces the R&D funds available for agencies to meet funding priorities and fund peer-reviewed research and that, given current budget conditions, additional funding for priority research will not be forthcoming. Language discouraging earmarking is prominent in nearly every FY 2003 OMB budget document.

For more information about congressional earmarking in the federal budget, see the OMB web site (www.whitehouse.gov/omb/budget/fy2003/budget.html), or the *Chronicle of Higher Education* web site (http://chronicle.com).

New Deputy Director and Commissioners Join USARC

In September 2001, the U.S. Arctic Research Commission (USARC) welcomed Lawson Brigham as its new deputy executive director. Brigham is a former U.S. Coast Guard captain with experience commanding arctic icebreakers, including the *Polar Sea*. An oceanographer whose research interests include sea ice and ocean processes in the Russian Arctic, Brigham earned his Ph.D. from the Scott Polar Research Institute at Cambridge University. He held the Office of Naval Research Arctic Chair in Marine Science at the Naval Postgraduate School from 1996–97.

In late January 2002, the USARC introduced two new commissioners—Mary Jane Fate, an Alaska Native leader from Rampart, Alaska, and Mead Treadwell, managing director of the Institute of the North, based in Anchorage, Alaska. Fate and Treadwell replace Richard Glenn and Walter Parker, respectively.

In the past several months, USARC representatives have attended a number of meetings. Highlights include:

- the April 2002 Arctic Science Summit Week in Groningen, the Netherlands;
- a European Union workshop in Brussels on arctic infrastructure;
- a United Nations meeting with Russian, Norwegian, and Canadian representatives to review a Russian claim to arctic territory under Article 76 of the U.N. Convention on the Law of the Sea; the USARC and other federal agencies are planning the conduct of the requisite surveys of the U.S. arctic margin;
- a meeting with the North Pacific Research Board, which has agreed upon a schedule for requests for proposals for research in the board's region of interest (the North Pacific, Bering Sea, and adjacent parts of the Arctic Ocean);
- a meeting of the Polar Research Board at which USARC Executive Director Garry Brass requested help in launching a planning process for the design and management of the next generation of polar icebreakers;
- a Marine Technology Society luncheon at which Commander Steven Warren, director of the Navy/National Ice Center, spoke on the issues involved in naval operations in an ice-free Arctic;
- an introduction to Canada's newest province by Paul Okalik, the Premier of Nunavut; and
- a meeting with Peter Spotts, reporter for the *Christian Science Monitor*, to discuss arctic issues.

For more information, see the USARC web site (www.uaa.alaska.edu/enri/arc_web/archome.htm), or contact Garry Brass in Arlington, VA (800/AURORAB or 703/525-0111; fax 703/525-0114; g.brass@arctic.gov).

Polar Research Board

PRB Explores Abrupt Climate Change, Polar Biology

The technologies and methods of biology are changing dramatically and opening new avenues for research. At the request of the NSF Office of Polar Programs and Directorate for Biological Sciences, the Polar Research Board (PRB) formed a committee to examine opportunities and challenges related to using these tools to conduct research on arctic and Antarctic organisms. The new Committee on Frontiers in Polar Biology will seek to:

- identify important research questions for polar regions, and
- recommend ways to facilitate and accelerate the transfer and use of genomic technologies to questions about the Arctic and Antarctic.

The committee will:

- discuss the potential applications of genomic sciences and functional genomics to molecular biology, microbiology, biochemistry, physiology, evolutionary processes, and microbial ecology in polar regions;
- note the need for development of new technologies or methods specifically for polar regions;
- seek ways to facilitate increased interaction between biological scientists working in polar regions and other biological scientists; and
- assess impediments to the conduct of polar genomics research (*e.g.,* issues related to facilities, infrastructure, maintenance of biological sample collections, education needs).

William H. Detrich, III (Northeastern University) chairs the nine-member committee, which began meeting in June 2002. The committee will host an information-gathering workshop in September 2002 and then produce a report with findings and recommendations.

In other PRB news, the National Academy Press published *Abrupt Climate Change: Inevitable Surprises* in May 2002 (see page 27). The report, by the PRB's Committee on Abrupt Climate Change, describes what is known about abrupt climate changes and their impacts—based on paleoclimate proxies, historical observations, and modeling—and highlights new findings that abrupt climate change can occur when gradual causes push the Earth system across a threshold. The report notes that we do not yet understand abrupt climate changes clearly enough to predict them, and that the models used to project future climate changes and impacts do not simulate the size, speed, and extent of past changes well, complicating assessments of potential future changes. The prepublication release of the report received extensive press coverage, including articles in the *New York Times* and *Washington Post.*

For more information about the PRB, see the National Academies web site (www.national-academies.org/prb), or contact PRB Director Chris Elfring in Washington, DC (202/334-3479; fax 202/334-1477; celfring@nas.edu).

Arctic Council Working Groups Launch Initiatives

The Senior Arctic Officials (SAOs) of the eight-nation Arctic Council met in November 2001 in Espoo, Finland to review progress on environmental and sustainable development projects. Council Chair Peter Stenlund of Finland, SAOs, Permanent Participant indigenous groups, and observers discussed reorganization plans for the council and how to present an "arctic voice" at the August 2002 World Summit on Sustainable Development in South Africa.

Working Group Activities

The Arctic Monitoring and Assessment Program (AMAP; see www.amap.no) working group is updating its 1997 contaminant studies. Focused on persistent organic pollutants (POPs), heavy metals, human health, and radioactivity, the updated assessments, including a condensed version for the general public, are to be completed by October 2002. U.S. agencies—including the State Department, National Oceanic and Atmospheric Administration, NSF, National Institutes of Health, Environmental Protection Agency, and U.S. Arctic Research Commission (see page 22)—have contributed more than $100,000 in the past year toward these publications, and many U.S. experts have been involved with research and drafting of the reports.

The Conservation of Arctic Flora and Fauna (CAFF; see www.caff.is) working group recently released two reports:

- *Seabird Harvest Regimes in the Circumpolar Nations,* and
- *Proceedings of the First CAFF Flora Group Workshop.*

CAFF's book *Arctic Flora and Fauna: Status and Conservation*, published in 2001 (see *Witness* Autumn 2001), is receiving excellent reviews. This first circumpolar overview of arctic biodiversity and related conservation issues concludes that:

- species are showing the effects of overexploitation, habitat loss, and pollution; and
- distance has not made the Arctic immune to global environmental issues.

Based on the findings, CAFF is developing policy recommendations to be presented at the October 2002 Ministerial meeting.

The Emergency Prevention, Preparedness, and Response (EPPR) working group has launched a source-control management project led by the U.S. Department of Energy and Russia's Emercom. The pilot project will develop and test a methodology for reducing the potential for emergencies at facilities that handle hazardous and radioactive materials. The resulting methodology and overall approach will be applicable to a broad spectrum of at-risk activities in the Arctic.

An emergency-response exercise is planned for summer 2002 at the Bilibino nuclear facility in the Chukotka region of Russia. The radiological release scenario will demonstrate capabilities both on-site (*e.g.,* plant response, communications, decision-making) and off-site (*e.g.,* notification procedures, public information dissemination, data gathering from radiation monitoring stations, plume modeling).

In December 2001, the Global Environment Facility (see www.gefweb.org) approved $10 million to fund a project of the Protection of the Arctic Marine Environment (PAME) working group—the Russian National Plan of Action for the Protection of the Arctic Marine Environment from Anthropogenic Pollution (NPA-Arctic). The plan will address both damage and threats to the arctic environment in Russia. Proposed demonstration projects include:

- the use of brown algae mats in coastal areas to absorb contaminants;
- transfer of two decommissioned military bases to civilian control; and
- enhancement of the environmental- and resource-management capacity of indigenous people in Russia.

The United States plans to organize a meeting to encourage governments, the private sector, and international financial institutions to invest in the NPA-Arctic.

The Sustainable Development Working Group (SDWG) held a workshop in Helsinki in November 2001 to begin developing an overall capacity-building strategy for the Arctic Council. Canada is preparing recommendations.

Finland is organizing an August 2002 conference on the status of women in the Arctic. The agenda for "Taking Wing" includes sessions on Women and Work, Self-Determination, and Women and Violence.

An initiative of the Arctic Council Action Plan to Eliminate Pollution of the Arctic (ACAP)—a project to phase out PCBs in Russia—has received sufficient financial pledges that a contract with the Russian participant can be signed. Three published fact sheets on heavy metals, POPs, and radioactivity will be translated into Russian and reprinted to improve indigenous people's access to the information. Denmark is preparing a revised work plan for the atmospheric mercury project, which is linked to the United Nations Environment Programme (UNEP) global mercury inventory; the first phase involves data collection in Russia. A project on obsolete pesticides, co-chaired by the United States and Russia, was launched in October 2001 in Moscow; UNEP Chemicals will provide secretariat support.

The Arctic Climate Impact Assessment (ACIA; see *Witness* Spring 2000) will investigate past and present indicators of changes in climate and UV radiation, possible changes in the future, and potential impacts of these changes (see www.acia.uaf.edu). By 2004, ACIA will publish:

- a scientific volume,
- a synthesis document, and
- a policy document providing recommendations for coping with climate change and variability.

NSF and NOAA are major sponsors, and many U.S. experts are contributing.

Meetings on the Arctic Horizon

The SAO met in May 2002 in Oulu, Finland and will meet again immediately before the third Ministerial meeting, which will convene 9–10 October 2002 in Inari, Finland. The Second AMAP International Symposium on Environmental Pollution of the Arctic will be held 1–4 October 2002 in Rovaniemi.

For more information, see the Arctic Council web site (www.arctic-council.org). For more information on U.S. involvement in the Arctic Council, contact Hale VanKoughnett at the Department of State in Washington, DC (202/647-4972; 202/647-4353; vankoughnetthc@state.gov).

CPC Addresses Global Change, Sovereignty, and Security

The Canadian Polar Commission, Canada's lead agency in the area of polar research, is responsible for promoting the development and dissemination of polar knowledge (see *Witness* Spring 2000). In January 2002, the CPC co-sponsored an international conference on "Sovereignty and Security in the Canadian Arctic" in Ottawa. Global experts addressed important issues, including:

- the implications for Canada should the northwest passage become navigable to commercial shipping, and
- post-11 September security issues on the open arctic frontier.

For more information about the conference, see the Spring/Summer edition of *Meridian*, the newsletter of the CPC, or see the Canadian Arctic Resources Committee web site (www.carc.org).

In 1999, the CPC launched the Indicators Project to provide an assessment of the state of Canadian polar knowledge as a basis for nongovernmental and governmental decision-making and policy formulation. The project has defined 15 quantifiable indicators of the state of Canada's polar knowledge (*e.g.,* the state of co-management research, incidence of polar matters raised in Canadian Parliament debates, number of Canadian university courses on polar subjects). While such indicators are not considered definitive, they highlight important trends. Thus far, the project has identified key areas of Canadian polar knowledge, identified information useful in refining research methods, and published two reports.

The CPC recently established the Polar Science Forum, an online communication center that enables the exchange of information and ideas within the Canadian polar research community, and an online directory that lists Canadian polar specialists by name, specialty, and geographical area in which they work. The directory will soon also list publications and current research projects.

For more information, see the commission's web site (www.polarcom.gc.ca), or contact Communications Manager John Bennett in Ottawa, ON (613/943-0716; fax 613/943-8607; bennettj@polarcom.gc.ca).

Education News

Arctic Speakers Share Expertise with Varied Audiences

In January 2000, ARCUS launched the Arctic Visiting Speakers' (AVS) Series to provide support for organizations to engage in and foster arctic science education on the local level (see *Witness* Spring 2000). The program is intended to:

- increase communication and collaboration within the dispersed arctic research community;
- nurture better communication among arctic researchers and arctic community residents; and
- improve the general public's appreciation of the importance of arctic research.

The series sponsors distinguished scholars and experts on the Arctic to visit academic institutions and community organizations for seminars, lectures, and discussions. Funded by the NSF Office of Polar Programs, the program covers travel costs and a modest honorarium for about 15 speakers each year. Speakers visit academic institutions, schools, and public venues such as libraries or radio broadcasts.

Since the program began, 24 speakers from five countries have addressed audiences at 51 institutions in the U.S., Russia, Greenland, and Canada on a broad range of topics, including linguistics, Native ways of knowing, geology, marine law, archeology, and oceanography. Participants have found the program is especially valuable for:

- helping scientists communicate directly with arctic communities;
- involving representatives of arctic communities with research and education efforts at lower latitudes;
- international visits, particularly with Russian researchers or organizations;
- science education partnerships involving academic institutions and schools; and
- enhancing educational opportunities associated with a meeting or workshop.

ARCUS accepts applications for the AVS series year-round. For more information, see the ARCUS web site (www.arcus.org/arctic_speaker/), or contact ARCUS Education Project Manager Janet Warburton (907/474-1600; fax 907/474-1604; janet@arcus.org).

Education Recommendations Available

ARCUS published *Arctic Science Education: Recommendations from the Working Group on Arctic Science Education to the National Science Foundation* in May 2002. The report resulted from a planning process initiated in March 2000, when a group of scientists, educators, and Alaska Native education specialists met in Fairbanks, AK to develop recommendations to guide the Arctic Section of the NSF Office of Polar Programs (OPP) in its education and outreach efforts. The report is available on the ARCUS web site (www.arcus.org) or as a hard copy. For more information or to request a copy, contact ARCUS Education Project Manager Janet Warburton (907/474-1600; fax 907/474-1604; janet@arcus.org;).

Iceland's Environmental Research Institute Expands

The Environmental Research Institute (ERI) at the University of Iceland in Reykjavik has many new opportunities for research scientists and students in environmental sciences. ERI fosters the global exchange of information and ideas to promote environmental awareness and responsibility, applying an interdisciplinary Earth-systems approach to problem solving.

ERI welcomes visiting scholars, educational exchange programs, and cooperative research. Iceland's many resources include arctic and subarctic freshwater and marine ecosystems, active glacial and volcanic processes, and geothermal and hydropower resources. Environmental stresses that warrant careful study include global marine pollution and global warming.

Interdisciplinary research projects at ERI include but are not limited to:

- using GIS to map natural hazards in Iceland and improve local communities' capacity to assess risk and plan land use;
- analysis of the potential to use renewable energy (*e.g.,* geothermal, hydropower) in Iceland to process recyclables;
- analysis of past and present biodiversity and stresses in extreme environments in the North Atlantic and Iceland; and
- assessment of coastal-zone processes and ecosystem effects in Iceland.

In June–July 2002, ERI will host a two-week field course on "Iceland's Wilderness, Natural Resources, and Resource Management." Participants will explore Iceland's coasts and remote volcanic interior, studying:

- unique glacial and volcanic formations;
- natural resource management issues (*e.g.,* fisheries and aquaculture; forestry, agriculture, soils, and erosion control; wilderness protection); and
- Iceland's sustainable development initiatives (*e.g.,* ecotourism, geothermal, and hydropower).

ERI will begin teaching the University of Iceland's masters program in environmental sciences in the English language beginning in fall 2002. This program cultivates an interdisciplinary approach to problem solving, emphasizing:

- practical aspects of environmental sciences, rather than theoretical analysis;
- the interaction of scientific knowledge and policy formulation.

Students of all backgrounds are encouraged to apply. Students may do elective course work and thesis research at foreign universities. Applications for the 2003 fall term are due on 15 March 2003.

ERI is working with the University of Iceland, the Icelandic government, and governmental and private research and funding organizations in Iceland to establish the International Center for the Environment (ICE) at the University of Iceland. ICE facilities, programs, and services will:

- support international collaboration on large-scale interdisciplinary research and monitoring projects; and
- create a forum for the international exchange of ideas, research results, and information on environmental issues.

For more information, see the ERI web site (www.uhi.hi.is/english), or contact Director Bjorn Gunnarsson in Reykjavik, Iceland (+354/525-5286; fax +354/525-5829; bjorng@hi.is).

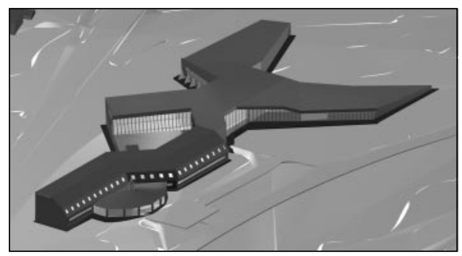
UNIS Outgrows Original Facilities

University Courses on Svalbard (UNIS) was established as a beneficial trust in January 1994 by Norway's four mainland universities (see *Witness* Spring/Autumn 1999). UNIS has grown steadily throughout its first eight years of operation in terms of the numbers of courses offered, students, research funding and activities, scientific papers published, and projects recognized by the Centres of Outstanding Research.

In 2001, UNIS offered 38 courses within four fields of study—Arctic Biology, Arctic Geology, Arctic Geophysics, and Arctic Technology. Of these, fully half were masters- or doctoral-level courses. Of 272 students, 58% were from 21 countries other than Norway.

The main UNIS building, completed in 1995, provides inadequate laboratory space and offices for today's staff, visiting lecturers, researchers, and fellows. In January 1999, representatives from UNIS, the Norwegian Polar Institute (Svalbard), and a government building corporation—the Cultural Heritage Office of the County Governor of Svalbard and Statsbygg Nord—selected a design for a 5,200-square-meter Svalbard Science Centre to be developed at Longyearbyen in connection with the existing UNIS building and neighboring plots.

The new Svalbard Science Centre, scheduled for completion in December 2005, is designed to accommodate the institution's growth and to host a wide range of activities and institutions with diverse visions and agendas. Locating academic institutions in Longyearbyen at the same site will provide scientific, logistical, social, and economic benefits. The new centre's design, submitted by Jarmund & Visnæs of Oslo:



The new 56,000-square-foot Svalbard Science Centre is designed to accommodate many educational and research initiatives at Longyearbyen by 2006 (figure by Jarmund & Visnæs).

- features new offices, a library, lecture rooms, laboratories, a cultural heritage repository, workshops, and storage space;
- offers space for international researchers and teams with projects and campaigns on the island of some duration; and
- affords UNIS added flexibility in its research activities and student numbers.

Construction is to begin in 2003.

For more information, see the UNIS web site (www.unis.no), or contact Director Lasse Lønnum in Longyearbyen (+47/7902-3305; fax +47/7902-3301; lasse.lonnum@unis.no) or Executive Officer Eystein Markusson (+47/7902-3306; fax +47/7902-3301; eystein.markusson@unis.no).

Arctic Alive! Engages Students in Field Research

Arctic Alive!, a distance-delivery education program implemented by ARCUS in 2002, allows students to participate in arctic research—and discover careers in science—from their classrooms. Funded as a pilot program by the NSF Directorate for Geosciences, *Arctic Alive!* is modeled on the successful LEARNZ program developed by Heurisko Ltd., in New Zealand.

In the first season, *Arctic Alive!* students took a five day "virtual field trip" to Barrow, AK in April 2002, focusing on geoscience research examining arctic climate, sea ice, and climate change. Middle school teacher and biologist Patrick Lovely accompanied sea-ice researchers and served as a liaison and guide for the distant students. Students learned about albedo-transect research, ice-core research, and ice-core data analysis from researchers Don Perovich and Tom Grenfell (Cold Regions Research and Engineering Lab), and Hajo Eicken and Andrew Mahoney (University of Alaska Fairbanks). Barrow community members Richard Glenn and Harry Brower and wildlife biologist Craig George offered their perspectives on climate change.

The primary goal of the pilot program was to provide a variety of ways for five classrooms (grades 6–9) and three home-school families from across Alaska to participate in a comprehensive field-based program. To achieve this, *Arctic Alive!* used simple technology—a speaker phone and an Internet connection—and developed the following tools:

- a comprehensive web site including secure areas for teachers and students to access all materials and resources;
- complete downloadable online lesson plans;
- lessons that can be used individually or as a unit and that meet state and national content standards in science, technology, and math;
- an online discussion forum where students and researchers interact;
- daily audioconference calls between students and researchers; and
- online audio files of the conference calls.

Students made excellent use of the Internet discussion forum, where Lovely posted a daily diary and photos of the expedition. The web site also served as a resource for additional information and lesson planning.

Initial feedback from program participants has been positive. ARCUS is soliciting in-depth evaluations from teachers and students and additional funding to make *Arctic Alive!* available to students across the United States next year.

For more information, see the *Arctic Alive!* web site (www.arcus.org/arcticalive/), or contact ARCUS Education Project Manager Janet Warburton in Fairbanks, AK (907/474-1600; fax 907/474-1604; janet@arcus.org).

Sea-ice researchers Hajo Eicken and Andrew Mahoney drill an ice core near Barrow, AK shortly before they meet with students in distant communities through an Arctic Alive! *audioconference (photo by Patrick Lovely).*

Students Awarded for Research Excellence

The Annual ARCUS Award for Arctic Research Excellence is a program sponsored by ARCUS to promote arctic research and education. In 2002, the sixth year of the competition, 48 students submitted papers. Nearly 60% were from schools outside the United States, and 80% were Ph.D. candidates; no undergraduates submitted papers this year. The submissions reflect the excellence of young researchers working in the Arctic and the diversity of their research.

Forty-three judges from a variety of disciplines reviewed the papers. In April 2002, awards were made in four categories and honorable mentions awarded to four other students. The winners are:

Interdisciplinary Research—M. Geoffrey Hayes (Department of Anthropology, University of Utah) for "Paleogenetic assessment of human migration and population replacement in North American arctic prehistory."

Life Sciences—Joël Bêty, Biologie (Centre d'Études Nordiques, Université Laval, Canada) for "Are goose nesting success and lemming cycles linked? Interplay between nest density and predators."

Physical Sciences—Anthony Arendt (Geophysical Institute, University of Alaska Fairbanks) for "Rapid wastage of Alaska glaciers and their contribution to rising sea level."

Social Sciences—Paul Berger (Department of Education, Lakehead University, Canada) for "Adaptations of Euro-Canadian schools to Inuit culture in selected communities of Nunavut."

These four students attended the ARCUS-sponsored Arctic Forum in Washington, DC in May 2002 and presented their papers to an audience of arctic researchers, federal agency personnel, and representatives of government and private organizations involved in arctic research. Each winner also received a $500 honorarium.

Honorable mentions were awarded to Wendy M. Loya (Kansas State University); Robin Brinkmeyer (University of Bremen, Germany); Tracy L. Speier (University of Alaska Anchorage); and Annette Watson (University of Minnesota). A listing of the participants, paper titles, and abstracts can be found on the ARCUS web site (www.arcus.org/sa/annual.shtml).

The announcement and entry information for the Seventh Annual ARCUS Award for Arctic Research Excellence (2003) will be distributed to the community in late summer 2002. Please encourage young researchers to participate.

ARCUS Arctic Research Consortium of the United States

3535 College Road, Suite 101
Fairbanks, Alaska 99709 USA
Phone: 907/474-1600
Fax: 907/474-1604
arcus@arcus.org
www.arcus.org

Executive Director
Wendy K. Warnick

ARCUS is a nonprofit organization consisting of institutions organized and operated for educational, professional, or scientific purposes. ARCUS was established by its member institutions in 1988 with the primary mission of strengthening arctic research to meet national needs. ARCUS activities are funded through a cooperative agreement and grants from NSF, by the Alaska Federation of Natives, by the National Fish and Wildlife Foundation, and by membership dues.

Witness the Arctic is published biannually by ARCUS. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of NSF. Submit suggestions for the Autumn 2002 newsletter by September 2002.

Managing Editor: Alison York
Editor/Designer: Marty Peale
Copy Editors: Sue Mitchell, Rose Meier, Diane Wallace

Contributors: M. Adams, J. Bennett, S. Bishop, G. Brass, J. Chamot, K. Clifford, L. Clough, J. Dionne, T. Eklund, C. Elfring, D. Ferguson, J. Ferris, D. Garcia-Novick, D. Gill, H. Goldman, B. Gunnarsson, G. Halverson, M. Hammer, C.R. Harrington, D. Hillmann, J. Hobbie, P. Hoffman, H. Huntington, B. Johns, T. Jorgenson, D. Jolly, S.A. Kaplan, T. Karafet, L. Keigwin, I. Krupnik, J. Kruse, M. Ledbetter, G. LeMoine, L. Lønnum, P. Lovely, D.B. MacMillan, E. Markusson, D. Maschino, D. Nemeth, L. Osipova, J.S. Picou, T. Pyle, G. Sheehan, N. Swanberg, J. Thayer, H. vanKoughnett, B. Wade, H.J. Walker, T. Walsh, J. Warburton, R.A. Woodgate.

wit.ness (wit nis) *n.* **1.a.** One who has heard or seen something. **b.** One who furnishes evidence. **2.** Anything that serves as evidence; a sign. **3.** An attestation to a fact, statement, or event. —*v. tr.* **1.** To be present at or have personal knowledge of. **2.** To provide or serve as evidence of. **3.** To testify to; bear witness. —*intr.* To furnish or serve as evidence; testify. [Middle English *witnes(se),* Old English *witnes*, witness, knowledge, from *wit,* knowledge, wit.]

Calendar

August 1–3 13th Inuit Studies Conference "Voices from Indigenous Communities: Research, Reality, and Reconciliation." Anchorage, AK. See the conference web site (www.uaf.edu/uafrural/ISC/), or contact Gordon Pullar in Anchorage (907/279-2700; fax 907/279-2716; g.pullar@uaf.edu).

August 8–11 American Quaternary Association (AMQUA) 17th Biennial Meeting "Climate Change and Human Migration in the North Pacific Basin." Anchorage, AK. Contact David Yesner in Anchorage (907/786-6845; fax 907/786-6850; afdry@uaa.alaska.edu).

August 26–29 Chapman Conference on High-Latitude Ocean Processes. L'Estérel (near Montréal), Québec, Canada. See the American Geophysical Union (AGU) web site (www.agu.org/meetings/chapman.html), or contact Charles Tang in Dartmouth, Nova Scotia, Canada (902/426-2960; fax 902/426-6927; tangc@mar.dfo-mpo.gc.ca).

August 26–30 International Symposium on Physical and Mechanical Processes in Ice in Relation to Glacier and Ice Sheet Modeling. Chamonix Mont-Blanc, France. Contact the International Glaciological Society in Cambridge, U.K. (+44/1223-355-974; fax: +44/1223-336-543; Int_Glaciol_Soc@compuserve.com; www.spri.cam.ac.uk/igs/Circ2fr1.htm)

September 18–21 53rd Arctic Science Conference "Connectivity in Northern Waters—Chukchi Sea, Bering Sea, and Gulf of Alaska Interrelationships." Fairbanks, AK. See the Arctic Division of the American Association for the Advancement of Science (AAAS) web site (http://arctic.aaas.org/), or contact Terry Whitledge (907/474-7229; fax 907/474-7204; terry@ims.uaf.edu) or Maggie Billington (907/474-7707; fax 907/474-7204; maggie@sfos.uaf.edu).

October 1–4 Second Arctic Monitoring and Assessment (AMAP) International Symposium on Environmental Pollution in the Arctic. Rovaniemi, Finland. Contact the AMAP Secretariat (+47/2324-1635; fax +47/2267-6706; amap@amap.no; www.amap.no).

For more events, see the Calendar on the ARCUS web site (www.arcus.org/misc/calendar.html).

Publications

Krupnik, I., and D. Jolly. (eds.) 2002. *The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change*. The Arctic Research Consortium of the U.S. (ARCUS), Fairbanks, AK, 384 pp. $20 U.S. Contact ARCUS (907/474-1600; fax 907/474-1604; sue@arcus.org; www.arcus.org).

Norwegian Polar Institute. 2001. Proceedings of H.U. Sverdrup Symposium on the Role of Ocean-Sea Ice-Atmosphere Interaction in Polar and Sub-Polar Climate. *Polar Research* 20(2), 125 pp. (www.npolar.no/PolarResearch).

Hammer, P. C., C. Moellendick, and J. Moellendick (eds.) 2001. *Native Education Directory*. The National Indian Education Association and the ERIC Clearinghouse on Rural Education and Small Schools at AEL, Inc. Online database continually updated (www.ael.org/eric/ned). Hardcopy available; contact Lena Tiller in Charleston, WV (800/624-9120; fax 304/347-0441; tillerl@ael.org).

Committee on Abrupt Climate Change. 2002. *Abrupt Climate Change: Inevitable Surprises.* National Academy Press, Washington, DC, 244 pp. Available from National Academy Press (800/624-6242; www.nap.edu).

Barrow Arctic Science Consortium (BASC). 2002. *Arctic Science in the Barrow Region: Recommendations for Future Facilities.* 67 pp. Contact BASC (907/852-4881; fax 907/852-4882; basc@nuvuk.net).

Norton, D. W. (ed.) 2001. *Fifty More Years Below Zero: Tributes and Meditations for the Naval Arctic Research Laboratory's First Half Century at Barrow, Alaska.* University of Alaska, Fairbanks, AK, 576 pp. Contact the University of Alaska Press (888/252-6657 or 907/474-5831; fax 907/474-5502; fypress@uaf.edu; www.uaf.edu/uapress).

A Note From the President

In April 2002, the Science Management Office for the NSF initiative on Human Dimensions of the Arctic System (HARC) held an online workshop on Humans and Arctic Hydrology (see www.arcus.org/harc/ and page 11). This venue provided an opportunity for the research community to discuss how humans affect and are affected by ways that water circulates through the arctic system and how that circulation may change. In both quantity and quality of discussion, the workshop was highly stimulating, raising many interesting ideas and research topics.

Later that month, I attended a meeting organized by Art Ivanoff, the environmental protection officer for the Native Village of Unalakleet in western Alaska. Art had arranged for several state and federal agencies to discuss the management of flooding and erosion in Alaska villages, a topic of serious concern in many places that had also come up in the online workshop.

In Art's meeting, the discussion was highly practical, reviewing the effectiveness of various methods of erosion control and examining the policy that requires a certain cost-benefit ratio for a project to be undertaken. Listening to the discussion, and contributing a short talk on climate change, it struck me that this was "human dimensions" in action. In our online workshop, we had discussed the ways erosion affects communities, how they are involved in related decision-making, and how researchers can learn about and respond to village priorities. When these ideas were being discussed by people responsible for action, they became —for me at least—more immediate and more complex.

The main problem in erosion response is not lack of information. The agencies and the villages know what is happening and how fast, and they have experience with a variety of erosion-control methods. The chief problem is the shortage of money, time, and personnel. Erosion control is expensive, and with low village populations, cost-benefit analyses rarely support vigorous action. Busy with many projects and demands, agencies and villages have often reacted only to crises rather than aiming for prevention. To be effective, erosion control also demands maintenance by trained personnel, which adds to costs and places further demands on villagers' time.

If information is not the bottleneck, it is nonetheless a long-term need. Effective planning depends on predictions of hydrological changes and the likelihood of extreme events, as well as an understanding of societal needs. Existing records for most of the Arctic are insufficient to quantify such parameters as the magnitude of the 100-year flood (*i.e.,* the most extreme event over the course of a century). Our response to erosion is conditioned on agency mandates and expertise, which may not correspond well with village needs and priorities. Social and environmental change alter the ways in which people interact with their environment and, thus, their community's needs.

By examining these topics in the pragmatic realm of the ways that villages are affected by hydrology, we are forced to move from the general to the specific, speculative though that step may be. And it reminds us that one challenge of human-dimensions research is to apply our understanding of the arctic system to the conditions faced by the people who live there.

Henry P. Huntington

Inside

ARCUS

Arctic Research Consortium of the United States

3535 College Road
Suite 101
Fairbanks, AK
99709
USA

Non-Profit Org.
U.S. Postage
PAID
Permit No. 957
Anchorage, AK

Printed on Recycled Paper

Witness The
ARCTIC
Arctic Research Consortium of the United States Member Institution Spring 2002

Arctic Research at the Louisiana State University

by H. Jesse Walker

Years before arctic research became formalized at Louisiana State University (LSU), archaeologist James Ford worked on St. Lawrence Island and at Point Barrow, Alaska (1930–56); geographer Fred Kniffen was in Alaska (1922–24); and geographer Richard Russell and geologist Henry Howe were in Novaya Zemblya (1937). These pioneers relayed their experiences to their students, two of whom—Jesse Walker and Fred Hadleigh-West—did LSU's first arctic dissertations in the 1960s on the interactions of indigenous peoples with their arctic environment.

Ice Island Research

In 1952, 15 years after Russians had pioneered the use of Arctic Ocean ice as a base for research, Americans established their first drifting station on Fletcher's Ice Island (T-3). In 1958, as part of the International Geophysical Year Program, the U.S. Air Force Cambridge Research Center initiated a major research effort on T-3, including a geomorphology study conducted by David Smith (Dartmouth College). Smith transferred to LSU, continued his T-3 work, and in 1961, conducted geologic/glaciologic field work on the Arctic Research Laboratory Ice Station, II (ARLIS II). Like T-3, ARLIS II had fractured from Ellesmere Island; unlike T-3, it had prominent rock-covered, ice-cored hills. Smith deciphered the complicated glacial ice, iced firn, lake ice, sea ice, and morainal character of the island.

Floodwaters at the mouth of the Colville River delta in 1971. The LSU research team calculated that 10 days of flooding during breakup that year contributed 4.64 x 10^9 m^3 of freshwater—nearly half of that year's total discharge—as a freshwater wedge beneath 3,000 km^2 of sea ice (photo by Donald Nemeth).

The Coastal Studies Institute and Arctic Research

In 1954, the LSU Board of Supervisors established the Coastal Studies Institute (CSI) as an affiliated unit in the School of Geology, which encompassed studies in geology, geography, and anthropology. Russell was its founding director. Funded primarily by the U.S. Office of Naval Research (ONR) through its geography programs, CSI was interdisciplinary and field-oriented with emphasis on coastal forms and processes. After several years of coastal research along the U.S. Gulf Coast, and in Europe, Asia, and South America, CSI expanded to other areas of the world including the Arctic. In the 1960s and 1970s, CSI initiated two major arctic endeavors:

- a multifaceted, long-term study of the Colville River Delta (1961–78), and
- a broader-based program addressing Alaskan Arctic Coastal Processes and Morphology (1971–73).

ONR supported both of these programs under the supervision of Louis Quam, Evelyn Pruitt, and Max Britton. The Naval Arctic Research Laboratory (NARL), directed by Max Brewer and John Schindler, provided logistical support.

Published by the Arctic Research Consortium of the United States • 3535 College Road • Suite 101 • Fairbanks, AK 99709

The Colville River Delta Studies

Some of the most distinctive deltas on Earth are found in the Arctic. In 1960, CSI selected the moderately sized (~670 km^2) Colville River delta in Alaska for detailed study. Little known outside the Iñupiat community and mentioned briefly in the journals of only a few explorers (*e.g.,* Vilhjalmur Stefansson), the Colville River delta was scientifically a *terra incognita*. In March 1962, after reconnaissance in 1960, CSI launched a cryologic/hydrologic/geomorphic field investigation by a team composed of Lennart Arnborg and Johan Peippo (University of Uppsala, Sweden), Jesse Walker and Morris Morgan (LSU), and members of the George Woods family who lived on the delta.

Colville River Discharge

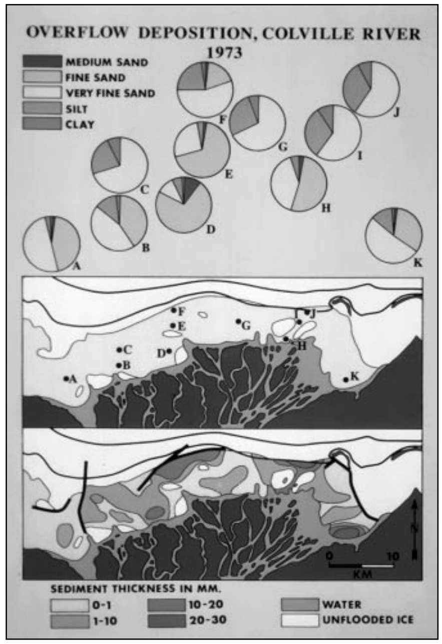
Prior to breakup (April–May 1962), the team monitored the ice and water regime of the Colville River from the ocean to 80 km upstream. Their observations that season included:

- no measurable flow in the river;
- a saltwater wedge extending 64 km upstream from the ocean;
- ice ~2 m thick—not thick enough to freeze to the bottom of the deepest part of the main channel, but thick enough to freeze portions of the west channel to the bottom, creating pockets of highly saline water (40–60‰);
- during high stages at breakup, the eastern channels carried some 70% of the water, Nechelik channel carried 20%, and other distributaries carried 10%; and
- during summer, generally the time of low discharge, the eastern channels carried about 77% of the discharge and the Nechelik channel about 22%.

Several seasons of study indicated that breakup occurs near the time of maximum stage. Ice jams are more common when breakup occurs on a falling stage than on a rising stage. Flood waters flow over bottom-fast river ice and also out over bottom-fast sea ice (see photo page 1).

Suspended Load in the Colville River

The research team also measured or calculated dissolved, suspended, and bed loads in the Colville River. Fine sediments deposited on the riverbed during the low flows beneath winter ice are the first to be entrained during the flood season. In 1962, some 5.8 x 10^6 tons of suspended inorganic material and 1.3 x 10^6 tons of dissolved salts were transported past the head of the delta. Of the total annual suspended load, 62% was transported in the 13-day breakup period.



The Colville River is one of many that flow from the Brooks Range to the Beaufort Sea, delivering freshwater and sediment loads that distinguish the Beaufort Sea ecosystem from that of the Chukchi Sea to the west. This chart maps sediment deposited on sea ice during flooding in 1973 (figure by H. Jesse Walker).

Channel Morphology

Echo-sounding of the river's channels (245 cross-sections in the two main channels and longitudinal profiles of the thalweg of other distributaries) revealed that channels were more than 12 m deep along cutbanks and at the mouths of tapped lakes and more than 1 km wide in some places. The nearly 500 km of channels include 53 bifurcations and 29 rejoinings, providing 5,200 possible routes to the sea.

Permafrost, Ice Wedges, and Bank Erosion

The Colville River and its delta are in the zone of continuous permafrost, where ice wedges are a common feature. High water often flows against a frozen bank with embedded ice wedges, carving a thermoerosional niche that undercuts as far as 8 m laterally into the frozen ground. The large hanging blocks may collapse, frequently along ice wedges, which are lines of weakness within the permafrost. This results in a major rate of bank retreat. Monitoring of bank retreat within the delta began in 1962 and continued into the mid-1990s.

In 1971 and 1973, teams of scientists, graduate assistants, and technicians turned their attention to the oceanography of the delta. The researchers calculated total freshwater discharge indirectly, by measuring the development of the freshwater wedge beneath the ice from stations they established on the sea ice at the front of the delta. In 1971, they occupied 29 stations a total of 59 times. In 1973, they occupied 56 stations 155 times and made another 54 observations and calculations at river sites. In 1971, 10 days of flooding during breakup spread 4.64 x 10^9 m^3 of freshwater—nearly half of the year's total discharge—across the bottom-fast sea ice at the front of the delta and then beneath about 3,000 km^2 of floating sea ice (see photo page 1).

Investigators measured the salinity and temperature of the sub-ice water column and took samples to determine the suspended load and the role of the river as a nutrient source during spring flooding. They found that breakup flooding raised the inorganic nitrogen:phosphate ratio to a state that was nutrient-balanced for phytoplankton in the nearshore waters of the Beaufort Sea.

Additional Colville River delta research during the early 1970s included:

- a detailed analysis of the processes and forms occurring on an arctic river bar (Lawrence Mckenzie, III);
- deposition on sea ice during flooding (Charles Wax);
- grain-size characteristics and fluvial processes on mid-channel gravel bars (Donald Nemeth); and
- the microclimate in a deltaic setting (Jeffrey Peake).

These studies earned the authors advanced degrees.

In 1971, William Ritchie (University of Aberdeen, Scotland) studied 170 riverbanks along the main channels. He noted that 59% of the riverbanks were erosional, 35% depositional, and 6% neutral. Righthand banks were 72% erosional; left-hand banks were only 46% erosional.

Other long-term field studies addressed:
- development of the active layer within sand dunes at the head of the delta (Walker and Harris, 1962–73), and
- the mapping of delta lakes as they were tapped by migrating river channels (Walker and Roselle, 1962–88).

Other Deltaic Research

Other arctic delta studies included:
- a morphologic and hydrologic study of the Blow River delta in Canada (James McCloy and Hyuck Kwon, 1967);
- an analysis of the structure and composition of deltaic sediments (Werner Furbringer, 1973);
- a classification of deltaic lakes (Alastair Dawson, 1975); and
- a classification of ice-wedge polygons using aerial photographs and Landsat digital data (Joann Mossa, 1983).

In the 1990s, more focused research led by Torre Jorgenson of Alaska Biological Research (ABR), Inc. built on results of the LSU Colville delta projects. The work by ABR addressed the environmental and engineering challenges of developing the Alpine oilfield in the dynamic deltaic terrain.

A few studies were more broadly based than the deltaic studies. Both Joseph Crotts (1972) and Chao-yu Wu (1983), for example, made morphometric analyses of the Colville drainage basin, and Walker (1973) worked on the morphology of the North Slope, including the small landforms present in the landscape.

The Colville River delta research resulted in more than 75 articles, monographs, and reports, as well as 12 theses and dissertations. Much of the material is available on the LSU web site (www.lsu.edu/diglib) under "Colville River Delta" in "Collections."

Ice wedges in peat banks melt more rapidly than the peat surrounding them erodes, leaving a riverbank that is serrated (photo by H. Jesse Walker).

Alaskan Arctic Coastal Processes and Morphology

Between May 1971 and June 1973, CSI conducted a study of the variability—both temporal and spatial—of the environment and physical processes of the Alaskan arctic coast. The intent was to characterize the interactions between the two fluid components of the environment—the ocean and the atmosphere—and between the two solid components—the land and the ice. Two sites—Point Lay on the Chukchi Sea, and less accessible Pingok Island in the Beaufort Sea—were chosen for detailed study of near-shore processes. Researchers analyzed existing data from arctic Alaska and made aerial field reconnaissance trips during breakup, open water, and freeze-up.

Atmospheric Processes

The objective of this study was to gather data at the Earth's surface in order to better understand the way the atmosphere affects the dynamic aspects of coastal processes. Shih Hsu and C. D. Walters, Jr., established wind-profile stations at Point Lay and on Pingok Island. They found that between wind speeds of 1–9 m/s (approximately 2.25–20 mph), the drag coefficient was approximately 1.7×10^{-3} for air-sea momentum transfer in the Chukchi Sea under summer conditions.

They also determined the vertical structure of wind across a sea-ice pressure ridge under winter conditions. They found that high-velocity air flow developed between the crest of the pressure ridge and one meter above it—a jet that contrasted with logarithmic wind profiles over smooth ice. This research, along with a similar study at a coastal dune site in Texas, led to the modification in the basic airflow models that were extant in the 1970s.

Subsequent to the field investigations of 1971–72, William Wiseman, Jr., and Andrew Short analysed Distant Early Warning (DEW) Line temperature records and concluded that:
- temperature variations on time scales of less than a month are larger in winter than summer;
- large warming trends occur between late fall and early spring; and
- temperature variation may have a periodicity of 45 days (based on spectrum analyses).

Nearshore Hydrodynamic Processes

Under the supervision of Wiseman and Joseph Suhayda, the CSI group selected four nearshore hydrodynamic phenomena for concentrated study:
- sea-level variations,
- wave motion,
- mesoscale currents, and
- mesoscale water-mass variability.

Among other things, the investigators observed meteorological tides greater in magnitude than astronomical tides. Energy input to the coastline was especially great during storms (*e.g.,* alongshore wave power was 2×10^8 ergs/sec/cm, contrasted with 1×10^6 ergs/sec/cm under non-storm conditions). Such contrast is reflected in a sediment transport ratio of 1:142 (*i.e.,* one day of that storm transported as much sediment alongshore as 142 days of transport under average wave conditions).

Wiseman and Suhayda also observed that the flushing of coastal lagoons introduced sediment as well as freshwater into the nearshore system. The lower salinities of this inlet water affected the timing of freeze-up at their mouths and alongshore.

Alaskan Arctic Coastal Morphology

The CSI morphological study (1971-73) encompassed 1,441 km of coastline from Point Hope to Demarcation Point. Principal investigators James Coleman, Andrew Short, and Lynn Wright identified 22 landform "provinces"—barrier islands characterized 56% of the coast, tundra bluffs 27%, deltas 9%, and rocky cliffs 8%.

Macroscale variability of the coast is the result of geologic structure, river distribution, oceanic circulation, thermal regime, ice-pack conditions, open-water periods, and wave power. A major difference between the Beaufort and Chukchi coasts is that all of the major rivers of the North Slope drain into the Beaufort Sea—affecting the development of deltas and the introduction of sediment into the Arctic Ocean. Compared to the Beaufort Sea coast, along the Chukchi Sea coast:

- breakup was earlier,
- open water lasted longer and covered a larger area, and
- wave energy was greater.

Beach Processes and Responses

The CSI team studied beach process-response interactions in the context of breakup, open water, and freeze-up. River-ice breakup precedes sea-ice breakup, often by weeks. Beach thaw is highly variable; timing and extent depend largely on wave conditions during freeze-up, as ice incorporated into the beach during storms affects beach thaw and beach morphology.

A study of ice movement revealed differences seaward and landward of an offshore bar because of the interaction between waves and tides and the bottom topography. Fathometer profiles at Pingok Island revealed four bars with steep shoreward slopes and gentle seaward slopes, intersecting the shoreline at an angle between 8° and 10°. These arctic bars were the first known evidence of outer bars consistently extending to and actively modifying the shoreline in the absence of inner bars.

Onshore beach ridges were well preserved compared with similar features in other climates because:

- severe storms are rare,
- the ridges are frozen 10 months/year,
- a gravel pavement on their surface reduces deflation, and
- swales full of water during summer undergo little eolian erosion.

Subsequent Coastal Research

Although the above represents the active field and laboratory phase of CSI's Alaskan Arctic Coastal Processes and Morphology Study, many of the principals of that group extended their involvement:

- Short and Wright identified two major sets of lineaments on the North Slope and suggested that there is a direct association between them and arctic coastal morphology;
- Short demonstrated the role of offshore standing waves in controlling the pattern of sand bars;
- Harper and Wiseman wrote on the temporal variation of surface roughness on a tundra surface;
- Harper completed a dissertation on the physical processes affecting tundra cliff stability;
- Douglas Fisher investigated active layer development on a barrier island; and
- CSI and Department of Geology personnel, especially Wiseman, Don Lowe, and David Prior, studied slope instabilities in arctic and sub-arctic fjords, which cause some of the most intense currents observed in deep fjords.

Environmental Geomorphology

Development of the petroleum industry and modernization of North Slope villages since the 1970s brought large demands for sand and gravel. The NSB opted to use unfrozen deposits beneath deeper rivers, lakes, lagoons, and nearshore ocean waters. Dredging began in 1981 on the Colville River delta. The NSB Public Works Department initiated environmental monitoring, with which Jesse Walker was associated from 1980 to 1994, noting alterations in the tundra surface after runway construction and changes in the dredge channels in the Kokolik, Meade, and Colville rivers.

An unabridged version of this overview of LSU research in the Arctic is available on the ARCUS web site at:

www.arcus. org/Witness_the_Arctic/Spring_02/Contents.html

For more information, contact:

H. Jesse Walker
Dept. of Geography & Anthropology
Louisiana State University
Baton Rouge, LA 70803
Phone: 225/578-6130
Fax: 225/578-4420
hwalker@lsu.edu
www.lsu.edu

Arctic Biology

Since 1980, a team from LSU's Department of Comparative Biomedical Sciences—Yahya Abdelbaki, Dennis Duffield, Jerrold Haldiman, William Henk, Robert Henry, Daniel Hillmann, and Diana Mullan—has been leading a study to collect baseline data on the anatomy of the bowhead whale *(Balaena mysticetus)* prior to potential environmental alteration. They are studying the anatomy of the lungs, kidneys, eyes, hearts, and brains, and the structure and thickness of the skin of whales harvested by Iñupiat and Yupik Eskimos off at least six coastal villages.

This is one of many research projects in arctic Alaska that have involved residents (*e.g.,* whaling captains and crews), and it reflects the Inuit's concern for their environment. Sponsors have included the U.S. Bureau of Land Management; the NSB, the Chinese Academy of Sciences, and the LSU School of Veterinary Medicine.

LSU is also involved in long-term research on the population biology of geese at Karrak Lake in Nunavut, Canada. Alan Afton (LSU's Biological Resources Division) has been a visiting research scientist with the Canadian Wildlife Service since 1993. Along with graduate students, he is focusing on the behavioral aspects, foraging ecology, and nutrition of Ross's geese *(Chen rossii)* and lesser snow geese *(Chen caerulescens caerulescens)*.

LSU Comparative Biomedical Sciences researchers collect baseline data on the dimensions of the skull of a bowhead whale harvested by North Slope residents at Barrow, Alaska (photo by Daniel Hillmann).

NSF Office of Polar Programs Arctic Section Addresses — Spring 2002

Arctic Sciences Section • www.nsf.gov/od/opp/arctic/start.htm

Office of Polar Programs (OPP)
National Science Foundation (NSF)
4201 Wilson Boulevard, Suite 755 S
Arlington, VA 22230
Phone: 703/292-8029 • Fax: 703/292-9082

Thomas E. Pyle, *Section Head*
tpyle@nsf.gov

Charles E. Myers, *Head of Interagency Arctic Staff*
cmyers@nsf.gov

Robin Muench, *Program Officer*
rmuench@nsf.gov

Renée Crain, *Science Assistant*
rcrain@nsf.gov

Arctic System Science Program (ARCSS)
www.nsf.gov/od/opp/arctic/system.htm

Neil Swanberg, *Acting Program Director*
nswanber@nsf.gov

Luis M. Tupas, *Associate Program Director*
ltupas@nsf.gov

Arctic Social Sciences Program
www.nsf.gov/od/opp/arctic/social.htm

Robin Muench, *Acting Program Manager*
rmuench@nsf.gov

Arctic Natural Sciences Program
www.nsf.gov/od/opp/arctic/natural.htm

Jane V. Dionne, *Program Manager*
jdionne@nsf.gov

Robin Muench, *Acting Program Manager*
rmuench@nsf.gov

Research Support & Logistics
www.nsf.gov/od/opp/arctic/suplog.htm

Simon N. Stephenson, *Program Manager*
sstephen@nsf.gov

Arctic System Science Program (ARCSS) Program Addresses

ARCSS Committee (AC) • www.arcus.org/ARCSS/ARCSS.html

Jonathan T. Overpeck, *Chair*
Institute for the Study of Planet Earth
University of Arizona, Tucson
Phone: 520/622-9065 • Fax: 520/792-8795
jto@u.arizona.edu

F. Stuart (Terry) Chapin, III
Institute of Arctic Biology
University of Alaska, Fairbanks
Phone: 907/474-7922 • Fax: 907/474-6967
terry.chapin@uaf.edu

Rudy J. Dichtl
Cooperative Institute for Research in Environmental Sciences (CIRES)
National Snow & Ice Data Center (NSIDC)
University of Colorado, Boulder
Phone: 303/492-5532 • Fax: 303/492-2468
dichtl@kryos.colorado.edu

Lawrence C. Hamilton
Department of Sociology HSSC
University of New Hampshire, Durham
Phone: 603/862-1859 • Fax: 603/862-3558
lawrence.hamilton@unh.edu

Lloyd D. Keigwin
Department of Geology & Geophysics
Woods Hole Oceanographic Institution, MA
Phone: 508/289-2784 • Fax: 508/457-2183
lkeigwin@whoi.edu

Amanda Lynch
CIRES
Program in Atmospheric & Oceanic Sciences
University of Colorado, Boulder
Phone: 303/492-5847 • Fax: 303/492-1149
manda@tok.colorado.edu

Glen M. MacDonald
Departments of Geography & Organismic Biology, Ecology & Evolution
University of California, Los Angeles
Phone: 310/825-2568 • Fax: 310/206-5976
macdonal@geog.ucla.edu

Bruce J. Peterson
The Ecosystems Center
Marine Biological Laboratory (MBL)
Woods Hole, MA
Phone: 508/289-7484 • Fax: 508/457-1548
peterson@mbl.edu

John Weatherly
Cold Regions Research & Engineering Laboratory (CRREL)
Hanover, NH
Phone: 603/646-4741 • Fax: 603/646-4644
weather@crrel.usace.army.mil

ARCSS Committee Coordination
www.arcus.org

Wendy K. Warnick, *Executive Director*
Arctic Research Consortium of the United States (ARCUS)
Fairbanks, AK
Phone: 907/474-1600 • Fax: 907/474-1604
warnick@arcus.org • arcus@arcus.org

Dan Ferguson, *Project Manager*
ARCUS
Phone: 907/474-1600 • Fax: 907/474-1604
dan@arcus.org

ARCSS Data Coordination Center
http://arcss.colorado.edu

Rudy J. Dichtl, *Data Manager*
CIRES/NSIDC
University of Colorado, Boulder
Phone: 303/492-5532 • Fax: 303/492-2468
dichtl@kryos.colorado.edu

Chris McNeave, *Data Coordinator*
CIRES/NSIDC
University of Colorado, Boulder
Phone: 303/492-1390 • Fax: 303/492-2468
mcneave@kryos.colorado.edu

Human Dimensions of the Arctic System (HARC) • www.arcus.org/harc

HARC Science Management Office

Henry P. Huntington, *Director*
Huntington Consulting
Eagle River, AK
Phone: 907/696-3564 • Fax: 907/696-3565
hph@alaska.net

Dan Ferguson, *Project Manager*
ARCUS
Fairbanks, AK
Phone: 907/474-1600 • Fax: 907/474-1604
dan@arcus.org

Land-Atmosphere-Ice Interactions (LAII) program • www.laii.uaf.edu

LAII Science Steering Committee

F. Stuart (Terry) Chapin, III, *Co-chair*
Institute of Arctic Biology
University of Alaska, Fairbanks
Phone: 907/474-7922 • Fax: 907/474-6967
terry.chapin@uaf.edu

Matthew Sturm, *Co-chair*
CRREL
Ft. Wainwright, AK
Phone: 907/353-5183 • Fax: 907/353-5142
msturm@crrel.usace.army.mil

Mary E. Edwards
Geografisk Institutt
Norwegian Univ. of Science & Technology
Trondheim, Norway
Phone: +47/7359-1915 • Fax: +47/7359-1878
mary.edwards@svt.ntnu.no

Brad Griffith
Alaska Coop. Fish & Wildlife Research Unit
University of Alaska, Fairbanks
Phone: 907/474-5067 • Fax: 907/474-6716
ffdbg@uaf.edu

Henry P. Huntington
Huntington Consulting
Eagle River, AK
Phone: 907/696-3564 • Fax: 907/696-3565
hph@alaska.net

Gary Kofinas
Institute of Arctic Studies
Dartmouth College
Hanover, NH
Phone: 603/646-1278 • Fax: 603/646-1279
gary.kofinas@dartmouth.edu

Andrea H. Lloyd
Department of Biology
Middlebury College, VT
Phone: 802/443-3165 • Fax: 802/443-2072
lloyd@middlebury.edu

Bruce J. Peterson
The Ecosystems Center, MBL
Woods Hole, MA
Phone: 508/289-7484 • Fax: 508/457-1548
peterson@mbl.edu

Joshua Schimel
Department of Ecology, Evolution & Marine Biology
University of California, Santa Barbara
Phone: 805/893-7688 • Fax: 805/893-4724
schimel@lifesci.lscf.ucsb.edu

Mark C. Serreze
CIRES/NSIDC
University of Colorado, Boulder
Phone: 303/492-2963 • Fax: 303/492-2468
serreze@kryos.colorado.edu

Gaius Shaver
The Ecosystems Center, MBL
Woods Hole, MA
Phone: 508/289-7492 • Fax: 508/457-1548
gshaver@mbl.edu

LAII Science Management Office

F. Stuart (Terry) Chapin, III, *Director*
Institute of Arctic Biology
University of Alaska, Fairbanks
Phone: 907/474-7922 • Fax: 907/474-6967
terry.chapin@uaf.edu

Patricia A. Anderson, *Deputy Director*
Center for Global Change & Arctic System Research
University of Alaska, Fairbanks
Phone: 907/474-5415 • Fax: 907/474-6722
patricia@iarc.uaf.edu

Ocean-Atmosphere-Ice Interactions (OAII) program • http://arcss-oaii.hpl.umces.edu

OAII Science Steering Committee

Don Perovich, *Chair-Elect*
Snow & Ice Division
CRREL
Hanover, NH
Phone: 603/646-4255 • Fax: 603/646-4644
perovich@crrel.usace.army.mil

Leonard A. Barrie
Atmospheric Sci. & Global Change Resources
Pacific Northwest National Laboratory
Richland, WA
Phone: 509/375-3998 • Fax: 509/372-6153
leonard.barrie@pnl.gov

Dennis A. Darby
Dept. of Ocean, Earth & Atmospheric Science
Old Dominion University
Norfolk, VA
Phone: 757/683-4701 • Fax: 757/683-5303
ddarby@odu.edu

Thomas L. Delworth
Geophysical Fluid Dynamics Laboratory
National Oceanic & Atmospheric Administration (NOAA)
Princeton, NJ
Phone: 609/452-6565 • Fax: 609/987-5063
td@gfdl.noaa.gov

Hajo Eicken
Geophysical Institute
University of Alaska, Fairbanks
Phone: 907/474-7280 • Fax: 907/474-7290
hajo.eicken@gi.alaska.edu

Rob W. Macdonald
Institute of Ocean Sciences
Department of Fisheries & Oceans
Sidney, BC Canada
Phone: 250/363-6409 • Fax: 250/363-6807
macdonaldrob@pac.dfo-mpo.gc.ca

Patricia A. Matrai
Bigelow Laboratory for Ocean Sciences
West Boothbay Harbor, ME
Phone: 207/633-9614 • Fax: 207/633-9641
pmatrai@bigelow.org

Astrid E. J. Ogilvie
Institute of Arctic & Alpine Research
University of Colorado, Boulder
Phone: 303/492-6072 • Fax: 303/492-6388
ogilvie@spot.colorado.edu

Paul B. Shepson
Departments of Chemistry, Earth & Atmospheric Sciences
Purdue University
West Lafayette, IN
Phone: 765/494-7441 • Fax: 765/494-0239
pshepson@purdue.edu

Michael Steele
Applied Physics Laboratory
Polar Science Center (PSC)
University of Washington, Seattle
Phone: 206/543-6586 • Fax: 206/616-3142
mas@apl.washington.edu

David Thompson
Department of Atmospheric Science
Colorado State University, Fort Collins
Phone: 970/491-3338 • Fax: 970/491-8449
davet@atmos.colostate.edu

Cynthia Tynan
NOAA
Northwest Fisheries Science Center
Seattle, WA
Phone: 206/860-6793 • Fax: 206/860-3267
cynthia.tynan@noaa.gov

John Weatherly *(non-OAII Representative)*
CRREL
Hanover, NH
Phone: 603/646-4741 • Fax: 603/646-4644
weather@crrel.usace.army.mil

OAII Science Management Office

Louis A. Codispoti, *Director*
Horn Point Laboratory
University of Maryland
Phone: 410/221-8479 • Fax: 410/221-8490
codispot@hpl.umces.edu

Jane Hawkey, *Manager*
Horn Point Laboratory
University of Maryland
Phone: 410/221-8416 • Fax: 410/221-8490
hawkey@hpl.unces.edu

Paleoenvironmental Arctic Sciences (PARCS) • www.ngdc.noaa.gov/paleo/parcs

PARCS Science Steering Committee

Darrell S. Kaufman, *Co-Chair*
Department of Geology
Northern Arizona University, Flagstaff
Phone: 928/523-7192 • Fax: 928/523-9220
darrell.kaufman@nau.edu

Glen M. MacDonald, *Co-Chair*
Departments of Geography & Organismic Biology, Ecology & Evolution
University of California, Los Angeles
Phone: 310/825-2568 • Fax: 310/206-5976
macdonal@geog.ucla.edu

Marianne Douglas
Department of Geology
University of Toronto, ON, Canada
Phone: 416/978-3709 • Fax: 416/978-3938
msvd@opal.geology.utoronto.ca

Mathieu Duvall, *Data Manager*
Department of Geology
Bates College, Lewiston, ME
Phone: 207/753-6945 • Fax: 207/786-8334
mduvall@bates.edu

Bruce P. Finney
Institute of Marine Science
University of Alaska, Fairbanks
Phone: 907/474-7724 • Fax: 907/474-7204
finney@ims.uaf.edu

Aslaug Geirsdottir
Department of Geosciences
University of Iceland, Reykjavik
Phone: +354/5254477 • Fax: +354/5254499
age@rhi.hi.is

Feng Sheng Hu
Department of Plant Biology
University of Illinois, Urbana
Phone: 217/244-2982 • Fax: 217/244-7246
fshu@life.uiuc.edu

Malcolm K. Hughes
Laboratory of Tree-Ring Research
University of Arizona, Tucson
Phone: 520/621-6470 • Fax: 520/621-8229
mhughes@ltrr.arizona.edu

Anne E. Jennings
Institute of Arctic & Alpine Research
University of Colorado, Boulder
Phone: 303/492-7621 • Fax: 303/492-6388
jenninga@spot.colorado.edu

Anatoly V. Lozhkin
Northeast Interdisciplinary Scientific Research Institute—Far East Branch
Russian Academy of Sciences
16 Portovaya Street
685000 Magadan, Russia
Phone: +7413/223-0944
Fax: +7413/223-0051
lozhkin@neisri.magadan.su

Gifford H. Miller, *CAPE Representative*
Institute of Arctic & Alpine Research
University of Colorado, Boulder
Phone: 303/492-6962 • Fax: 303/492-6388
gmiller@colorado.edu

Bette L. Otto-Bliesner
Climate Change Research
National Center for Atmospheric Research
Boulder, CO
Phone: 303/497-1723 • Fax: 303/497-1348
ottobli@ncar.ucar.edu

Eric J. Steig
Department of Earth & Space Sciences
University of Washington, Seattle
Phone: 206/685-3715 • Fax: 206/685-3836
steig@ess.washington.edu

PARCS Science Management Office

Larry Coats, *Manager*
Department of Geology
Northern Arizona University, Flagstaff
Phone: 928/523-0958 • Fax: 928/556-7500
larry.coats@nau.edu

Russian-American Initiative on Shelf-Land Environments in the Arctic (RAISE) • www.raise.uaf.edu

Russian Science Steering Committee

Igor Melnikov, *Co-chair*
P.P. Shirshov Institute of Oceanology
36, Nakhimovski Pr.
117997 Moscow, Russia
Phone: +7095/124-5996
Fax: +7095/124-5983
migor@online.ru

Sergey Priamikov, *Co-chair*
Arctic & Antarctic Institute
38, Bering Street
199397 St. Petersburg, Russia
Phone: +7812/352-0096
Fax: +7812/352-2685
priamiks@aari.nw.ru • aaricoop@aari.nw.ru

Vladimir Pitulko (*Pending*)
Institute for the History of Material Culture
Russian Academy of Sciences
18, Dvortsovaya nab.
191186 St. Petersburg, Russia
Phone: +7812/233-6802
Fax: +7812/311-6271
archeo@archeo.spb.ru

Nikolai N. Romanovskii
Moscow State University Faculty of Geology
Department of Geocryology
Vorobyovy Gory
119899 Moscow, Russia
Phone: +7095/939-1937
Fax: +7095/932-8889
nromanovsky@glas.apc.org

Igor P. Semiletov
Pacific Oceanological Institute in Vladivostok
through mid-2002:
Frontier Research System for Global Change
International Arctic Research Center (IARC)
University of Alaska, Fairbanks
Phone: 907/474-6286 • Fax: 907/474-2643
igorsm@iarc.uaf.edu • arctic@online.marine.su

U.S. Science Steering Committee

Lee Cooper, *Chair*
Dept. of Ecology & Evolutionary Biology
University of Tennessee, Knoxville
Phone: 865/974-2990 • Fax: 865/974-3067
lcooper1@utk.edu

Steve Forman
Department of Geological Sciences
University of Illinois, Chicago
Phone: 312/413-9404 • Fax: 312/413-2279
slf@uic.edu

Richard Lammers
Water Systems Analysis Group
University of New Hampshire, Durham
Phone: 603/862-4699 • Fax: 603/862-0587
richard.lammers@unh.edu

Bruce Peterson
The Ecosystems Center, MBL
Woods Hole, MA
Phone: 508/548-3705 ext. 7484
Fax: 508/457-1548
peterson@mbl.edu

Andrey Proshutinsky
Department of Physical Oceanography
Woods Hole Oceanographic Institution, MA
Phone: 508/289-2796 • Fax: 508/457-2181
aproshutinsky@whoi.edu

Vladimir Romanovsky, *Project Office Director*
Geophysical Institute
University of Alaska, Fairbanks
Phone: 907/474-7459 • Fax: 907/474-7290
ffver@uaf.edu

Laurence Smith (*Pending*)
Department of Geography
University of California, Los Angeles
Phone: 310/825-1071 • Fax: 310/206-5976
lsmith@geog.ucla.edu

Pan-Arctic Community-wide Hydrological Analysis & Monitoring Program (Arctic-CHAMP)

www.arcus.org/ARCSS/hydro/index.html

Arctic-CHAMP Science Steering Committee

Larry D. Hinzman, *Co-chair*
Water & Environmental Research Center
University of Alaska, Fairbanks
Phone: 907/474-7331 • Fax: 907/474-7979
ffldh@uaf.edu

Charles Vörösmarty, *Co-chair*
Water Systems Analysis Group
University of New Hampshire, Durham
Phone: 603/862-0850 • Fax: 603/862-0587
charles.vorosmarty@unh.edu

Roger G. Barry
CIRES/NSIDC
University of Colorado, Boulder
Phone: 303/492-5488 • Fax: 303/492-2468
rbarry@kryos.colorado.edu

Mark Fahnestock
Complex Systems Research Center
Inst. for the Study of Earth, Oceans & Space
University of New Hampshire, Durham
Phone: 603/862-5065 • Fax: 603/862-0188
mark@essic.umd.edu

Henry P. Huntington
Huntington Consulting
Eagle River, AK
Phone: 907/696-3564 • Fax: 907/696-3565
hph@alaska.net

Rob W. Macdonald
Institute of Ocean Sciences
Department of Fisheries and Oceans
Sidney, BC Canada
Phone: 250/363-6409 • Fax: 250/363-6807
macdonaldrob@pac.dfo-mpo.gc.ca

Kyle C. McDonald
Terrestrial Science Research Element
Jet Propulsion Laboratory (JPL)
California Institute of Technology, Pasadena
Phone: 818/354-3263 • Fax: 818/354-9476
kyle.mcdonald@jpl.nasa.gov

David A. McGuire
Institute of Arctic Biology
University of Alaska, Fairbanks
Phone: 907/474-6242 • Fax: 907/474-6716
ffadm@uaf.edu

Don K. Perovich
CRREL
Hanover, NH
Phone: 603/646-4255 • Fax: 603/646-4644
perovich@crrel.usace.army.mil

Bruce J. Peterson
The Ecosystems Center, MBL
Woods Hole, MA
Phone: 508/289-7484 • Fax: 508/457-1548
peterson@mbl.edu

Michael Steele
Applied Physics Laboratory, PSC
University of Washington, Seattle
Phone: 206/543-6586 • Fax: 206/616-3142
mas@apl.washington.edu

Matthew Sturm
CRREL
Ft. Wainwright, AK
Phone: 907/353-5183 • Fax: 907/353-5142
msturm@crrel.usace.army.mil

James Syvitski
Institute of Arctic & Alpine Research
University of Colorado, Boulder
Phone: 303/492-7909 • Fax: 303/492-6388
james.syvitski@colorado.edu

John E. Walsh
Department of Atmospheric Sciences
University of Illinois, Urbana
Phone: 217/333-7521 • Fax: 217/244-4393
walsh@atmos.uiuc.edu

Robert S. Webb
National Geophysical Data Center E/GC
NOAA
Boulder, CO
Phone: 303/497-6967 • Fax: 303/497-7013
rwebb@cdc.noaa.gov

Study of Environmental Arctic Change (SEARCH)

http://psc.apl.washington.edu/search

SEARCH Science Steering Committee

Jamie Morison, *Chair & Project Office Director*
Applied Physics Lab, PSC
University of Washington, Seattle
Phone: 206/543-1394 • Fax: 206/616-3142
morison@apl.washington.edu

Vera Alexander
School of Fisheries & Ocean Sciences
University of Alaska, Fairbanks
Phone: 907/474-6824 • Fax: 907/474-7386
vera@ims.alaska.edu

Louis A. Codispoti
Center for Environmental Science
Horn Point Laboratory
University of Maryland
Phone: 410/221-8479 • Fax: 410/221-8490
codispot@hpl.umces.edu

Thomas L. Delworth
Geophysical Fluid Dynamics Laboratory
NOAA
Princeton, NJ
Phone: 609/452-6565 • Fax: 609/987-5063
td@gfdl.gov

Bob Dickson
Centre for Environment, Fisheries & Aquaculture Science (CEFAS)
Suffolk, UK
Phone: +44/1502-524282
Fax: +44/1502-513865
r.r.dickson@cefas.co.uk

Hajo Eicken
Geophysical Institute
University of Alaska, Fairbanks
Phone: 907/474-7280 • Fax: 907/474-7290
hajo.eicken@gi.alaska.edu

Jacqueline M. Grebmeier
Dept. of Ecology & Evolutionary Biology
University of Tennessee, Knoxville
Phone: 865/974-2592 • Fax: 865/974-7896
jgrebmei@utk.edu

George Hunt
Dept. of Ecology & Evolutionary Biology
University of California, Irvine
Phone: 949/824-2181 • Fax: 949/824-2181
hlhunt@uci.edu

Jack Kruse
Department of Geosciences
University of Massachusetts, Leverett
Phone: 413/367-2240 • Fax: 413/367-0092
jkruse@geo.umass.edu

Dennis Lettenmaier
Civil & Environmental Engineering
University of Washington, Seattle
Phone: 206/543-2532 • Fax: 206/685-3836
dennisl@u.washington.edu

Dave McGuire
Institute of Arctic Biology
University of Alaska, Fairbanks
Phone: 907/474-6242 • Fax: 907/474-6716
ffadm@aurora.uaf.edu

Jim Overland
Pacific Marine Environmental Laboratory
NOAA, Seattle, WA
Phone: 206/526-6795 • Fax: 206/526-6485
overland@pmel.noaa.gov

Jonathan Overpeck
Institute for the Study of Planet Earth
University of Arizona, Tucson
Phone: 520/622-9065 • Fax: 520/792-8795
jto@u.arizona.edu

Peter Schlosser
Lamont-Doherty Earth Observatory
Columbia University, Palisades, NY
Phone: 914/365-8707 • Fax: 914/365-8155

Mark C. Serreze
CIRES/NSIDC
University of Colorado, Boulder
Phone: 303/492-2963 • Fax: 303/492-1149
serreze@kryos.colorado.edu

Gus Shaver
The Ecosystems Center, MBL
Woods Hole, MA
Phone: 508/289-7492 • Fax: 508/457-1548
gshaver@mbl.edu

John Walsh
Department of Atmospheric Sciences
University of Illinois, Urbana
Phone: 217/333-7521 • Fax: 217/244-4393
walsh@atmos.uiuc.edu

ARCUS Board of Directors • www.arcus.org/ARCUS/directors.html

Henry P. Huntington, *President*
Huntington Consulting
23834 The Clearing Drive
Eagle River, AK 99577
Phone: 907/696-3564 • Fax: 907/696-3565
hph@alaska.net

Lilian Alessa
Department of Biology
University of Alaska Anchorage
3211 Providence Drive
Anchorage, AK 99508
Phone: 907/786-1507 • Fax: 907/786-4607
lil@uaa.alaska.edu • www.uaa.alaska.edu

Raymond S. Bradley
Department of Geosciences
University of Massachusetts
Morrill Science Center
Campus Box 35820
Amherst, MA 01003-5820
Phone: 413/545-2120 • Fax: 413/545-1200
rbradley@geo.umass.edu • www.umass.edu

Louis A. Codispoti, *Secretary*
Center for Environmental Science
Horn Point Laboratory
University of Maryland
PO Box 775
Cambridge, MD 21601-0775
Phone: 410/221-8479 • Fax: 410/221-8490
codispot@hpl.umces.edu • www.umd.edu

Gregory M. Flato
Canadian Centre for Climate Modeling & Analysis–Atmospheric Environment Service
University of Victoria
PO Box 1700
Victoria, BC V8W2Y2 Canada
Phone: 250/363-8233 • Fax: 250/363-8247
greg.flato@ec.gc.ca • www.uvic.ca

Harald Gaski
Faculty of Humanities–Department of Sámi
University of Tromsø
N-9037 Tromsø, Norway
Phone: +47/7764-4259 • Fax: +47/7764-4239
harald.gaski@hum.uit.no • www.uit.no

Taqulik Hepa
Department of Wildlife Management
North Slope Borough
PO Box 69
Barrow, AK 99723
Phone: 907/852-0350 • Fax: 907/852-0351
thepa@co.north-slope.ak.us • www.co.north-slope.ak.us

David R. Klein, *Treasurer*
Institute of Arctic Biology
University of Alaska Fairbanks
PO Box 757020
Fairbanks, AK 99775-7020
Phone: 907/474-6674 • Fax: 907/474-6967
ffdrk@uaf.edu • www.uaf.edu

Daniel H. Mann
Institute of Arctic Biology
University of Alaska Fairbanks
PO Box 757000
Fairbanks, AK 99775-7000
Phone: 907/474-2419 • Fax: 907/474-7640
dmann@mosquitonet.com • www.uaf.edu

Wieslaw Maslowski, *Executive Committee*
Department of Oceanography–Code OC/Ma
Naval Postgraduate School
833 Dyer Road, Room 331
Monterey, CA 93943-5122
Phone: 831/656-3162 • Fax: 831/656-2712
maslowsk@ncar.ucar.edu • www.nps.navy.mil

Astrid E. J. Ogilvie
Institute of Arctic and Alpine Research
University of Colorado Boulder
Campus Box 450
1560 30th Street
Boulder, CO 80309-0450
Phone: 303/492-6072 • Fax: 303/492-6388
ogilvie@spot.colorado.edu • www.colorado.edu

Mark C. Serreze, *Executive Committee*
CIRES/National Snow & Ice Data Center
University of Colorado Boulder
Campus Box 216
Boulder, CO 80309-0449
Phone: 303/492-2963 • Fax: 303/492-2468
serreze@kryos.colorado.edu • www.colorado.edu

Bernard D. Zak
Environmental Characterization & Monitoring Systems Department
Sandia National Laboratories
PO Box 5800
Albuquerque, NM 87185-0755
Phone: 505/845-8631 • Fax: 505/844-0116
bdzak@sandia.gov • www.sandia.gov

ARCUS Member Institutions, Representatives, and Alternates

Alaska North Slope Borough Department of Wildlife Management

www.co.north-slope.ak.us

Robert Suydam
Department of Wildlife Management
North Slope Borough
PO Box 69
Barrow, AK 99723
Phone: 907/852-0350 • Fax: 907/852-0351
rsuydam@co.north-slope.ak.us

Todd O'Hara
address, phone, & fax same as Robert Suydam
tohara@co.north-slope.ak.us

Arizona State University

www.asu.edu

Anthony J. Brazel
Department of Geography
Arizona State University
PO Box 870104
Tempe, AZ 85287-0104
Phone: 480/965-6436 • Fax: 480/965-8313
abrazel@asu.edu

Bates College

www.bates.edu

Michael Retelle
Geology Department
Bates College
44 Campus Avenue
Lewiston, ME 04240
Phone: 207/786-6155 • Fax: 207/786-8334
mretelle@bates.edu

William G. Ambrose
Biology Department
address same as Michael Retelle
Phone: 207/786-6114 • Fax: 207/786-6123
wambrose@bates.edu

Brown University

www.brown.edu

Douglas D. Anderson
Department of Anthropology
Brown University
PO Box 1921
Providence, RI 02912
Phone: 401/863-7060 • Fax: 401/863-7588
douglas_anderson@brown.edu

The Center for Northern Studies

http://community.middlebury.edu/~cns

Steven Young
The Center for Northern Studies
479 Cross Road
Wolcott, VT 05680-4088
Phone: 802/888-4331 • Fax: 802/888-3969
cnsnorth@together.net

Steven Cox
contact information same as Steven Young

Cold Regions Research & Engineering Laboratory (CRREL)

www.crrel.usace.army.mil

Debra Meese
Snow & Ice Division
Cold Regions Research & Engineering Laboratory
72 Lyme Road
Hanover, NH 03755-1290
Phone: 603/646-4594 • Fax: 603/646-4644
dmeese@crrel.usace.army.mil

Walter (Terry) Tucker, III
address same as Debra Meese
Phone: 603/646-4268 • Fax: 603/646-4644
wtucker@crrel.usace.army.mil

(continued next page)

ARCUS Member Institutions, Representatives, and Alternates *(continued)*

Dartmouth College
www.dartmouth.edu

Oran R. Young
Institute of Arctic Studies
Dartmouth College
6214 Fairchild
Hanover, NH 03755-3517
Phone: 603/646-1278 • Fax: 603/646-1279
oran.r.young@dartmouth.edu

Ross A. Virginia
Environmental Studies Program
Dartmouth College
6182 Steele Hall
Hanover, NH 03755-3577
Phone: 603/646-1456 • Fax: 603/646-1682
ross.a.virginia@dartmouth.edu

Desert Research Institute
www.dri.edu

Randy Borys
Storm Peak Laboratory
Desert Research Institute
PO Box 770799
Steamboat Springs, CO 80477-0799
Phone: 970/879-8796 • Fax: 970/879-7819
borys@dri.edu

Joseph R. McConnell
Division of Hydrologic Sciences
Desert Research Institute
2215 Raggio Parkway
Reno, NV 89512
Phone: 775/673-7348 • Fax: 775/673-7363
jmcconn@dri.edu

Embry-Riddle Aeronautical University
www.erau.edu

Gulamabas G. Sivjee
Physical Sciences Department
Embry-Riddle Aeronautical University
600 S. Clyde Morris Boulevard
Daytona Beach, FL 32114-3900
Phone: 904/226-6711 • Fax: 904/226-6713
sivjee@db.erau.edu

John J. Olivero
address same as Gulamabas G. Sivjee
Phone: 904/226-6709 • Fax: 904/226-6713
oliveroj@db.erau.edu

Foundation for Glacier and Environmental Research
www.mines.uidaho.edu/glacier

Maynard M. Miller
Foundation for Glacier & Environmental Research
University of Idaho
514 East First Street
Moscow, ID 83843
Phone: 208/882-1237 • Fax: 208/882-6207
jirp@uidaho.edu

Lance D. Miller
Foundation for Glacier & Environmental Research
4470 North Douglas Highway
Juneau, AK 99801
Phone & Fax: 907/463-5186
lancemiller@gci.net

Iḷisaġvik College
http://ilisagvik.co.north-slope.ak.us

Edna MacLean
Iḷisaġvik College
PO Box 749
Barrow, AK 99723-0749
Phone: 907/852-9101 • Fax: 907/852-9102
emaclean@co.north-slope.ak.us

Lamont-Doherty Earth Observatory of Columbia University
www.ldeo.columbia.edu

William M. Smethie
Lamont-Doherty Earth Observatory
PO Box 1000
Palisades, NY 10964-8000
Phone: 845/365-8566 • Fax: 845/365-8176
bsmeth@ldeo.columbia.edu

James R. Cochran
address same as William M. Smethie
Phone: 845/365-8396 • Fax: 845/365-8179
jrc@ldeo.columbia.edu

Louisiana State University
www.lsu.edu

H. Jesse Walker
Department of Geography & Anthropology
Louisiana State University
Baton Rouge, LA 70803-4105
Phone: 225/578-6130 • Fax: 225/578-4420
hwalker@lsu.edu

Robert H. Baumann
Center for Energy Studies
120 Energy Center
Louisiana State University
Baton Rouge, LA 70803
Phone: 225/578-4400 • Fax: 225/578-4541
rbaumann@lsu.edu

Marine Biological Laboratory
www.mbl.edu

Bruce J. Peterson
The Ecosystems Center
Marine Biological Laboratory
Woods Hole, MA 02543
Phone: 508/289-7484 • Fax: 508/457-1548
peterson@mbl.edu

Knute Nadelhoffer
address same as Bruce J. Peterson
Phone: 508/289-7493 • Fax: 508/457-1548
knute@mbl.edu

Michigan State University
www.msu.edu

Patrick J. Webber
Department of Botany & Plant Pathology
Michigan State University
100 N. Kedzie Hall
East Lansing, MI 48824-1031
Phone: 517/355-1284 • Fax: 517/432-2150
webber@msu.edu

Robert D. Hollister
address same as Patrick J. Webber
Phone: 517/432-2399 • Fax: 517/432-2150
holliste@msu.edu

Northern Illinois University
www.niu.edu

Ross D. Powell
Department of Geology
Northern Illinois University
312 Davis Hall
DeKalb, IL 60115-2854
Phone: 815/753-7952 • Fax: 815/753-1945
ross@geol.niu.edu

The Ohio State University
www.acs.ohio-state.edu

W. Berry Lyons
Byrd Polar Research Center
The Ohio State University
1090 Carmack Road
Columbus, OH 43210-1002
Phone: 614/688-3241 • Fax: 614/292-4697
lyons.142@osu.edu

Oregon State University
www.orst.edu

Timothy Boyd
College of Oceanic & Atmospheric Sciences
Oregon State University
104 Ocean Administration Building
Corvallis, OR 97331-5503
Phone: 541/737-4035 • Fax: 541/737-2064
tboyd@oce.orst.edu

Evelyn B. Sherr
address same as Timothy Boyd
Phone: 541/737-4369 • Fax: 541/737-2064
sherrb@ucs.orst.edu

San Diego State University
www.sdsu.edu

W. Timothy Hushen
San Diego State University Foundation—Research Management
San Diego State University
5250 Campanile Drive
San Diego, CA 92182
Phone: 619/594-4102 • Fax: 619/582-9164
thushen@foundation.sdsu.edu

Douglas A. Stow
Department of Geography
San Diego State University
5500 Campanile Drive
San Diego, CA 92182-4493
Phone: 619/594-5498 • Fax: 619/594-4938
stow@sdsu.edu

Sandia National Laboratories
www.sandia.gov

Jeffrey Zirzow
Sandia National Laboratories
PO Box 5800, MS 0755
Albuquerque, NM 87185-0755
Phone: 505/284-4446 • Fax: 505/844-0968
jazirzo@sandia.gov

ARCUS Member Institutions, Representatives, and Alternates *(continued)*

Smithsonian Institution
www.si.edu

Aron L. Crowell
Anchorage Museum of History & Art
Smithsonian Arctic Studies Center
Smithsonian Institution
121 W. 7th Avenue
Anchorage, AK 99501
Phone: 907/343-6162 • Fax: 907/343-6130
acrowell@alaska.net

Stephen Loring
Arctic Studies Center
Department of Anthropology
Smithsonian Institution
NMNH MRC-112
10th and Constitution NW
Washington, DC 20560
Phone: 202/357-4742 • Fax: 202/357-2684
loring.stephen@nmnh.si.edu

SRI International
www.sri.com

John D. Kelly
Ionospheric & Space Physics Group
SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025
Phone: 650/859-3749 • Fax: 650/322-2318
kelly@sri.com

Jeff Thayer
Engineering & Systems Division
address same as John D. Kelly
Phone: 650/859-3557 • Fax: 650/322-2318
thayer@sri.com

Texas A&M University
www.tamu.edu

David A. Brooks
College of Geosciences
Texas A&M University
3148 CAMPUS
College Station, TX 77845-3148
Phone: 979/845-3651 • Fax: 979/845-0056
dbrooks@ocean.tamu.edu

Mahlon C. Kennicutt, II
Geochemical & Environmental Research Group
Texas A&M University
833 Graham Road
College Station, TX 77845
Phone: 979/862-2323 • Fax: 979/862-2361
mck2@gerg.tamu.edu

University of Alaska Anchorage
www.uaa.alaska.edu

Bjartmar Sveinbjornsson
Department of Biological Sciences
University of Alaska Anchorage
3211 Providence Drive
Anchorage, AK 99508
Phone: 907/786-1366 • Fax: 907/786-4607
afbs@uaa.alaska.edu

University of Alaska Fairbanks
www.uaf.edu

Roger W. Ruess
Institute of Arctic Biology
University of Alaska Fairbanks
PO Box 757000
Fairbanks, AK 99775-7000
Phone: 907/474-7153 • Fax: 907/474-6967
ffrwr@uaf.edu

Ted DeLaca
Office of Arctic Research
University of Alaska Fairbanks
PO Box 757560
Fairbanks, AK 99775-7560
Phone: 907/474-7314 • Fax: 907/474-1836
fnted@uaf.edu

University of Alaska Statewide
www.alaska.edu

Craig E. Dorman
University of Alaska Statewide
PO Box 755000
Fairbanks, AK 99775-5000
Phone: 907/474-5750 • Fax: 907/474-7570
craig.dorman@alaska.edu

University of Colorado
www.colorado.edu

Rudy J. Dichtl
CIRES/NSIDC
University of Colorado
Campus Box 449
Boulder, CO 80309-0449
Phone: 303/492-5532 • Fax: 303/492-2468
dichtl@kryos.colorado.edu

University of Massachusetts
www.umass.edu

Julie Brigham-Grette
Department of Geosciences
University of Massachusetts
Morrill Science Center
Campus Box 35820
Amherst, MA 01003-5820
Phone: 413/545-4840 • Fax: 413/545-1200
juliebg@geo.umass.edu

University of Miami
www.miami.edu

Peter J. Minnett
Rosenstiel School of Marine &
Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149
Phone: 305/361-4104 • Fax: 305/361-4622
pminnett@rsmas.miami.edu

Zafer Top
address same as Peter J. Minnett
Phone: 305/361-4110 • Fax: 305/361-4911
ztop@rsmas.miami.edu

University of Nebraska-Lincoln
www.unl.edu

Clinton M. Rowe
Department of Geosciences
University of Nebraska–Lincoln
Bessey Hall, Room 305C
Lincoln, NE 68588-0340
Phone: 402/472-1946 • Fax: 402/472-4917
crowe1@unl.edu

University of New Hampshire
www.unh.edu

Cameron Wake
Climate Change Research Center
Institute for the Study of Earth, Oceans, & Space
University of New Hampshire
39 College Road–Morse Hall
Durham, NH 03824-3525
Phone: 603/862-2329 • Fax: 603/862-2124
cameron.wake@unh.edu

Jack Dibb
Glacier Research Group
address same as Cameron Wake
Phone: 603/862-3063 • Fax: 603/862-2124
jack.dibb@grg.sr.unh.edu

University of Washington
www.washington.edu

Ronald S. Sletten
Quaternary Research Center
University of Washington
Box 351360
Seattle, WA 98195-1360
Phone: 206/543-0571 • Fax: 206/543-3836
sletten@u.washington.edu

Jody W. Deming
School of Oceanography
University of Washington
Box 357940
Seattle, WA 98195
Phone: 206/543-0845 • Fax: 206/543-0275
jdeming@u.washington.edu

University of Wisconsin-Madison
www.wisc.edu

James G. Bockheim
Department of Soil Science
University of Wisconsin–Madison
1525 Observatory Drive
Madison, WI 53706-1299
Phone: 608/263-5903 • Fax 608/265-2595
bockheim@facstaff.wisc.edu

Woods Hole Oceanographic Institution
www.whoi.edu

Andrey Proshutinsky
Woods Hole Oceanographic Institution, MS 29
Woods Hole, MA 02543
Phone: 508/289-2796 • Fax: 508/457-2181
aproshutinsky@whoi.edu

Susumu Honjo
Woods Hole Oceanographic Institution, MS 23
Woods Hole, MA 02543
Phone: 508/540-1162 • Fax: 508/540-9439
shonjo@whoi.edu

ARCUS International Affiliates

Alfred Wegener Institute for Polar & Marine Research
www.awi-bremerhaven.de

Jörn Thiede
Alfred Wegener Institute for Polar & Marine Research
Columbusstrasse
D-27568 Bremerhaven, Germany
Phone: +49/471-4831-1100
Fax: +49/471-4831-1102
jthiede@awi-bremerhaven.de

Rainer Paulenz
address, phone, & fax same as Jörn Thiede
rpaulenz@awi-bremerhaven.de

Association of Canadian Universities for Northern Studies (ACUNS)
www.cyberus.ca/~acuns

Robert C. Bailey
Department of Zoology & Aquatic Ecology
University of Western Ontario
Biological and Geological Sciences Building
London, ON N6A 5B7 Canada
Phone: 519/661-4022 • Fax: 519/661-2014
drbob@uwo.ca

Frances Abele-Kinloch
School of Public Administration
Carleton University
1125 Colonel By Drive
Ottawa, ON K1S 5B6 Canada
Phone: 613/520-2600 ext 2553
Fax: 613/520-2551
frances_abele@carleton.ca

GEOMAR Research Center for Marine Geosciences
www.geomar.de

Heidemarie Kassens
Department of Paleoceanography
GEOMAR Research Center for Marine Geosciences
Wischhofstrasse 1-3, Geb 4
D-24148 Kiel, Germany
Phone: +49/431-6002-850
Fax: +49/431-6002-941
hkassens@geomar.de

McGill University
www.mcgill.ca

Marianne Stenbaek
Cultural Studies Department
McGill University
853 Sherbrooke Street
Montreal, QC H3A 2T6 Canada
Phone: 514/398-6579 • Fax: 514/398-8146
mstenb@po-box.mcgill.ca

Norwegian Polar Institute
www.npolar.no

Olav Orheim
Polar Environmental Center
Norwegian Polar Institute
Polarmiljøsenteret
N-9296 Tromsø, Norway
Phone: +47/7775-0620 • Fax: +47/7775-0501
olav.orheim@npolar.no

(continued next column)

Pål Prestrud
Research Department
Norwegian Polar Institute
Polarmiljøsenteret
N-9296 Tromsø, Norway
Phone: +47/7775-0530 • Fax: +47/7775-0501
pal.prestrud@npolar.no

Scott Polar Research Institute
www.spri.cam.ac.uk

Keith S. Richards
Scott Polar Research Institute
University of Cambridge
Lensfield Road
CB2 1ER Cambridge, UK
Phone: +44/1223-336-579
Fax: +44/1223-336-549
ksr10@cam.ac.uk

William J. Mills
address same as Keith S. Richards
Phone: +44/1223-336-557
Fax: +44/1223-336-549
wjm13@cam.ac.uk

The University Courses on Svalbard
www.unis.no

Lasse Lønnum
The University Courses on Svalbard
PO Box 156
N-9170 Longyearbyen, Norway
Phone: +47/7902-3305 • Fax: +47/7902-3301
lasse.lonnum@unis.no

Trond Dokken
Department of Geology
University of Bergen
Allégt 55
N-5007 Bergen, Norway
Phone: +47/7902-3331 • Fax: +47/7902-3301
trond.dokken@unis.no

University of Northern British Columbia
www.unbc.ca

Kevin Hall
Geography Program
University of Northern British Columbia
3333 University Way
Prince George, BC V2N 4Z9 Canada
Phone: 250/960-5864 • Fax: 250/960-5538
hall@unbc.ca

Katherine Parker
Forestry Program
address same as Kevin Hall
Phone: 250/960-5812 • Fax: 250/960-5539
parker@unbc.ca

University of Tromsø
www.uit.no

Ingvild Broch
Research Department
University of Tromsø
N-9037 Tromsø, Norway
Phone: +47/7764-4262 • Fax: +47/7764-4900
ingvild.broch@adm.uit.no

Geir Gotaas
Roald Amundsen Centre for Arctic Research
address same as Ingvild Broch
Phone: +47/7764-5241 • Fax: +47/7767-6672
geir.gotaas@arctic.uit.no

ARCUS Arctic Research Support and Logistics Working Group •
www.arcus.org/Logistics/RSLWG/working_group.html

Peter Schlosser, *Co-chair*
Lamont-Doherty Earth Observatory
Palisades, NY
Phone: 845/365-8707 • Fax: 845/365-8155
peters@ldeo.columbia.edu

Terry Tucker, *Co-chair*
Cold Regions Research & Engineering Laboratory
Hanover, NH
Phone: 603/646-4268 • Fax: 603/646-4644
wtucker@crrel.usace.army.mil

Julie Brigham-Grette
Department of Geosciences
University of Massachusetts, Amherst
Phone: 413/545-4840 • Fax: 413/545-1200
juliebg@geo.umass.edu

Jack Dibb
Glacier Research Group
University of New Hampshire, Durham
Phone: 603/862-3063 • Fax: 603/862-2124
jack.dibb@grg.sr.unh.edu

Jack Kruse
Department of Geosciences
University of Massachusetts, Amherst
Phone: 413/367-2240 • Fax: 413/367-0092
jkruse@geo.umass.edu

Miles McPhee
McPhee Research
Naches, WA
Phone: 509/658-2575 • Fax: 509/658-2575
mmcphee@starband.net

Craig Nicolson
Department of Natural Resources Conservation
University of Massachusetts, Amherst
Phone: 413/545-3154 • Fax: 413/545-4358
craign@forwild.umass.edu

Roger W. Smith
Geophysical Institute
University of Alaska, Fairbanks
Phone: 907/474-7416 • Fax: 907/474-5882
roger.smith@gi.alaska.edu

Matthew Sturm
Cold Regions Research & Engineering Laboratory
Ft. Wainwright, AK
Phone: 907/353-5183 • Fax: 907/353-5142
msturm@crrel.usace.army.mil

Taneil Uttal
Environmental Research Laboratory
National Oceanic & Atmospheric Administration (NOAA)
Boulder, CO
Phone: 303/497-6409 • Fax: 303/497-6978
taneil.uttal@noaa.gov