Witness The
ARCTIC

Chronicles of the Arctic System Science Research Program Autumn 1998, Volume 6 Number 2

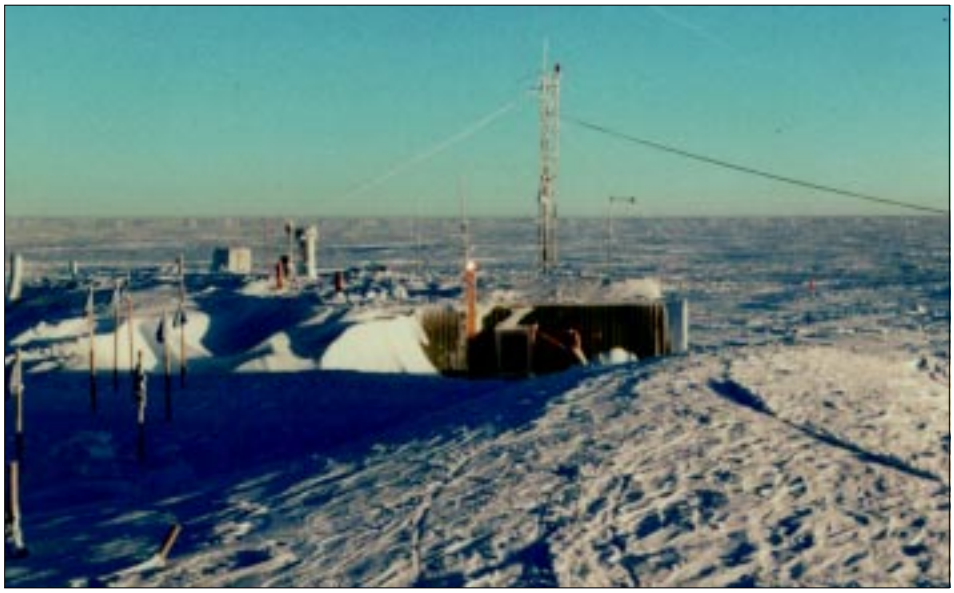
Team Pioneers All-Winter Research at Greenland Summit

by Jack Dibb

In early August 1997, four Americans watched with mixed emotions as the final flight of the season left the ice sheet at the summit of Greenland with the summer crew. The four would be the first people to stay the winter at Summit. For the next eight months, NSF funded Phil Austin, Robert Hawley, Patrick Smith, and Sarah Sturges to test the feasibility of maintaining a year-round, long-term presence at Summit—the highest point in the Arctic. When the plane returned to pick them up in April 1998, the four shared unprecedented observations and a justifiable sense of pride in demonstrating that a small crew could be safe, reasonably comfortable, and highly productive scientifically year-round at Summit.

In February 1998, while the four were still collecting data, preliminary information about their accomplishments contributed to the decision by the Danish Science Commission, the European Polar Science Board, and NSF to proceed with establishing the proposed winter facility and to complete the related science plan.

Research began at the site in 1987 with surveys to locate the best deep drilling site in the region. European and American research teams recovered two 3-km long ice cores during the 1989-93 summer seasons from the crest of Greenland where the ice sheet is nearly two miles thick and minimally deformed by the flow of the ice toward sea level (see *Witness* Spring 1997). The cores recovered by the Greenland Icecore Project (GRIP) and Greenland Ice Sheet Project Two (GISP2) provide exceptionally high-resolution information about climate change over the last 110,000 years. These records of accumulation rates, concentrations of chemicals, and stable isotopes have allowed researchers to examine details, such as the precise nature and timing of rapid climate change events, that have important implications for understanding the Earth's climate system.



The 32' x 34' modular structure known as the Green House was the center of activity for four researchers studying air/snow relationships at Summit through winter 1997-98. High winds overwhelmed efforts to keep snowdrifts at bay. This and any similar structures will be on elevated platforms in future year-round campaigns (photo by Jack Dibb).

Quantitative interpretation of the records in the cores, however, requires the development and verification of transfer functions relating the chemical composition of the ice to that of the atmosphere. For example, complex seasonal variations in snow accumulation, depositional processes, and the combination of tropospheric transport and chemical processing interact to determine the chemical composition of snow at Summit. The goal of inverting ice-core records to time series of atmospheric composition and temperature leads directly to a series of questions that can only be addressed with year-round sampling. Nearly all field experiments to develop such transfer function models in Greenland have been restricted to the summer season. Year-round sampling will improve the ability to separate effects of seasonal to inter-annual changes from long-term signals in the ice-core records.

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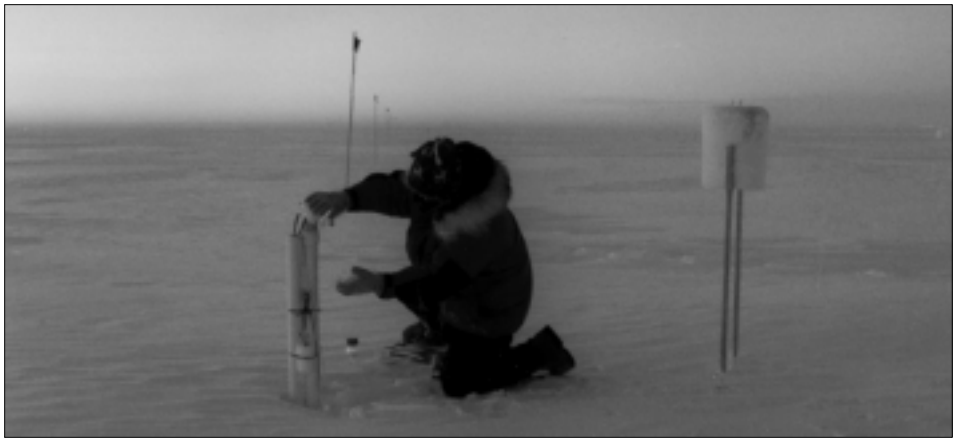
Because of its elevation, latitude, and research history, the Summit site is ideally suited for studies that cannot be conducted at low-elevation sites in the Arctic. In addition to work on ice-core interpretation, data gathered at Summit would uniquely inform studies addressing:

- tropospheric chemistry;
- radiation and energy balance;
- boundary layer dynamics;
- stratospheric observations; and
- atmospheric electricity.

Summit data could also contribute to:

- polar aeronomy and space sciences, and
- seismic and geodetic measurements.

The following report provides only an overview of the data sets that have resulted from the 1997-98 experiment and the questions to which they are being applied. Preliminary analyses of data were presented in October 1998 at an NSF/NASA planning meeting for 1999 operations in Greenland. More complete comparisons and collaborative interpretations were presented at a special session on the Summit winter-over campaign at the December 1998 AGU meeting in San Francisco. Publications featuring these results are expected to appear in 1999.



Sarah Sturges (pictured here changing an aerosol filter in early February) and Robert Hawley collected samples, operated instruments, and made observations for ten different research teams during the study (photo by Jack Dibb).

Precipitation and Snow Accumulation

The frequency and timing of snowfall events defines an upper limit to the temporal resolution with which the snowpack can record variations in the composition of the overlying air. High winds degrade the resolution of such records, as drifting of surface snow mixes signals from different events and partially erases some of them through enhanced sublimation of the snow crystals. Until the winter of 1997-98, routine observations of falling and drifting snow had never been made at Summit. Preliminary review of the new data sets demonstrate that:

- there were no extended periods without accumulation during the year of the experiment, and
- the summer and fall seasons had greater accumulation than at other times.

Atmospheric Gas-Phase Measurements

The 3200 m elevation of Summit provides a surface-based observatory with access to the arctic mid-troposphere. Tropospheric chemistry in the polar regions is unique because of the extreme seasonal variation in available light, with photochemistry essentially shut down through the winter night. However, transport of air masses from sunlit regions at lower latitudes may make important contributions to the composition of the arctic winter troposphere.

Gas-phase measurements made by the the 1997-98 team included:

- ozone (NOAA-CMDL),
- a large suite of non-methane hydrocarbons and halocarbons (UCI), and
- radon (UH).

Ozone and hydrocarbons allow assessment of the photochemical and oxidative state of the troposphere through the year. Radon is a sensitive indicator of air masses originating over continental regions and can indicate transport time from these regions to Summit. Hydrocarbon and halocarbon "signatures" (characteristic enhancements in groups of compounds) can be linked to more specific continental regions with dominant emission patterns from anthropogenic sources and also indicate natural sources like oceanic emissions.

Atmospheric Particles (Aerosols)

Unlike the gases listed above, many aerosol-associated compounds are incorporated into snow and then pass into the glacial ice archives with little post-depositional modification. As a result, these compounds have been studied in ice-core investigations, and identifying temporal patterns in the abundance and composition of atmospheric particles was a major focus of this year-round sampling campaign.

The Summit data on the ionic compounds in aerosol (Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, SO_4^{2-}, MSA) are characterized by spikes indicative of specific episodes of transport (CMU, LGGE). Some of the aerosols (*e.g.*, MSA, NH_4^+) also show clear seasonal variations. Analyses are now focused on relating the spikes to similar patterns in other transport tracers and to known events such as episodes of fire.

During the 1997-98 study period the natural radionuclide tracers ^{7}Be and ^{210}Pb showed no sign of the broad winter maximum characteristic of sea-level sites in the Arctic (UNH). A similar lack of winter peaks also was observed during the only other previous year-round atmospheric sampling program on the ice sheet (1988-1989 at Dye 3, 2.5 km elevation on the southern dome of the Greenland Ice Sheet), suggesting that the Arctic Haze phenomenon does not extend to the 2-3 km altitude of the crest of the Greenland Ice Sheet. This inference is supported by other tracers measured in the two campaigns.

On the other hand, the radionuclide tracers showed spring and fall peaks at Dye 3 that were not apparent at Summit. Since the peaks at Dye 3 were attributed to large-scale atmospheric motions (more vigorous vertical mixing of tropospheric air down to the surface of the ice sheet), we expected similar patterns at Summit. It is hoped that analyses of other tracers and meteorological data will clarify whether the differences between the two records can be attributed to systematic difference between the two sites or anomalous atmospheric circulation in one of the two years.

Back Trajectory Modeling

Winter-over researchers applied a model that estimates where air masses arriving at Summit came from (UW-M). These "back trajectories" were calculated twice each day throughout the year. The purpose is to use these meteorologically based trajectories in conjunction with the various chemical tracers to confirm the locations of source regions impacting the air over central Greenland. In addition to examining variations in apparent atmospheric transport from one day to the next, the winter-over trajectories will be statistically compared to a set of trajectories previously calculated for every day of the last 40 years in order to determine whether the strong El Niño of 1997-98 made this an anomalous year.

Micrometeorology and Energy Budget

The sampling tower at Summit was instrumented for continuous meteorological measurements using CRREL equipment. The measurements made during the winter-over experiment include:

- wind speed, air temperature, and relative humidity sensors at two levels;
- incoming and reflected long-wave and short-wave radiation;
- incoming radiation in the red band; and
- infrared snow-surface temperature measurements.

Because the researchers checked the instrumentation at least once each day and removed any deposits of frost and ice, the data series from all sensors were continuous and appear to be of high quality. Energy balance calculations are currently in progress (CRREL). A quick look at the raw data has shown that temperatures at Summit were notably warmer in mid-winter than the average of the previous seven years—a lucky break for the four staff members, but also perhaps an indication that this single year may not be representative of the norm.

Surface Snow Sampling and Analysis

Winter-over staff collected daily samples of surface snow for air-snow comparisons and examination of post-depositional changes in snow composition.

Concentrations of hydrogen peroxide (H_2O_2), which is produced in sunlight, confirm the very low wintertime levels inferred from previous pit studies (UA). The Summit record did not, however, capture the highest concentrations typically seen in snow pits, suggesting that this peak occurs between mid-April and early-June (when no samples were collected in the present study) rather than during mid-summer when daylight hours are longest and atmospheric concentrations of H_2O_2 are expected to be highest.

Early results from the analysis of carbonaceous particles filtered from snow samples (NIST) indicate clear seasonal patterns in their volatility "spectra" as well as strong concentration peaks in spring and summer. The spring peaks correlate with continental dust tracers in surface snow samples (UNH) and show a volatility pattern similar to that of an urban reference material (NIST). The summer peak correlates with ionic tracers of biomass burning (UNH) and transport from the boreal forest fire zone of Canada (UW-M). Further analyses are underway to unambiguously identify biomass and fossil carbon sources.

Snow and Firn Physical Characteristics

Measurements of the roughness of surface snow show that the surface becomes covered with sastrugi (wind-sculpted drifts) and dunes that are much larger during the winter than during any other season (CRREL). Greater roughness creates larger pressure gradients, greater air flow, and accelerated exchange of material (*e.g.*, water, airborne chemical compounds) between the snowpack and atmosphere.

Air flow is also controlled, however, by the permeability of the medium; it is therefore possible that the rougher winter snow surface is counterbalanced by a reduction in permeability. Examination of preserved samples should provide insight into seasonal changes in permeability.

A remarkable logistical and human endeavor, the initial Summit winter-over experiment collected unique data that will contribute important information to a number of investigations. Future research programs at the site are expected to continue this same careful integration to maximize the scientific return on this investment. ■

The Team

The field team was certainly the most visible component of the winter-over campaign, but their success was made possible by the support of a large number of people. Special thanks are due to:

- Bill Barber, Project Manager
- NSF Office of Polar Programs ARCSS Program—Mike Ledbetter, Program Manager;
- Polar Ice Coring Office (PICO) at the University of Nebraska-Lincoln;
- New York Air National Guard;
- Jonas Finnbogason and Greenland Air; and
- Kangerlussuaq Airport Authority.

Researchers at the following eleven institutions are now processing data collected during the 1997-98 winter-over experiment:

- Carnegie Mellon University (CMU)
- Cold Regions Research and Engineering Laboratory (CRREL)
- INSTAAR stable isotope laboratory
- Laboratoire de Glaciologie et Geophysique de l'Environment (LGGE)
- National Institute of Standards and Technology (NIST)
- NOAA-CMDL
- University of Arizona (UA)
- University of California at Irvine (UCI)
- University of Heidelberg (UH)
- University of New Hampshire (UNH)
- University of Wisconsin-Milwaukee (UW-M)

For more information on Summit, see http://www.hwr.arizona.edu/Alpine/Summit/observatory.html. ■

Jack Dibb is a Research Associate Professor with the Climate Change Research Center at the University of New Hampshire. He is the chief scientist for the 1997-98 and 2000-02 year-round sampling campaigns at Summit and the ongoing summertime investigation into reactive nitrogen oxides at the same site. Jack has the dubious distinction of having "visited" Summit at least once each year since 1989.

 Late-breaking news: The HARC Program is now inviting proposals! Details on page 19.

ARCSS Committee Advances Integration

Following on the 1998 publication of the new ARCSS science plan, *Toward Prediction of the Arctic System*, the ARCSS Committee (AC) met in Fairbanks, Alaska in October 1998 to explore implementation of the plan's recommendations for integrative research on the arctic system and global environmental change. The committee discussed three high-priority areas for advancing ARCSS integration:

- integrated assessment of climate change,
- arctic hydrologic cycles and feedbacks,
- integration of contemporary and paleoenvironmental terrestrial studies.

Integrated Climate Change Assessment

To meet ARCSS Program objectives, a hierarchy of models is needed to integrate global models, regional climate models, and simulations of key environmental changes, such as land cover and sea ice. This integrated assessment would seek to predict arctic system change, using:

- improved process understanding,
- quantification of feedbacks, and
- spatial and temporal extrapolations.

A major challenge to this integration is a relative lack of expertise focused on arctic climate modeling questions, in particular a combined capability for interdisciplinary system modeling to:

- run experiments on various models,
- improve representation of the arctic system in global models,
- conduct specific modeling studies using simpler models, and
- use results from global models in regional models.

One approach forwarded by the AC is an ARCSS-sponsored, post-doctoral fellowship program to develop a cohort of model-savvy, interdisciplinary system scientists to work on these problems in collaboration with stakeholder groups and the ARCSS research community.

Arctic Hydrologic Cycles and Feedbacks

Changes in arctic freshwater budgets have the potential to foster abrupt climate change outside of the Arctic, thus, predicting how changes in freshwater cycles in the Arctic may change the global climate system is critical. Collaboration among the ARCSS community and global systems researchers will be essential to identify the levels of change in arctic freshwater budgets likely to effect global systems. Such collaboration would:

- enable arctic researchers to identify the resolution required for global system feedbacks, and
- allow global systems researchers to determine the most important arctic system processes for representation in global system models.

Linkages between arctic freshwater budgets and thermohaline circulation are important to this discussion. Also relevant are cloud radiative feedbacks, moisture transport, global trace gas budgets, biological productivity, terrestrial ecosystems, sea ice, societal impacts, sea level rise, and glacier mass balance. Other factors may be identified in future discussions.

The committee recommended that the ARCSS Program convene a workshop, including experts in various global models, regional climate modeling, terrestrial ecosystems, river runoff modeling, land and marine paleoenvironmental studies, Arctic Ocean circulation and links to global ocean circulation, sea ice, glaciology, and social sciences. This workshop would focus on the role of arctic freshwater budgets in global climate change, to:

- evaluate current understanding of the relationships between arctic freshwater cycles and the global climate system;
- highlight uncertainties and important linkages; and
- identify priority research areas.

Integration of Contemporary and Paleoenvironmental Terrestrial Studies

Investigators working through the ARCSS Land-Atmosphere-Ice Interactions (LAII) and Paleoclimates from Arctic Lakes and Estuaries (PALE) programs have initiated discussions on integrating contemporary process studies and paleoenvironmental research on terrestrial interactions, focusing on potential changes in these interactions with altered climate forcing. LAII brings process- and model-oriented studies to the discussion; PALE brings long records of climate and land cover change and variability, as well as an international scope. The AC recommended that the ARCSS Program sponsor a workshop to catalyze collaborations and advance these important syntheses.

These AC recommendations are under consideration by the ARCSS Program.

For more information, contact ARCSS Program Director Mike Ledbetter (703/306-1029; fax 703/306-0648; mledbett@nsf.gov) or ARCSS Committee Chair Jack Kruse (413/367-2240; fax 413/367-0092; jkruse@geo.umass.edu) or see the ARCSS web site (http://www.nsf.gov/od/opp/arctic/system.htm) or the ARCUS web site (http://www.arcus.org).

ARCSS Educational CD-ROM Available

The ARCSS Data Coordination Center (ADCC) at the National Snow and Ice Data Center (NSIDC) has recently published and released *Into the Arctic: Information and Educational Activities for Studying Climate*, an instructional CD-ROM containing classroom activities focusing on climate studies. The CD-ROM, created in cooperation with the Greenland Ice Sheet Project Two (GISP2) Science Management Office at the University of New Hampshire, includes information and data from GISP2 (see *Witness* Spring 1998) as well as data from other sources.

Designed to offer materials and activities for teachers and students, the unique feature of the CD-ROM is access to "real" data collected and used by research scientists. Using these data allows students to simulate the process scientists follow when answering research questions. The CD-ROM also provides information, graphics, activities, and a glossary to enhance the experience of learning about earth science.

For more information, visit the ARCSS Data web site (http://arcss.colorado.edu) and go to the "Education Resources" section in the online Data Catalog.

LAII/ATLAS Collects Baseline Data to Bracket Transitions

The Arctic Transitions in the Land-Atmosphere System (ATLAS) Program began in Summer 1998 as part of the NSF Arctic System Science (ARCSS) Program. ATLAS builds on the work of the Land-Atmosphere-Ice Interactions (LAII) Flux Program in the Kuparuk Basin (see *Witness* Spring 1998), focusing on understanding how the tundra ecosystem might respond to climate change.

One goal of the project is to produce large-area extrapolations of energy and trace gas fluxes, by integrating remote sensing with an understanding of basic ecosystem processes and landscape variations. The project brings together ecologists, biologists, atmospheric physicists, snow physicists, and modelers.

Fieldwork will take place in Alaska on the North Slope and Seward Peninsula, and in Siberia. On the North Slope, continuous measurements are already underway at Barrow, Atkasuk, and Ivotuk. At Barrow and Atkasuk, continuous year-round measurements of the weather and CO_2 emissions are being made using towers. These are being supplemented during the growing season with airborne measurements from a specially equipped aircraft, and with space-borne measurements of Normalized Difference Vegetation Index (NDVI), a measure of plant "greenness." Using the tower, aircraft, and satellite data, researchers will scale-up trace-gas flux measurements from the plot to the landscape scale.

The Ivotuk site is new to many ATLAS investigators, but is well known to archaeologists as the location of The Mesa, a hunting lookout used by indigenous people 12,000-10,000 years BP. Sharing logistics with Bureau of Land Management archaeologists, an ATLAS crew established four permanent 100 m^2 vegetation plots, ranging from shrub tundra to dry, non-acidic tussock tundra. At each plot, researchers made detailed measurements of:

- plant community composition;
- soil substrate;
- energy and trace gas fluxes (and compared these to measurements at a reference plot using a series of portable eddy-correlation towers);
- biomass; and
- shrub architecture along transects, in preparation for winter snow measurements that will commence in November 1998.

Catherine Copass (left), Larry Hinzman, and Erika Edwards climb the limestone ridge at Lisburne Hills at midnight in mid-July. The Ivotuk airstrip is visible in the distance. The archaeological research site known as The Mesa is off the photo to the left (photo by Andrew Slater).

In 1999, fieldwork will move to the Seward Peninsula, which is warmer, wetter, and topographically more diverse than the North Slope. The Seward Peninsula also differs in that it is surrounded by an ocean that is principally ice-free, while the North Slope borders an ocean that is often ice-covered.

On the Seward Peninsula, fieldwork at Quartz Creek and Council is designed to encompass a transition from tundra to forest tundra. Comparable sets of vegetation, energy, and mass flux data from the Seward Peninsula and the North Slope will bracket the extremes of a climatic gradient. Accordingly, the vegetation and land-surface processes described at the two sites are expected to be analogs for a climate change transition.

The next LAII All-Hands Meeting will take place 11-13 March 1999.

For more information, contact Patricia A. Anderson at the LAII Science Management Office (907/474-5415; fax 907/474-6722; patricia@gi.alaska.edu; http://www.laii.uaf.edu).

The 9th Annual ITEX Meeting

In 1990, the Man and the Biosphere Northern Sciences Network (MAB-NSN) launched the International Tundra Experiment (ITEX) to document plant response to increased temperatures (see *Witness* Spring 1998). The U.S. contribution to ITEX (USTEX) is included within the ARCSS LAII Program.

After seven years of fieldwork monitoring species-level responses to temperature, ITEX researchers are now preparing to launch the second phase of research, focusing on integration with the climate change community. This focus will be initiated at the 9th International ITEX Workshop 4-9 January 1999 in East Lansing, Michigan. For more information, see the conference web page at http://www.cevl.msu.edu/ael/itex/index.html or contact Bob Hollister (517/432-2399; fax 517/432-2150; holliste@pilot.msu.edu).

OAII Completes the SHEBA Year

In early October 1998, researchers successfully completed a full year of fieldwork in residence on the arctic pack ice. On 11 October, the Canadian icebreaker *Des Groseilliers* broke out of the arctic ice pack into which it had been frozen since 2 October 1997 and brought the Surface Heat Budget of the Arctic Ocean (SHEBA) experiment home.

During the course of the year, the ship served as a residence, research station, and hub for the research village that spread onto the surrounding ice. The station ended the year 800 km from its starting point but had actually drifted much farther along its circuitous route under the influence of wind and currents. In the last week alone, the ice station drifted 95 km, under the influence of 20-30 knot winds.

SHEBA researchers collected roughly 10 billion data points. Preliminary insights include the observation that the anomalously thin ice noted at the beginning of the experiment had, in general, become even thinner by the end of the year, suggesting that warming of the Arctic Ocean is continuing. Investigators are striving to determine whether this is an oscillation, a secular change, or some combination of both; whether it relates to meteorological phenomena such as the North Atlantic and Arctic oscillations; and, if so, how.

For information, see the SHEBA web site (http://sheba.apl.washington.edu).

Western Arctic Shelf Basin Interactions (SBI) Announcement of Opportunity

Fifty-one proposals submitted to NSF in June 1998 in response to the Western Arctic Shelf Basin Interactions (SBI) Announcement of Opportunity are in review. The Science Plan for this biologically and biogeochemically oriented program is available from the OAII Science Management Office (SMO) and on the OAII web site (see below). The Office of Naval Research and the Oceanography Section of the NSF Geosciences Directorate have already agreed to contribute funding, and several other potential supporters have expressed interest. Although the exact nature of the SBI Phase I research cannot be described until this review process is complete, the goal is to support modeling, analysis of existing data, and opportunistic fieldwork that will provide a strong foundation for Phase II experiments.

Science Steering Committee

The OAII SSC met in Stevenson, Washington in October 1998. NSF ARCSS Program Director Mike Ledbetter stated that the increased funding levels for FY 1999 (see page 10) should result in several new opportunities, possibly including announcements of opportunity for arctic environmental observatories and for automated sampling instruments. The SSC reviewed a summary of potential sites for arctic marine environmental observatories. The committee suggested that there were scientifically compelling reasons to establish sites in the Chukchi Sea and the MacKenzie Beaufort shelf. Conceivably, such sites could take advantage of shoreside facilities in Barrow, Alaska and Tuktoyuktuk, Northwest Territories, Canada.

Jamie Morison updated the SSC on the developing Study of Environmental Arctic Change Program (see page 7). The SSC thought the scientific reasons for proceeding with this effort (including the recent changes noted by SHEBA) are compelling. The SSC will appoint a working group to coordinate a science-planning workshop, tentatively scheduled for early Spring 1999. Discussion resulted in modification of the informal name, Study of Arctic Change, to Study of the Environmental Arctic Change (SEARCH).

The next OAII All-Hands Meeting will take place on 20-22 October 1999. For more information, see http://arcss-oaii.ccpo.odu.edu/ or contact Lou Codispoti in Norfolk, VA (757/683-5770; fax 757/683-5550; lou@ccpo.odu.edu) or OAII SSC Chair Jackie Grebmeier in Knoxville, TN (423/974-2592; fax 423/974-3067; jgreb@utkux.utk.edu).

"Finally, we must consider the ice.... Were it not for the ice, the sea here would be little different from the sea elsewhere in the world. We travel and work on the ice constantly, just as if it were solid land, and we tend to forget that 2 m beneath us is a 4 km void. But this is the polar ice pack, and it is constantly in motion. Since late January, the pack has been especially active near the ship. The science camp was separated by a lead that opened 50 m, then crushed together again to form a pressure ridge and a keel 10 m deep. The main camp was moved north half a kilometer and now has to generate its own power rather than be hooked to the ship.... Sometimes we are awakened by a lurch as the ice snaps and the ship moves, or we hear the ice grinding against the side. No matter the time of day or night, the bridge immediately fills with people anxious to see where the action is, and whether their huts and instruments are in the water or crushed in the ice."

—Harold Welch, biological oceanographer
Department of Fisheries and Oceans, Canada
May 1998
quoted in *Arctic*
September 1998

(photo by Richard Moritz, courtesy of University of Washington)

Study of the Environmental Arctic Change (SEARCH)

The final *Report on the Arctic Change Workshop* that took place in November 1997 was completed and distributed in August 1998 by the Polar Science Center at the Applied Physics Laboratory of the University of Washington as an OAII report. The report summarizes observations of marked changes in the Arctic since 1990 (see *Witness* Spring 1998) and urges the development of a program to examine them further.

Observations have revealed that the Arctic is in the midst of change extending from the top of the atmosphere to below 1,000 m in the ocean. A strengthening of the atmospheric polar vortex has resulted in lower surface pressure and a consequent weakening and distortion of the Beaufort Sea Ice Gyre. This weakening has been apparent in drifting buoy data; it is also associated with divergence of the ice pack. It is now postulated that the ice divergence has caused increased summer ice melt and the freshening of the Beaufort Sea mixed layer, as observed during the SHEBA field experiment (see page 6).

The change in atmospheric circulation may also account for:

- the decreased ice cover on the Siberian shelves described by several authors;
- the rising North Atlantic Oscillation index; and
- increased advection of heat and moisture into the Greenland Sea and Barents Sea regions. This, in turn, has resulted in an increase in the temperature of Atlantic Water flowing into the Arctic Ocean and can explain the warming observed there.

The report recommends a coordinated program of long-term observations, modeling, and process studies to track and understand the change that is underway.

Jamie Morison presented the report at the October 1998 meeting of the ARCSS-Ocean-Atmosphere-Ice Interactions (OAII) Science Steering Committee. The SSC endorsed the effort thus far and is urging that the planning effort go forward (see page 6).

The *Report on the Arctic Change Workshop* is available at http://psc.apl.washington.edu/publication/Arctic_Change/arctic.pdf. For more information, contact Jamie Morison in Seattle, WA (206/543-1394; fax 206/543-3521; morison@crosby.apl.washington.edu).

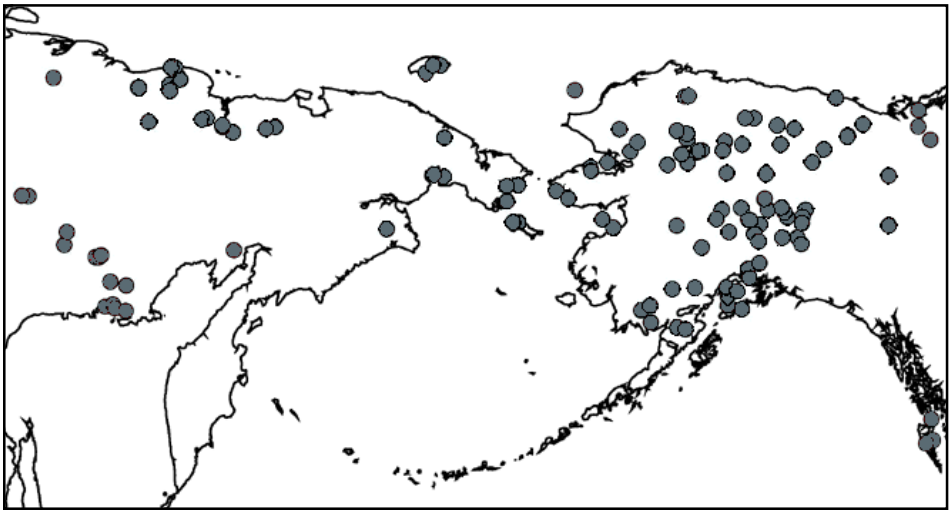
PALE Atlas Serves as Model for Circumarctic Syntheses

While individual researchers in the Paleoclimates from Arctic Lakes and Estuaries (PALE) Program continue to work on past climate reconstruction within their own field areas, there is also a general movement toward synthesis projects. These include:

- the PALE high-resolution research group synthesis of climate change in the Arctic over the last 400 years (*see Witness* Spring 1998); and
- several projects that are part of different initiatives within Past Global Changes (PAGES), a core project of the International Geosphere/Biosphere Programme (IGBP). These include Circum-Arctic PaleoEnvironments (CAPE; see *Witness* Autumn 1997), BIOME (see *Witness* Spring 1998), and the PALE *Paleoenvironmental Atlas* (see *Witness* Spring 1998).

The *Atlas* (http://www.ngdc.noaa.gov/paleo/pale/atlas/index.html) has become a key tool in providing a better understanding of past environmental and climatic spatial variability. The success of the *Beringian Atlas* pilot project has led CAPE researchers to adopt the atlas approach as a way to further regional synthesis efforts elsewhere in the Arctic. A Spring 1999 workshop is planned to begin development of an atlas for the Northwestern North Atlantic region (Iceland to the Canadian Archipelago). The *Atlas* is unique in that it combines paleo- and modern environmental data. The synthesis process is fully documented so that the resulting interpreted data can be traced directly to the primary paleo-data. This, combined with the ease of updating data, sets the *Atlas* apart from more traditional means of data synthesis. Direct any comments on the *Atlas* to the Coordinator, Matt Duvall (duvall@u.washington.edu).

For more information, contact Kim Marsella at the PALE Science Management Office in Boulder, CO (303/492-0246; fax 303/492-6388; pale@spot.colorado.edu), and see the PALE web site (http://www.ngdc.noaa.gov/paleo/pale/index.html).



The Paleoenvironmental Atlas of Beringia *is designed to synthesize environmental conditions from primary paleoenvironmental data. This map shows the sites containing the fossil pollen and beetle data used in Atlas reconstructions. For more information, see the web site (http://www.ngdc.noaa.gov/paleo/pale/atlas/beringia/index.html; map by Matt Duvall, Quaternary Research Center, University of Washington).*

Svalbard Offers Extensive Logistics Capabilities

by Thomas Pyle, Jan Erling Haugland, and Per Kyrre Reymert

During an August 1998 meeting in Tromsø, Norway, representatives from several arctic countries planned establishment of an Arctic Operators' Forum (see page 13) to improve coordination of research planning and logistics. The NSF Arctic Program is attempting to publicize the availability of international facilities and exploring arrangements for use of these facilities by U.S. scientists. To help assure full access to the Arctic, NSF encourages researchers to consider sites, such as those located in Canada (see *Witness* Spring 1998), Greenland (see *Witness* Spring 1997), and Svalbard, when planning their research. Facilities in Svalbard are described here.

Svalbard is notable as an arctic research platform because it is the world's northernmost community with modern facilities and infrastructure. Under the Svalbard Treaty, it is open to scientists from 42 nations, including the U.S. In 1998, investigators from more than 15 nations conducted research on Svalbard.

Half of Svalbard's area is protected as national park, nature reserve, plant protection reserve, or bird sanctuary. These reserves and the islands' more than 100-year history of scientific activity make Svalbard an excellent laboratory for studying the environment of the high Arctic.

Longyearbyen, the main habitation (pop. 1,200), offers researchers all transportation, telecommunication, and logistic services year-round and is the site of several scientific installations.

University Studies in Svalbard (UNIS) is a foundation established by the Norwegian government in cooperation with Norway's four universities to offer university-level courses and perform research relevant to the high Arctic. Field courses are an important part of study at UNIS, which is based in Longyearbyen. Twenty-three instructors offer 35 courses in arctic geology, arctic geophysics, arctic biology, and arctic technology to students from 16 countries. For more information, see http://aurora.unis.no.

One of the world's northernmost settlements, Ny-Ålesund is an international base for research in the natural sciences that has a well-developed infrastructure, including regular commercial air service and a modern harbor. The Ny-Ålesund International Research and Monitoring Facility includes research stations for Norwegian, German, British, Italian, French, and Japanese institutions, as well as the European Union's Large Scale Facility (LSF). The LSF includes facilities for atmospheric climate and biological research (Norwegian Polar Institute Svalbard or NPS), atmospheric air research (NPS and the Norwegian Institute for Air Research), ozone/stratospheric and climate research (Alfred Wegener Institute), and space geodetic research (Norwegian Mapping Authority). More than 9,000 user-days were logged by visiting scientists at Ny-Ålesund in 1998. Many of the research activities, coordinated by the Ny-Ålesund Science Managers Committee, continue year-round. A new Norwegian research station will be available for use in early 1999. Russia and Poland also have research stations on Svalbard. The NPS operates its own research vessel, the R/V *Lance*, over the high Arctic.

The NPS offers logistics services to Norwegian researchers and to foreign researchers working under collaborative agreements. The Svalbard Science Forum, established by the Research Council of Norway, coordinates research facilities, the development of infrastructure, and information concerning research in Svalbard.

For more information, contact Jan Erling Haugland, Director of the NPS, or Per Kyrre Reymert, Science Secretary of the Svalbard Science Forum (+47/79-02-26-00; fax +47/79-02-26-04; nps@lby.npolar.no or ssf@lby.npolar.no; http://www.lby.npolar.no).

Ny-Ålesund is situated on Kongsfjorden on northwestern Spitsbergen, the largest of the Svalbard islands. The area is typical of high-arctic ecosystems, offering a variety of arctic fjord environments, access to several bird and plant sanctuaries, and diverse geological systems (photo © Bjørn Frantzen).

The Svalbard Archipelago crosses 80°N, but the ports of Longyearbyen (★) and Ny-Ålesund (◆) are kept clear of ice in the summer by warm water from the North Atlantic current (map by Mountain High Maps).

Workshop Details Opportunities in Arctic Research

A community workshop held at the request of the National Science Foundation and conducted by ARCUS in September 1998 developed recommendations regarding needs and opportunities in arctic research. NSF requested community input on a short time scale to aid its planning process and ability to respond effectively to significant budget increases in the FY99 Congressional appropriation (see page 10 for more information on the budget and page 11 for opening remarks by the Director of NSF).

Twenty-eight scientists, representing a wide spectrum of arctic research interests, identified current opportunities in arctic research and challenges in arctic research support needs. These issues are outlined in *Opportunities in Arctic Research*, which was reviewed in draft form by the workshop participants and the core organizing group and has been forwarded to NSF. The report, which attempts to balance perspectives provided by the physical, biological, and social science communities, stresses the need for integrated research approaches to study change in the Arctic and to improve our understanding of the links between physical and biological phenomena and socioeconomic changes. The introduction, scientific opportunities, and recommendations for research support and logistics infrastructure are summarized here. Ongoing community discussion on these issues will continue to be very important.

Introduction

For the last few decades, the scientific community has expressed concern about the vulnerability of the Arctic and its residents to environmental, social, and economic changes. Research results show that arctic climate and ecosystems are indeed changing substantially, impacting people living in and outside the Arctic. Concern about physical and biological change is heightened by new evidence that contaminants are accumulating in arctic ecosystems and that the upper atmosphere is undergoing changes as well.

Many of the processes regulating arctic physical and biological systems are not well understood, offering numerous opportunities for advancing basic knowledge. Ice, snow, glaciers, tundra, permafrost, boreal forests, and peatlands are sensitive integrators and indicators of change; investigating these can also provide fundamental information about the interactions and processes that regulate them. The polar region is also unique in its direct electrodynamic coupling to space environments through the geomagnetic field.

Rapid changes also are taking place in the political and economic systems of arctic societies. These processes are more apparent and less affected by extraneous influences in the Arctic than they are in many other areas of the world. The ways in which these changes take place and the variations in the processes and outcomes are poorly understood.

Recent arctic changes—climatic, contaminant, UV, biological, social, economic, political—add urgency to the need for scientific understanding that will permit meaningful prediction, adaptation to, and mitigation of these changes. Key questions include the following:

- How are rapid social, political, economic, and environmental changes occurring in the Arctic affecting the people there? How have similar changes affected arctic residents in the past?
- How close is the Arctic Ocean to a transition to an alternate state? Is natural variability, when superimposed on any greenhouse-related trends, sufficient to make an ice-free Arctic likely in the next 100 years?
- Are the observed trends of warming going to continue, or are they the result of a multi-decadal cycle? How have these changes varied around the Arctic?
- Are recent large population changes of some arctic animal species linked to changes in climate, ice conditions, landscape cover, or human resource use?
- How will distributions of arctic vegetation and permafrost change over the next decades to centuries?
- What are the origin and effects (at the surface) of recent arctic upper- and lower-atmosphere changes (*e.g.*, the increase of polar stratospheric clouds and Arctic Haze, the decrease of stratospheric ozone)?

Research Support Needs

An arctic research strategy of planning, coordinated measurements, and modeling will improve our present levels of understanding, predictive skill, and assessment. Workshop participants concurred with the recent U.S. Arctic Research Commission/NSF report, *Logistics Recommendations for an Improved U.S. Arctic Research Capability* (ARCUS 1997; see *Witness* Autumn 1997), and outlined additional ways in which a network of environmental observatories could facilitate an observational strategy to measure important time and space scales of changes in the Arctic. The following emerged as priorities:

Collect long-term observations with remote sensing, and integrate with paleorecords. Strategies to promote systematic observation and elucidation of the linkages within the arctic system include:

- environmental observatories,
- sustained off-site observations,
- technology development and increased utility of remote sensing,
- integration of paleo-data,
- year-round safe access, and
- communications.

Develop modeling and predictive capability. A fusion of modeling and observational efforts is required to effectively focus modeling on critical science questions, and data collection, where possible, should be relevant to the modeling effort.

Synthesize local and academic knowledge on Arctic Change. Methods need to be developed to improve cooperation and sharing of knowledge, information, and research data between academic scholars and arctic residents, including indigenous northern communities and local experts. Strategies to promote these include:

- joint, locally based meetings; and
- active dissemination of data.

International cooperation/collaboration. Cooperation with the international community is required to achieve better global coverage and the needed mix of instrumentation and facilities.

The full report is available on the ARCUS web site at http://www.arcus.org. For more information, contact ARCUS.

FY 1999 R&D Budget Recoups Losses of Previous Years

This article has been abstracted from the preview report on the FY 1999 federal investment in research and development (R&D) prepared each year by the American Association for the Advancement of Science (AAAS) Office of Science and Policy Programs. The FY 1999 edition of Congressional Action on Research and Development *was released in early December 1998. For more information, see the AAAS web site (http://www.aaas.org/spp/dspp/rd/cafy99.htm).*

On 21 October 1998, President Clinton signed an omnibus appropriations bill (Public Law 105-277) funding R&D for FY 1999. This and four other FY 1999 bills provide unprecedented funding levels for federal R&D.

Highlights

Last-minute infusions of billions of dollars allowed for increases for nearly all categories of discretionary spending. FY 1999 appropriations were supposed to be limited by spending caps enacted last year that allowed for a less than 1% increase in total discretionary spending; the final discretionary budget, however, is expected to be $573 billion—an increase of more than 8%.

The result is the most favorable appropriations for federal R&D in more than a decade. Total federal support for R&D in FY 1999 is expected to exceed $80 billion for the first time in history.

The total FY 1999 R&D is 3.1% above the President's request. Most agencies received more than requested. While NSF did not, it nevertheless won increases above FY 1998 levels.

Every major R&D funding agency except the National Aeronautic and Space Administration (NASA) and the Department of Commerce won increases well ahead of the expected 2% inflation rate. The National Institutes of Health (NIH) received the largest dollar increase in history—$2 billion (a 14.1% increase)—to $14.9 billion for R&D.

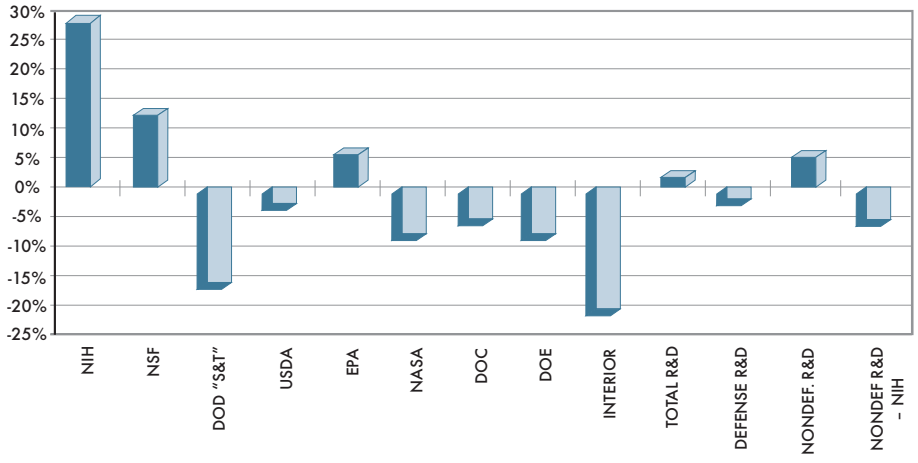
Basic Research

Basic research has been given a high priority. Federal support is expected to increase 11.3% to $17.5 billion in FY 1999. This is nearly $600 million more than requested by the Administration.

Every major R&D funding agency received significant increases for basic research, including an estimated 10% boost for NSF basic research to $2.4 billion. In dollar terms, the biggest increases are for NIH, which now accounts for 48% of all federal support for basic research, compared to 37% a decade ago.

In the past four years, increases to basic research have more than kept pace with inflation. The FY 1999 funding level is 14.6% above the FY 1994 level, after adjusting for inflation.

The total R&D for defense programs in DOD and DOE is $41.8 billion—an increase of 3.5%.



Trends in U.S. R&D over the last 5 years: Percent change in constant dollars FY 94-99. Source: AAAS.

The non-defense R&D total of $38.3 billion is 7.4% ($2.7 billion) more than FY 1998, far ahead of the 2% expected inflation rate. Funding for non-defense R&D is 5% higher than the FY 1994 level in inflation-adjusted terms (due primarily to increases for NIH), after four years below that mark. Without NIH, however, funding for non-defense R&D is still below the FY 1994 level in inflation-adjusted terms (see Figure).

NSF received $2.8 billion for R&D. While this is less than the request, it is 8.4% ($216 million) more than FY 1998. The core Research and Related Activities (R&RA) account is up 8.8% (to $2.8 billion). Because of significant increases in the past two years, the NSF R&D budget is now 11.3% above the FY 1994 funding level in inflation-adjusted terms.

Of particular interest to arctic researchers, the NSF budget includes $22 million for the U.S. Arctic Program "to support ongoing and planned high priority research in the arctic region, including appropriate logistic needs."

For the first time in nearly 30 years, the federal government recorded a budget surplus. The final FY 1998 surplus was $70 billion, compared to an FY 97 deficit of $23 billion. Current projections show that surpluses are likely to continue for the next decade, assuming current budget policies and moderate economic growth.

Industry-Funded R&D

As federal R&D expands, the total national R&D enterprise continues to expand. Private industry is expected to fund $144 billion in R&D in 1998, an increase of nearly 10% from 1997. 1997 was the first year that the total national R&D exceeded $200 billion.

Industry has consistently expanded its share of the total R&D over the past four decades, and now accounts for nearly two-thirds of national R&D expenditures.

Growth in total R&D is expected to exceed growth in the U.S. economy as a whole (as measured by the Gross Domestic Product); NSF estimates that total U.S. R&D will amount to 2.61% of the economy, up from 2.54% in 1997.

The National Science Foundation's Role in the Arctic

by Rita Colwell

I am eager to share with you the great anticipation I feel about my new post at the helm of NSF. Part of the excitement is the opportunity we have to chart a visionary course—to shape the future of research in the Arctic.

As Eric Hoffer wrote, "the only way to predict the future is to have the power to shape the future." NSF needs the community's advice to strengthen its leadership role in this extreme region of the world, whose physical and human resources can teach us so much.

Anticipation and pro-action—these are directions in which science should move in the next century. We know that the Arctic and the rest of the world can no longer afford to focus on remedial solutions. Now, with our sophisticated tools and the explosion of knowledge, we have the power to foresee and to predict, in a way we never could do in the past.

A physical phenomenon that is specific to the polar regions can provide a clue to a direction we should take: on a cloudy day in the Arctic, a ship's captain may not be able to see very far into the distance, but a brilliant patch of clouds in an otherwise dull sky signals a patch of ice ahead, even though it can't be seen.

Just the opposite—a dark spot in a dazzling expanse of cloud—can indicate open water ahead. This "water sky," as it is known, physically indicates the way to go. Similarly, the Arctic can inform and give direction to the rest of the world.

Interdisciplinary connections are absolutely fundamental. They are synapses in this new capability to look over and beyond the horizon. The interfaces of the sciences are where the excitement will be most intense. I think a great deal about what I call "biocomplexity"—the network of chemical, biological, and social interactions among our planet's systems. Study areas that are optimal for this new way of understanding are the polar regions. Let me touch on a few of the reasons why.

How can we grasp the enormous complexity of our world—our planet? This is something that science, engineering, and technology must help us to do. In the Arctic—with its huge ocean that is relatively little understood, and its living systems with their human adaptations—we sense that we stand on the threshold of countless discoveries. One of the virtues of the Arctic may be the raw opportunity to trace the interactions of the physical environment and the living inhabitants. NSF's initiative on Life in Earth's Environment provides a way to investigate these opportunities in a truly integrated way. I expect the polar regions—with their lessons about extreme environments and marvelous teachings about the sustainability of life—to be central to this exploration.

The Arctic also offers a model for the fusion of the science, engineering, and technology I mentioned above with the ethical conduct of research. We have a wonderful opportunity to use groundbreaking interdisciplinary teamwork as a foundation for building absolutely exceptional partnerships with arctic communities.

The Arctic also should be a beacon for international cooperation in the world of research. A natural impetus for international collaboration is the critical issue of contaminants in the Arctic—on land, in the region's great rivers, and in the sea. Enhancing our fledgling cooperation with Russia, and making good use of the declassification of arctic data on both sides of the Bering Sea—these are the kinds of international connections that suggest promising new directions to explore.

A little over a decade ago, I chaired a National Science Board study that made recommendations on NSF's role in the polar regions. For the Arctic, the report suggested that NSF establish research centers and logistics frameworks to support science. We can now celebrate implementation of several major recommendations of the study.

Although marked progress has been made, much remains to be pioneered. Just one intriguing possibility is that NSF could establish a network of environmental observatories—but we need your advice about their potential for the Arctic. It would be efficient, but would it be effective, to build on facilities that already exist? How can we best build on the history of data collection that we have already achieved? Monitoring the arctic environment at established sites and at new sites over the long-term will usher us further into the science of pro-action that I mentioned earlier. Like "water sky," observatories could help us to see the way ahead.

One such NSF priority is the Polar Cap Observatory, which would enable unique measurements of the ionosphere and atmosphere in the high Arctic. These studies would help us better understand "space weather" that disrupts satellites and communications systems. Only in the Arctic can we fill the gaps in our understanding of energy transfer between the solar wind and our atmosphere.

A network of facilities that integrate research and education might also help us anticipate and shape our future in another very important way: it could help us train future generations. We are all aware that polar science has the potential to catalyze young imaginations—to fire them up to learn more, connect with science, and thereby, strengthen our collective scientific literacy. This has to be an integral part of future polar science.

I have attempted in this short time to offer a few ideas for you to mull over, but I'm conscious of standing before a gathering of experts—really solid arctic expertise of great breadth. I'm eager to hear your questions and comments on our opportunities in the Arctic. ■

Rita Colwell took office as the Director of NSF in August 1998. Immediately prior to becoming NSF Director, Dr. Colwell was President of the University of Maryland Biotechnology Institute and Professor of Microbiology at the University of Maryland. For a more complete biography, see http://www.nsf.gov/od. This article is excerpted from remarks she delivered in the opening session of Opportunities in Arctic Research: A Community Workshop *in September 1998 (see page 9).*

U.S. Arctic Research Commission

USARC Advances International Cooperation

Actvities of the U.S. Arctic Research Commission (USARC) in the past six months centered around facilitating logistical access and international collaborations in arctic research. Another ongoing effort is advancing the use of research in the preparation of environmental impact statements. Toward these ends, the USARC met in August 1998 at the SeaLife Center in Seward, Alaska, then toured Prudhoe Bay oil field facilities and the Toolik Field Station. Members of the commission also attended the initial meeting of Forum of Arctic Operators in Tromsø, Norway and toured research facilities in Svalbard (see pages 8 and 13).

At the University-National Oceanographic Laboratory System (UNOLS) Annual Meeting in September, UNOLS member representatives were briefed by USARC Executive Director Garrett Brass on Arctic Ocean research logistics. Brass also attended the Arctic Icebreaker Coordinating Committee meeting (see page 17) in November 1998 for discussions on use of the USCGC *Healy*.

The October 1998 meeting of the USARC in Fairbanks, Alaska included:

- a briefing by Tom Pyle, Arctic Section Head, NSF Office of Polar Programs;
- discussion with Alaska Senator Frank Murkowski and members of his staff;
- briefings from the Bureau of Land Management, University of Alaska, and Alaska Department of Environmental Conservation.

Commission members attended an International Arctic Research Center (IARC) science advisory committee meeting in association with the IARC inauguration (see page 13). Brass is U.S. co-chair of the IARC Implementation Committee.

The U.S. now chairs the Arctic Council; USARC Chairman George Newton and Brass attended a high-level meeting in November at the State Department to discuss agency commitments to the chairing process. Newton and Brass joined Norman Cherkis of the Naval Research Laboratory in October to present the Canadian government with newly declassified arctic bathymetric data collected by U.S. nuclear submarines between 1957 and 1982; the data will soon be publicly available.

The USARC has also been discussing with the White House Office of Science and Technology Policy the future of joint U.S.-Russian arctic research activities under the Gore-Primakov Agreement.

The USARC will meet next in March 1999 in association with the ARCUS Annual Meeting and Arctic Forum. For more information contact Garrett Brass in Arlington, VA (800/AURORAB or 703/525-0111; fax 703/525-0114; g.brass@arctic.gov). ■

Polar Research Board

PRB Reviews NSF Arctic Natural Sciences Program

A review conducted by a special committee of the Polar Research Board (PRB) concluded that the NSF's Arctic Natural Sciences Program (ANS) makes important contributions to arctic science, and the special challenges presented by its broad scope are manageable.

In 1997, the NSF Office of Polar Programs (OPP) commissioned the PRB to review the new program's management and research strategies and to provide guidance on setting research priorities (see *Witness* Spring 1998).

The ANS Program funds research in an exceptionally wide range of fields, from atmospheric sciences, space sciences, and biology to earth sciences, glaciology, and oceanography. Established in 1996, it is the main NSF program responsible for funding cutting-edge research:

- dealing with any aspect of the Arctic's atmospheric, terrestrial, and marine systems; and
- contributing to understanding and predicting the unique elements and processes of the arctic environment.

In contrast to the ARCSS Program, ANS is not specifically chartered as a Global Change Research Program, and ANS tends to focus on proposals from individuals or small groups of investigators, rather than large integrated groups.

Future Directions for the NSF's Arctic Natural Sciences Program (see Publications, page 23) provides guidelines for selecting proposals suitable for ANS funding and suggests that, as an administrative aid, the ANS's broad scientific program be managed in three spheres:

- atmospheric systems,
- terrestrial systems, and
- marine systems.

The committee strongly affirms, however, that the fundamental strength of the ANS Program is its breadth. As a general program ANS provides important opportunities for individual researchers, new ideas, and disciplinary approaches that do not fit into the focused, multidisciplinary themes that guide many other relevant programs.

Although the boundaries between the ANS Program and other NSF programs with arctic elements are sometimes unclear, the solution, according to the report, lies in improved management rather than in restructuring or redefining the program. Program managers should use mail reviews, panels, and NSF and agency staff with relevant expertise to identify priorities and maintain a dynamic balance among the three research spheres.

The report further comments on the program's scope, structure, management strategy, research priorities, international and interagency cooperation, support for logistics, and availability of data about the program. Information about the committee membership, charge, process, and the final report is available through the PRB's web site (http://www2.nas.edu/prb/).

For more information, contact PRB Director Chris Elfring or Project Assistant Rob Greenway in Washington, DC (202/334-3479; fax 202/334-1477; celfring@nas.edu). ■

IASC Promotes Science and Policy Interactions

The International Arctic Science Committee (IASC) orients its activities around the development of long-term projects dealing with thematic issues of interest to scientists, stakeholders, and policymakers. Many of these projects are now well established and beginning to produce significant scientific results; others are at earlier stages of development. As described in the 1998 *IASC Project Catalogue*, current projects address four broad arctic topics:

- natural processes within the region,
- processes of relevance to global systems,
- the impact of global changes in the region, and
- sustainable development.

IASC has directed increased attention during 1998 to three other activities. First, IASC has been confirmed as an accredited observer to the Arctic Council and has expanded its efforts to promote mutually beneficial dialogue between the science and policy communities. Current efforts focus on initiatives designed to improve understanding of climate change and UV-B radiation in the Arctic.

Second, IASC is encouraging the establishment of a Forum of Arctic Operators, which would play a role similar to that of the Council of Managers of National Antarctic Programmes. An initial meeting took place in Tromsø, Norway in August 1998; another meeting is planned for April 1999.

Third, IASC is interested in initiating an annual Arctic Science Summit Week that would join the annual meetings of IASC and several other organizations to create a high-profile meeting place for scientists, program managers, funders, and policymakers interested in arctic issues. An initial experiment along these lines will take place in Tromsø in conjunction with the next annual meeting of IASC now scheduled for 25-30 April 1999.

For more information, contact Odd Rogne at the IASC Secretariat in Oslo, Norway (+47/22-57-37-37; fax +47/22-57-37-40; iasc@iasc.no), or see the IASC web site (http://www.iasc.no). ■

AAAS Focuses on International Cooperation

The 49th American Association for the Advancement of Science (AAAS) Arctic Division Science Conference convened in Fairbanks, Alaska in October 1998 with the theme of *International Cooperation in Arctic Research: Detecting Global Change and its Impacts in the Western Arctic.* The event, chaired by Dr. Syun-Ichi Akasofu, also served as the inauguration of the International Arctic Research Center and as a Wadati Conference on Global Change. Plenary sessions included:

- International Collaboration in Global Change Research in the Arctic,
- Ocean-Atmosphere-Ice Interactions,
- Land-Atmosphere-Ice Interactions,
- Paleoclimates,
- Regional Impacts of Global Change, and
- Global Implications of a Changing Arctic.

Rita Colwell, the new director of NSF (see page 11), addressed the conference twice, relating an informal personal history entitled, "Trailblazing: One Woman's Trek in Science" and giving a public lecture on her own research entitled "Global Climate and Infectious Disease: The Cholera Paradigm."

For more information on the Arctic Division Science Conference, contact Mary Farrell in Fairbanks, AK (907/474-7790; fax 907/474-7290; fnmrf@uaf.edu; http://www.gi.alaska.edu/aaas/). ■

Polar Libraries Colloquy Fosters International Links

The Polar Libraries Colloquy, formerly the Northern Libraries Colloquy, was founded in 1971 to provide a forum through which librarians, information specialists, and others concerned with the collection, preservation, and dissemination of polar information can discuss issues of mutual interest and promote initiatives leading to improved collections and services. A central objective has been to foster greater international collaboration.

Recent meetings have been held in Cambridge (1994), Anchorage (1996), and Reykjavik (1998). The meeting in the year 2000 will convene in Winnipeg, Canada.

Participants at the Reykjavik meeting discussed:

- library support for the concept of the University of the Arctic (see page 14);
- support for the Stefansson Arctic Institute in Akureyri, Iceland; and
- the future of the Antarctic Bibliography.

Colloquy proceedings are published by the host organization. *Polar Libraries Bulletin*, a biannual newsletter, and *Polar and Cold Regions Library Resources* (3rd ed., 1994) are published by the Colloquy.

Colloquy Steering Committee members are Philip Cronenwett, *Chair* (Dartmouth College), Julia Finn (Indian and Northern Affairs, Canada), William Mills (Scott Polar Research Institute), Vibeke Sloth Jakobsen (Danish Polar Center), Palina Heidensdottir (Icelandic Museum of Natural History), Liisa Kurppa (Arctic Centre, University of Lapland), Lynn Lay (Byrd Polar Research Center), Fred Inge Presteng (Norwegian Polar Institute), and Anne Morton (Hudson's Bay Company Archives).

For more information, see the Polar Web web site (http://www.urova.fi/~arktinen/polarweb/polarweb.htm), or contact Philip Cronenwett in Hanover, NH (603/646-2037; fax 603/646-0447; phil.cronenwett@dartmouth.edu). ■

NABO Sponsors International Northern Field School

In September 1997, the North Atlantic Biocultural Organization (NABO) formed an Education Working Group. Many scholars and agencies have identified the early involvement of students in northern fieldwork as a critical factor in recruiting future arctic researchers. The cost of logistics in remote field sites has, however, effectively limited student participation. Many members of NABO and the wider arctic research community have discussed the need for a regular field school capable of accommodating a range of undergraduates, graduate students, K-12 educators, and northern residents.

Thanks to the generous cooperation of the Archaeological Institute of Iceland (Fornleifastofnun Islands, FSI), and support from the National Geographic Society, City University of New York (CUNY), and the Icelandic Science Council, the NABO Education Working Group has been able to develop such a field school in northern Iceland. This location boasts:

- a modern infrastructure;
- regularly scheduled air connections;
- complex geomorphology;
- a long history of human-environmental interaction; and
- ongoing multidisciplinary investigations carried out by Icelandic and other, international, teams.

The NABO field school focuses on archaeological and paleoecological investigations at the 9th-11th century Viking site of Hofstadir near Lake Myvatn. This site, first investigated in 1908, has produced evidence of a huge long hall, initially identified as a pagan temple site, and one of the first zooarchaeological samples from Iceland. Since 1995, the FSI has uncovered still earlier structures dating to the period of first colonization, and NABO specialists have aided in recovery and analysis of rich bioarchaeological evidence for early farming strategies and environmental impact (see *Witness* Autumn 1996 and 1994).

The first field school season in August 1997 involved 10 students from eight countries and instructors from the FSI, CUNY, the Universities of Edinburgh, Sheffield, and Stirling; and the Icelandic Myvatn Science Centre at nearby Skutustadir.

Students from Canada, Iceland, Norway, the U.S., and the U.K. at the 1998 NABO Field School (photo by Tom McGovern).

In 1998, two public high-school science teachers and 13 students from the United States worked alongside students from Norway, Iceland, and the United Kingdom. Formal affiliation with Hunter College of CUNY provided support for undergradute and graduate instructors, and facilitated course credit transfers in North America.

Students helped to uncover what may be the earliest structures in northern Iceland, excavated volumes of well-preserved animal bone and wood, skinned bird carcasses from the Myvatn Science Center, participated in whale watches, and attended evening lectures and demonstrations ranging from soil micromorphology to techniques for illustrating artifacts.

Summer 1999 field students will participate in an interdisciplinary workshop on "Sustainability and History: Challenges to Human Adaptability in the North Atlantic" before the field work begins.

Collaboration with other educational initiatives and educational centers is welcome. For more information, contact Orri Vesteinsson in Reykjavik, Iceland (+354/551-10-33; fax +354/551-10-47; fsi@mmedia.is), or Tom McGovern (212/772-5410; fax 212/772-5423; nabo@voicenet.com) or see the NABO web site (http://www.geo.ed.ac.uk/nabo/home). ■

University of the Arctic

Since early 1997, stakeholders from all eight arctic countries have been exploring the utility and feasibility of establishing a circumpolar institution of higher education. Ministers of the Arctic Council stated, in the Iqaluit Declaration adopted in September 1998, that they "welcome ... the establishment of a University of the Arctic—a university without walls—as proposed by a working group of the Circumpolar Universities Association." The vision has been to pool resources to offer courses without creating a fixed campus, a comprehensive curriculum, or a residential student body.

The programmatic emphases of the University of the Arctic (UoA), as currently conceived, include:

- comparative, interdisciplinary, and problem-oriented studies designed to contribute to policymaking regarding current arctic issues;
- partnerships with northern peoples organizations, and communities; and
- support for small, community-based institutions of higher education in the North.

Following the endorsement of the Arctic Council, the UoA planning process will now shift to implementation. The working group welcomes suggestions.

For more information, contact Working Group secretary Richard Langlais in Rovaniemi, Finland (+358/16-324-76; fax +358/16-324-77; richard.langlais@urova.fi), Karen Erickson in Fairbanks, AK (907/474-6503; fax 907/474-5817; ffkje@uaf.edu), Oran Young in Hanover, NH (603/646-1278; fax 603/646-1279; oran.young@dartmouth.edu), and Steven Young in Wolcott, VT (802/888-4331; 802/888-3969; cnsnorth@together.net). ■

MAB Northern Sciences Network Reviews Progress

The Man and the Biosphere Northern Sciences Network (MAB-NSN) was established in 1982 under the umbrella of UNESCO. In October 1998, the MAB-NSN International Advisory Group met in Girdwood, Alaska to discuss initiatives and connections to other arctic science programs. In addition to the International Tundra Experiment (see page 5), the board reviewed the following updates.

The Arctic-Alpine Terrestrial Research Ecosystem Initiative (ARTERI), funded by the European Union for the period February 1996-January 1999, has been deeply involved in the planning of two major initiatives in northern sciences:

- University of the Arctic (see page 14); and
- the high-latitude Scandinavian transect SCANTRAN (Heal *et al.* 1997).

A report from the March 1998 SCANTRAN workshop will be published in December 1998.

The Circumpolar Biosphere Reserves Managers' Working Group has revived. For more information, contact Johan Kling in Abisko, Sweden (+46/980-400-20; fax +46/980-401-71; johan.kling@ans.kiruna.se).

The Integrated Mountain Studies (St. Elias Climate and Ecology) project in western Canada is now seeking funding. Indigenous people in the St. Elias area are enthusiastic and would like to take an active part in the project.

Investigators with the Mountain Birch Ecosystem (MBE) project, initiated a decade ago, have published several papers. Like ITEX, MBE is moving into a synthesis phase, which will be discussed at the MBE meeting in 1999.

The proposed Research Collaborative Programme on Sustainable Use of Biological Resources aims to assess knowledge in:

- western scientific ecology,
- traditional ecology,
- socio-economics, and
- cultural science;

and to bring these together in an interdisciplinary consideration of the sustainable use of biological resources.

The report from the Girdwood meeting will be published in MAB-NSN Newsletter #24, December 1998. MAB-NSN is not a funding agency but will assist in fundraising for this program.

For more information, contact Thomas Björneboe Berg at the MAB-NSN Secretariat in Copenhagen, Denmark (+45/328-80-118; fax +45/328-80-101; tbb@dpc.dk; http://www.dpc.dk).

References

Heal, O.W., *et al.* 1997. *Ecotones, Biome Dynamics and the Cryosphere: An Outline Plan for the Establishment of an IGBP High Latitude Transect in the Scandinavian/Northern European Region (SCANTRAN).* 71 pp. Research Council of Norway, P.O.Box 2700 St. Hanshaugen, N-0131 Oslo, Norway.

Arctic River Discharge is the Focus of a New Science Plan

Fully 10% of the world's fresh water runs into the Arctic Ocean. Despite the importance of this discharge on the global climate system and the existence of international projects that involve arctic paleo-river discharge, there is no comprehensive, multidisciplinary, international research program on circumarctic river discharge and its change through time.

In April 1996, the Arctic Ocean Science Board (AOSB)—composed of research and governmental institutions from 15 countries (http://deschutes.gso.uri.edu/~cara/AOSB.html)—recognized that freshwater input to and balance in the Arctic, and their (paleo-) environmental significance, are a high priority for many institutions active in arctic oceanographical, chemical, biological, and geological research. The following Fall, the board convened an international, multidisciplinary workshop on Arctic Paleo-River Discharge (APARD) at the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, Germany. This workshop outlined the major scientific objectives and linkages to international research programs dealing with arctic river discharge. In April 1998, following a November 1997 workshop to develop a science plan, the AOSB accepted APARD as an official AOSB program.

The APARD science plan was published in *Berichte zur Polarforschung (Reports on Polar Research)* in September 1998. This publication presents:

- the APARD science plan;
- the relationships of APARD to other research programs dealing with arctic paleo-river discharge (*e.g.*, the IASC Land-Ocean Interactions in the Russian Arctic, Quaternary Environment of the Eurasian North, CircumArctic Paleo-Environments, and Nansen Arctic Drilling [see *Witness* Spring 1998]); and
- summaries of existing/proposed projects to implement the program.

This document may serve as a basis for planning and coordinating future research activities on arctic paleo-river discharge.

An APARD Core Group (see APARD web site) will:

- inform the scientific community about existing and planned APARD-related activities;
- encourage contacts, cooperation, and exchange between research institutions involved in APARD-related studies; and
- stimulate joint multidisciplinary circumarctic data compilation and syntheses studies.

For more information, contact Ruediger Stein, Chair of the APARD Core Group, in Bremerhaven, Germany (+49/471-4831-576; fax +49/471-4831-580; rstein@awi-bremerhaven.de; http://www.awi-bremerhaven.de/GEO/Arctic/index.html).

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Stein, R. (ed.). 1998. Arctic Paleo-River Discharge (APARD)—A New Research Programme of the Arctic Ocean Science Board (AOSB). *Berichte zur Polarforschung (Reports on Polar Research)*, Vol. 279, 128 pp.

Frostfire to Study Effects of Fire in Permafrost Regions

Boreal forests account for about 33% of the carbon sequestered in terrestrial ecosystems. If global warming increases the frequency or severity of fire, or rates of decomposition of organic matter, boreal forests could shift from serving as a carbon sink to acting as a net source of carbon.

Frostfire is a research project that will conduct a prescribed fire during the summer of 1999 or 2000 on more than 2,000 acres of the Long Term Ecological Research site north of Fairbanks, Alaska. Research on this prescribed fire is designed to help to understand:

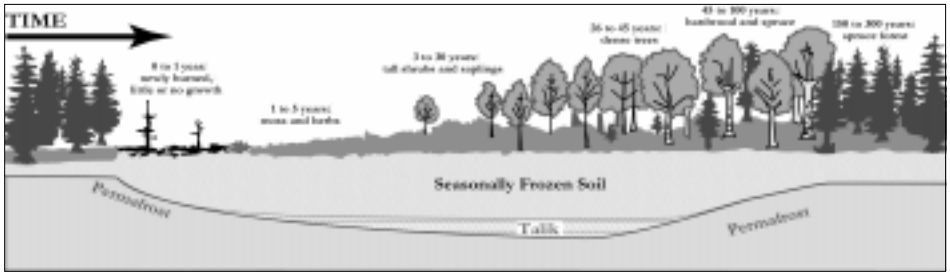
- the causes and consequences of fire regimes,
- the role of fire in the Alaskan regional system, and
- the feedbacks from boreal fire to global climate.

Global warming may increase or decrease the extent of boreal forests, depending on whether forests expand into tundra more or less rapidly than wildfire and logging result in deforestation. Current global models of vegetation change do not consider how the rate of disturbance by fire and logging might change over time. Much of the area currently covered by boreal forest could change to a different biome, however, and the species composition may change in much of the remainder. Changes in the distribution or function of boreal forests could alter regional energy budgets enough to either amplify or nullify the expected rapid climatic warming in the Arctic and sub-Arctic.

Forest fires have an immediate effect on the surface energy and water budget by drastically changing:

- surface albedo,
- surface roughness,
- infiltration rates, and
- moisture absorption capacity in organic soils.

In permafrost regions, these effects contribute to long-term (20-50 years) cumulative impacts. The intensity of a burn, for instance, may determine immediate impacts as well as long-term disturbance. Where trees are removed, evaporation of water from tree leaves decreases or ceases, soil moisture increases markedly, and the soil remains quite wet throughout the year. Where the organic layer, with its insulating qualities, is removed, permafrost begins to thaw near the surface and to warm at greater depths. Within a few years, permafrost may give way to a permanently thawed layer in the soil (a talik), allowing soils to drain internally throughout the year and become quite dry. Plants and animals using such sites must continuously adapt to the changing temperature and moisture regimes of the soil. These and many other processes (see box) will be the subject of Frostfire research.



Plant succession and effects of a fire on permafrost over time. After the insulating quality of the organic layer is removed, permafrost begins to thaw near the surface and warm to greater depths. Within a few years, it may thaw to the point where it can no longer completely refreeze every winter, creating a permanently thawed layer in the soil called a "talik." After formation of a talik, soils may be able to drain internally throughout the year and may become quite dry. The local plants and animals continuously adapt to the changing soil thermal and moisture regimes (illustration by Sue Mitchell).

Support for this work is provided by:

- NSF Division of Environmental Biology under the Terrestrial Ecosystems Program,
- USDA Forest Service Research, and
- Japanese New Energy and Industrial Technology Development Organization.

For more information, contact F. Stuart Chapin (fschapin@lter.uaf.edu), or Larry Hinzman (ffldh@uaf.edu); or see the USDA Forest Service, Pacific Northwest Research Station web site (http://www.fsl.orst.edu/home/usfs/gepp/alaska/frstfire.htm).

Research Associated with Frostfire

- Vegetation Dynamics & Succession
- Landscape Scale Biomass Mapping & Modeling
- Ecological Modeling
- Remote Sensing of Terrestrial Ecosystem Processes
- Radiative Transfer in Vegetation
- Ecosystem Modeling & Analysis
- Effects of Fire on Reproductive Ecology & Biology of Black Spruce
- Hydrologic Process Studies & Modeling
- Aquatic Ecology
- Erosion & Sedimentation in Streams
- Primary Productivity in Streams
- Groundwater Chemistry & Hydrology
- Prediction of Future Climate & Fire Regimes
- Response of Small Mammals to Fire Disturbance
- Fire Safety
- Public Opinion Response to Fire & Fire Control
- Influence of Fuel & Weather on Fire Behavior
- Long-Term History of Fire Effects in Boreal Catchments (Quaternary Plant Ecology)
- Detection of Fire Severity in Alaska Using Remote Sensing Data
- LIDAR Profiling of Smoke Plume
- Forestry Practices & System Response
- Nitrogen Transformation & Transport
- Consequences of Wildfire on Below-Ground Carbon Balance
- Carbon Storage in Soils
- Soil Enzymes
- ^{14}C Deep Soil Respiration
- Carbon Budget of Taiga
- Mycorrhizal Fungi Before & After the Burn
- Permafrost Response, Thermal Condition of Active Layer
- Thermokarst Formation
- Geophysical Sounding for Permafrost Distribution
- Methane Emission from Soil & Permafrost
- Atmospheric CO_2 Dynamics
- Isotopic Chemistry
- LIDAR Aerosol Physics
- Aerial Measurements of Carbon Flux & Surface Effects of Fire on Surface Energy Balance

400 Years of Arctic Sea-Ice Charts are Valuable Resource

Old ship logs and literature surveys documenting sea-ice history from as far back as the 16th century reside at the Norwegian Polar Institute (NPI). Otto Sverdrup collected the ship logs in 1922, and Torgny Vinje of NPI gathered the literature surveys from libraries all over the world more recently. NPI has recently converted the masses of information in the collection to digital form, making it more available to the scientific community studying climate.

The Arctic Climate System Study (ACSYS) Program convened the Workshop for Sea Ice Charts of the Arctic—Scientific Achievements from the first 400 Years in August 1998 in Seattle, Washington. Participants agreed that ice-chart information is the basis for the long-term observational understanding of ice state and ice extent. Information that can be derived from ice charts of the historical era (1200-1930) is limited to ice extent, while ice charts of the modern era (1930-present) generally provide information about the ice pack interior as well. Several workshop reports illustrated the quantity and quality of the ice-chart information and suggested that the data are adequate to support scientific investigations of the historical era (*e.g.*, the Historical Ice Chart Archive Project) and from the modern era (*e.g.*, Global Digital Sea Ice Data Bank).

Workshop participants divided into three working groups:

- The Historical Data Working Group worked on the use of early ice-edge data. Primary recommendations included studies to illustrate the robustness of the historical data (*e.g.*, covariance of ice edge with other geophysical variables).
- The Data Management group focused on issues of data format, metadata, data archives, and international cooperation. Many of their recommendations were carried to the meeting on sea-ice charts sponsored by the Commission on Marine Meteorology held in August 1998 in Boulder, Colorado.
- The Science/Operations group outlined the partnership between the research and operations communities necessary for the effective preparation and use of ice-chart information.

For more information, contact Tordis Villinger at the ACSYS Project Office in Tromsø, Norway (tvilling@npolar.no).

UNOLS Arctic Icebreaker Coordinating Committee

United States Coast Guard icebreakers have long been made available to serve as research platforms for scientists. To enhance the effective use of these platforms, the University-National Oceanographic Laboratory System (UNOLS) established the Arctic Icebreaker Coordinating Committee (AICC; see *Witness* Spring 1997) to help the Coast Guard and scientists conduct and coordinate their respective missions in the Arctic. The most recent AICC meeting was 18-20 November 1998 at NSF in Arlington, VA.

The Coast Guard now accepts ship-time requests for arctic marine science support on USCGC *Polar Star* or *Polar Sea*, generally for spring or summer operations. The Coast Guard recently informed the AICC that a limited number (10-20) of berths may be available for scientists on a western Arctic Science-Of-Opportunity (SOO) cruise on *Polar Star* during mid-summer 1999, should no funded missions—which have higher priority—materialize. The AICC has called for submission of Icebreaker Science-of-Opportunity Request forms, available through the UNOLS web site (see third column). The AICC will assess requests submitted by 4 January 1999 for suitability, including geographic region, seasonality, number of berths, compatibility of scientific programs and personnel responsibilities, USCG equipment requests, and laboratory requirements. This advisory process is independent of proposals for funding, or acceptance by the Coast Guard of any proposed SOO science participation.

The new arctic research vessel, USCGC *Healy*, is expected to be available beginning January 2001 for 180 or more days of arctic marine science support during that year. Advance assessment of scientific interest in use of *Healy* during 2001 indicates a likelihood of work in the eastern Arctic, including the Nansen-Gakkel Ridge, during mid-late summer 2001. Additional marine science programs in the western or eastern Arctic from *Healy* are also logistically feasible earlier in the year.

The AICC invites the community to participate in the long-range process of advising on science use of *Healy*, to provide a temporal and regional palette of science missions, options, and requirements from which the Coast Guard and agencies can draw science and funding scenarios. To expand this planning process for the years 2002 and beyond, the AICC will hold annual arctic vessel long-term planning workshops in San Francisco one day before the AGU Fall Meeting, beginning in December 1999. Announcements of these meetings will be widely circulated.

The AICC urges that all proposals requiring U.S. arctic icebreaker support during 2001 be submitted to the appropriate agencies no later than February 2000, accompanied by a UNOLS Ship-Time Request Form (see below). Ship support costs need not be included in the submitted science budget of proposals to NSF requiring U.S. Coast Guard icebreaker support for arctic research, if an NSF Form 831 (or other logistics form approved by the NSF Office of Polar Programs) is attached that clearly indicates ship-time requirements.

The AICC meets next in March 1999 in Avondale, Louisiana. For more information, contact AICC Chair Jim Swift in La Jolla, CA (619/534-3387; fax 619/534-7383; jswift@ucsd.edu) or the UNOLS Office (unols@gsosun1.gso.uri.edu); a ship-time request form is available at http://gso.uri.edu/unols/unols.html).

Regional Change Surveys Cultivate New Participants

In early 1997, the U.S. Global Change Research Program and the Office of Science and Technology Policy initiated a series of regional climate change workshops throughout the country (see Witness *Autumn* 1997). By early 1998, this initiative had grown into a comprehensive U.S. National Assessment on the Potential Consequences of Climate Variability and Change. A number of federal agencies are collaborating to sponsor the workshops and compile results, including:

- Department of Agriculture,
- Department of Energy,
- Department of the Interior,
- Environmental Protection Agency,
- National Aeronautics and Space Administration,
- National Institute for Environmental and Health Sciences,
- National Oceanic and Atmospheric Administration, and
- National Science Foundation.

The national assessment is being conducted through 20 regional workshops and five conferences on sectors of cross-cutting concern. The sectors selected for analytical treatment at a national scale are agriculture, coastal areas and marine resources, forests, human health, and water resources. The National Assessment intends to:

- publish 20 regional reports, five sector reports, and an overall synthesis in early 2000; and
- launch a long-term process to engage networks throughout the country in analysis, assessment, and reporting on 1) the consequences of global change and 2) associated coping strategies.

The assessment is also notable in its emphasis on stakeholders—users of information (*e.g.*, natural resource managers, farmers, ranchers, water managers, decision makers, elected officials) and others who will be affected by future climate changes or who are positioned to develop response strategies.

The 20 regional conferences, completed in October 1998, have developed recommendations on engaging stakeholders to improve the relevance of the information generated and to create communities of people who are informed and committed to taking action:

- bring stakeholders into every stage of the process;
- incorporate stakeholders into the institutional machinery (steering and advisory committees, review panels);
- go to the stakeholders' places of work, meetings, and boardrooms—rather than relying solely upon workshops and town meetings to bring them together.

To elicit indigenous perspectives, Native lands across the country were treated as one of the 20 regions. Alaska Yup'ik Caleb Pungowiyi opened the October 1998 workshop in Albuquerque, New Mexico, citing observed impacts on indigenous peoples and subsistence lifestyles in the Arctic. The 175 participants from all regions of the U.S., including Hawaii and Alaska, began a comprehensive assessment documenting change and potential impacts of climate variability and change on Native people and Native homelands.

The Alaska Regional Assessment (Bering Sea Impact Study, see *Witness* Autumn 1997) was initiated with a scoping workshop in June 1997 and has, thus far, been most successful in summarizing recent changes in climate and their effects on the physical environment, including snow and ice features. Quantitative synthesis of the impacts on ecosystems and biota has proven more difficult. An October 1998 follow-on workshop convened in Fairbanks, Alaska sought to strengthen understanding of global change impacts on economic activities including fisheries, forestry, transportation, and subsistence (see box).

For more information, contact Melissa Taylor in Washington, DC (202/314-2239; fax 202/488-8681; mtaylor@usgcrp.gov; http://www.nacc.usgcrp.gov).

> *"The...workshop was a wonderful opportunity for the Native community and scientists to share technology and spiritual philosophy as it relates to climate and its impact on the Earth and her people. Over 30 tribal elders shared the ancient wisdom and knowledge...regarding the relationship between humans and the forces of nature. The Native Peoples Workshop was the beginning of a very important dialogue that must be shared and continued as the work continues toward creating a world that is sustainable... environmentally, economically, and socially. The cross-validation of science and the traditional spiritual knowledge of the Native People of the Americas is the fulfillment of a prophecy that all life is cyclical. This historic gathering is the beginning of the closing of that circle of wisdom—science and spirituality."*
>
> —Verna Teller, Workshop Project Director

Potential Impacts of Climate Change on Alaska

- Major changes in fisheries catches in recent years, due to both longer term climate change and El Niño conditions (+ and -).
- Accelerated permafrost thawing, leading to costly increases in road damage and road maintenance (-).
- Major landscape changes from forest to bogs, and in grasslands and wetland ecosystems, due to permafrost thawing, affecting land use (-).
- Increased forest fire frequency and insect outbreaks with reduced economic forest yields (-).
- A lengthening of the growing season for agriculture and forestry by up to 20%, producing higher yields (+).
- Increased coastal erosion and inundation, due to less sea ice in the Bering Sea and more severe storm surges, threatening structures (-).
- Impacts on Native subsistence lifestyles as snow and sea ice changes affect land and marine animals used in hunting/fishing (-).

from Weller, G., and P.A. Anderson (eds.), 1998. *Implications of Global Change in Alaska and the Bering Sea Region.* Proceedings of a Workshop at the University of Alaska Fairbanks on 3-6 June 1997. Center for Global Change and Arctic System Research, University of Alaska Fairbanks, 155 pp.

Agencies Shape Bering Sea Research

Representatives from federal and state agencies engaged in research in the Bering Sea have made further progress in their cooperative efforts to coordinate research and planning (see *Witness* Spring 1998). Since June 1998, the National Oceanic and Atmospheric Administration (NOAA), Department of the Interior (DOI), and the Alaska Department of Fish and Game (ADF&G) have produced results on three major projects related to work in the region.

In September 1998, *The Bering Sea Ecosystem Research Plan* was updated to include the viewpoints of university researchers, conservation organizations, Native groups, fishing industry members, and other constituents. The plan outlines the most pressing needs for further research in fishery management and the marine ecosystem. Understanding the complex biophysical system interactions, including direct and indirect effects of fishery removals, that structure the Bering Sea ecosystem is critical to determining and monitoring diversity and production. The plan proposes a pair of hypotheses that span current management and science issues:

- natural variability in the physical environment causes shifts in trophic structure and changes in the overall productivity of the Bering Sea; and
- human impacts lead to environmental degradation, including increased levels of contaminants, loss of habitats, and increased mortality on certain species in the ecosystem that may trigger changes in species composition and abundance.

The plan is available at NOAA's Bering Sea and North Pacific Ocean web site (http://www.pmel.noaa.gov/bering/) by linking to "Interagency Information Exchange."

The U.S. Congress recently approved an appropriation for FY 1999 of $6.6 million to the University of Alaska for conduct of North Pacific Ocean marine research activities either directly or through subgrants. The work will be guided by a plan approved by the Department of Commerce, DOI, and State of Alaska. *The Bering Sea Ecosystem Research Plan* will be the starting point for directing research activities to be conducted in the North Pacific and Bering Sea.

In October 1998, key representatives of NOAA, DOI, and ADF&G presented a white paper entitled "The Bering Sea Ecosystem—A Call to Action" at the Lowell Wakefield Fisheries Symposium on Ecosystem Considerations in Fisheries Management. This paper serves two important purposes:

- it highlights the importance of the Bering Sea as a national resource; and
- it encourages an interagency approach to research and management in the Bering Sea.

In response to indications of unusual conditions in the Bering Sea during the summers of 1997 and 1998, Fisheries-Oceanography Coordinated Investigations (FOCI) directors convened a workshop in November 1998. The workshop's objectives included sharing information, generating hypotheses, and outlining future research needs to address and understand changing conditions and their effects on the management of marine resources in the Bering Sea. The draft report from this workshop, which endorses *The Bering Sea Ecosystem Research Plan*, is available at http://www.pmel.noaa. gov/foci/bs_98workshop/.

The Bering Sea Ecosystem Biophysical Metadatabase (see *Witness* Autumn 1997) is designed to assist scientists, managers, students, fishermen, and the general public to investigate and understand the complex ecosystem of the Bering Sea. The metadatabase (http://www.pmel.noaa.gov/bering/mdb/) now contains nearly 1,000 separate records.

The Organizing Committee for Bering Sea Ecosystem Research has recently recommended that the metadatabase and the Bering Sea and North Pacific Ocean web site that hosts it serve as the hub to which all related research projects are linked and the locus for interagency coordination of research.

For more information, contact Pat Livingston at the Alaska Fisheries Science Center in Seattle, WA (206/526-4242; fax -6723; pat.livingston@noaa.gov).

HARC Program Invites Proposals

The Human Dimensions of the Arctic System (HARC), the most recent addition to the National Science Foundation (NSF) Arctic System Science (ARCSS) Program, is designed to build on the contemporary and paleoenvironmental components of ARCSS to integrate physical, ecosystem, and climate research with a broad range of social sciences. The major goal of the HARC program will be to understand human interactions with physical and biological environmental change in the Arctic, at scales ranging from local to global. HARC research will focus on impacts on human activities that may be expected in response to global change, by

- illuminating the present and future role of humans in the arctic system;
- focusing on the development of predictive capabilities; and
- building upon the existing body of ARCSS research.

In addition, HARC research should seek to integrate methods and principles from the natural and social sciences; interpret scientific results on temporal and spatial scales relevant to policy decisions; incorporate traditional knowledge; involve indigenous peoples; and interact with and complement the activities of other arctic and U.S. Global Change Research Program projects.

Proposals are due April 30, 1999. For a copy of the program announcement (NSF 99-61), see the NSF Arctic Sciences web site at http://www.nsf.gov/od/opp/arctic/. For background information on the HARC initiative, see *People and the Arctic: A Prospectus for Research on the Human Dimensions of the Arctic System*, at http://www.arcus.org/HARC/ or by request from ARCUS. Questions can be directed to Dr. Michael Ledbetter or Dr. Fae Korsmo at the Office of Polar Programs (703/306-1029; fax 703/306-0648; mledbett@nsf.gov or fkorsmo@nsf.gov).

Traditional Knowledge is Focus of Radionuclides Project

"The most important concern is our world we live in.... Things such as testing bombs is a wound that will never heal—a world that will never grow plants again. This world that we live in must be protected. Where will our children, grandchildren, and great grandchildren live if this world is ruined?"

—Herman Toolie
Savoonga, Alaska, October 1998

The Alaska Native Science Commission (ANSC) and the Institute of Social and Economic Research (ISER) at the University of Alaska Anchorage have received a three-year grant from the Environmental Protection Agency, Office of Radiation and Indoor Air for a Radionuclides and Traditional Knowledge project. This project follows ISER/ANSC's two-year study of Contaminants and Native Food.

Alaska Natives have many concerns about radionuclides and other types of contamination. They are constantly reminded about the close proximity of the former Soviet Union and the potential for trans-boundary migration of radionuclides from this area. During the era of atmospheric testing of nuclear weapons, subsistence consumers of caribou were, perhaps, the most exposed individuals in the western hemisphere; the most important ecological pathway for radionuclides in the Arctic is the lichen-reindeer/caribou-human food chain. After Chernobyl, the ^{137}Cesium in lichen peaked in 1986-87 at levels that are comparable to the peak in fallout from nuclear weapons tests. While current data from Canada suggests that radionuclide contamination in the lichen-caribou-human food chain is not a problem in the Canadian north, we do not have corresponding first-hand information for Alaska.

Many Alaska Native communities believe that they live in the shadow of nuclear radiation from military practices from the former Soviet Union, Project Chariot, Amchitka, and from more than 640 military sites in Alaska. In addition, communities report observations of changes or abnormalities in wildlife including lesions in fish and caribou livers; hairless seals the color of Eskimo tea; and tumors and sores in birds, fish, marine and land mammals. Furthermore, virtually every community speaks of a deeply held concern over the diminished health of its members.

The first year of the Radionuclides and Traditional Knowledge project is designed to use traditional practices and protocols to gather traditional knowledge about radionuclide concerns across five major regions of Alaska. Regional meetings will document first-hand observations of changes in the environment, issues, concerns, understandings, and questions.

Year two is dedicated to a second series of regional meetings and a synthesis meeting. The purpose of the regional meetings is to enable communities to consider the implications of their own knowledge of environmental changes and scientific information. The purpose of the synthesis meeting is to enable scientists and communities to identify common and divergent understandings of environmental change and the role of radionuclides and other contaminants.

In years two and three, a community grant program will support Alaska Native grassroots action projects to address community concerns about radionuclides.

The first regional meeting for northwestern Alaska was held in Nome in September/October 1998. Native elders, hunters, gatherers, scientists, and resource managers met to discuss and map observations of changes in their environment and document other issues of concern to their communities. Their concerns include:

- abnormalities in fish populations in relation to known hazardous sites;
- increasing numbers of bears and beavers and the effect they are having on human health, fish populations, and stream and terrestrial habitats;
- higher cancer rates in particular communities surrounding known nearby hazardous sites;
- increase in Alzheimer's disease;
- die-off of seabirds and waterfowl, abnormalities, fewer and more fragile eggs, change in migration patterns;
- changes in weather, ice, and currents including wetter and windier conditions, changing frequency and intensity of storms, years of dirty ice, and decrease in ice thickness;
- plants that taste different, healing power affected, new locations of berries, early/late berry production, plants not existing anymore;
- contaminants from Russian nuclear power plants, dumping of waste; and
- need for testing for contaminants—key species and people; local training for collection, testing, monitoring stations.

A summary report of the Nome meeting is currently being compiled.

For more information, contact ANSC Executive Director Patricia Cochran (907/786-7704; fax 907/786-7739; anpac1@ uaa.alaska.edu).

Roseanne Waghiyi, Faye Ongtowasruk, Myrtle Johnson, Hannah Miller, Irene Merchant, and Ellen Richard discuss women's issues and concerns at the Northwest Alaska Regional Meeting on Traditional Knowledge and Radionuclides (photo by Amy Craver).

Science Education Program Engages Arctic Residents

At each of the three locations where the Department of Energy operates Atmospheric Radiation Measurement (ARM) facilities, federal funding also supports science education projects within the community. On Alaska's North Slope, the ARM Science Education and Training (ASET) Program awards small contracts (up to $2,000) under two programs to:

- community members, and
- school teachers.

Ilisagvik College has coordinated the implementation of two community-based science projects. In September 1998, resident stargazers inaugurated a scale-model solar system in Barrow, with dignitaries and schoolchildren in attendance. Enthusiastic planet hoppers from Ipalook Elementary School journeyed from planet to planet. By the time they reached Saturn, it was time for most of the space travelers to return to class. Only an intrepid group of 12 who had special permission from their captains (parents) completed the 3.6 billion mile (4,248 feet) journey to Pluto and back.

The second community grant funded three residents to investigate the reported presence of scattered stands and lone specimens of dwarf, cone-bearing conifer trees along the Chipp/Ikpikpuk River drainage. The investigators held a community outreach meeting to gather first-hand knowledge and information from residents of Barrow who had hunting camps in the targeted area. They then explored parts of the North Slope and visited several Iñupiat fishing camps. They found no evidence of living spruce trees; however, one tree that had been called to their attention, an alder (*Alnus crispa*) on the Chipp River, was considerably north of the published range for that species.

At another location, in an area that had obviously been recently flooded by spring snowmelt, the team collected a driftwood sample. It proved to be a small spruce tree, about four feet tall, that had grown approximately 30,900 years ago—during the middle of the last Ice Age. The 102 rings in the basal trunk, which is only 6.5 cm in diameter, corroborate that the tree grew in a cold climate.

Space travelers from Ipalook Elementary School in Barrow, Alaska reached Pluto (on Okpik Street between Momegana and Kiogak) for the first time on 2 September 1998 (photo by Craig George).

The three residents intend to continue their exploration of ancient flora of the North Slope with the support of other funding sources. They affirm that the ASET Program has provided an opportunity to make a lasting contribution to the scientific knowledge of the region.

Under the program which funds teachers, coordinated by ARCUS, the North Slope Borough School District has initiated Science Nights, in which a team of kindergarten teachers at Ipalook Elementary will bring together family members and students to explore themes such as:

- water, ice, snow, and colors;
- magnets, simple machines, physics, and chemistry; and
- changes in plants, eggs, and insects.

In another school project, second grade students at Ipalook Elementary will collect water samples, and small plant and animal specimens, at various aquatic sites and from the Chukchi Sea/Arctic Ocean to add to an existing aquarium at the school.

In Point Hope, Science in a Bag will team kindergartners with fourth graders to conduct simple experiments relating to their immediate environment. Students will also interview an Elder about traditional knowledge that relates to the western science.

*Barrow residents directed investigators to a seed-bearing alder (*Alnus crispa*) on the Chipp River, considerably north of the published range for this species (photo by Frank Willingham).*

For more information, contact Frank Willingham in Barrow, AK (907/852-9176; fax 907/852-2729; fwillingham@co.north-slope.ak.us) and Alison Carter at ARCUS.

K-12 Teachers Collaborate with Community Mentors

Partners in Science is an NSF-funded project bringing communities and schools together to teach science and math to students in the Fairbanks North Star Borough and Iditarod Area school districts of Alaska. The objectives of the grant are threefold:

- Train K-12 teachers to teach process-based math and science skills using hands-on methods aligned with state and nationally set standards for education—students learn to construct their own knowledge based on their experiences. They learn how to predict, hypothesize, observe, question, and infer, as well as how to design experiments, control variables, collect and analyze data, and draw conclusions.
- Teach students how to use technology as a research, investigative, and communication tool to support the curriculum—students learn how to produce multimedia presentations, create web pages, and communicate using e-mail. They also learn data-management and computation techniques.
- Convey the relevance of math and science in the real world—classrooms are partnered with science, engineering, and math professionals in the university community, private business, and government agencies. Together, they collaborate on writing unit plans that integrate the science partner's expertise into the existing curriculum. These mentors then interact with students in the classroom, on field trips, and in their workplace.

Students learn how technology can be used in meaningful ways. For example:

- elementary-school students compile data in spreadsheets;
- middle-school students use probe ware for measuring pH and temperature; and
- high-school students determine confidence intervals in population dynamics studies.

Partners in Science has focused on developing a flexible yet effective model for supporting teachers by providing training in:

- technology,
- collaborations,
- science processes, and
- assessment in and outside the classroom.

Teachers continue to work on new ways to measure what students are learning from their innovative teaching strategies. While teachers gain a better understanding of science and math, scientists are learning how to enhance their ability to reach the community and share their knowledge.

Since Partners in Science was first funded in 1995, the project has grown to include 11 home-schooled students in Fairbanks, 23 classrooms in 12 Fairbanks schools, and students in five remote villages in interior Alaska. More than 50 science, engineering, and math professionals have volunteered their time to work with students. It is expected that by the end of the project in the year 2000, most schools in Fairbanks and Iditarod areas will participate in Partners in Science.

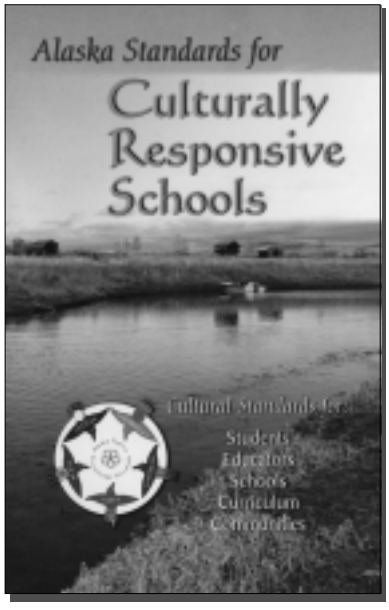
Partners in Science teachers and students have also participated in Global Learning and Observations to Benefit the Environment (GLOBE)—a worldwide science and education program, partially funded by NSF and NOAA, that coordinates students, teachers, and scientists to study and understand the global environment (see W*itness* Autumn 1997).

For more information, contact Martha Kopplin in Fairbanks, AK (907/452-2000 ext. 338; fax 907/451-6160; mkopplin@northstar.k12.ak.us), or visit the Partners in Science web site (http://www.northstar.k12.ak.us/NSFPIS/vsm.html).

Native Educators Adopt and Endorse Cultural Standards

At the Alaska Native Educators' Conference in February 1998, the Assembly of Alaska Native Educators adopted and endorsed the *Alaska Standards for Culturally Responsive Schools*. In June 1998, the Alaska State Board of Education adopted and endorsed the same standards. The Native educators who developed the standards intended that all forms of knowledge, ways of knowing, and world views be recognized as equally valid, adaptable, and complementary to one another in mutually beneficial ways. Each community can adapt the standards to fit local needs. Five areas are addressed:

- Cultural Standards for Students,
- Cultural Standards for Educators,
- Cultural Standards for Curriculum,
- Cultural Standards for Schools, and
- Cultural Standards for Communities.



The Cultural Standards complement the Content Standards of the Alaska Department of Education. The Cultural Standards along with curriculum resources to implement the kind of learning experiences they call for, may be found through the Alaska Native Knowledge Network (ANKN) web site (http://www.ankn.uaf.edu).

For more information, contact Sean Topkok in Fairbanks, AK (907/474-5897; fax 907/474-5615; fncst@uaf.edu or sean@arcus.org).

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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 with NSF; by DOE, AFN; 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 ideas for the Spring 1999 newsletter by 1 March 1999.

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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

February 10-14, 1999 The Human Role in Reindeer/Caribou Systems: Coping with Threats to Environmental Security in Northern Landscapes. Rovaniemi, Finland. Contact Deborah Robinson at Dartmouth College (603/646-1897; fax 603/646-1279; debo@dartmouth.edu; http://www.dartmouth.edu/~arctic/conf/index.html).

March 7-12, 1999 Gordon Research Conference on Polar Marine Science: Controls and Significance of Carbon Fluxes in Polar Seas. Ventura, California. Contact Louis Legendre at the Université Laval in Quebec, Canada (418/656-2339; fax 418/656-5788; louis.legendre@bio.ulaval.ca; http://www.grc.uri.edu/).

April 19-23, 1999 European Geophysical Society: Session on Land Surface Physical and Biological Processes in the Arctic. Den Haag, the Netherlands. Contact Colin Lloyd at the Institute of Hydrology in Wallingford, UK (+44/1491-692-330; fax +44/1491-692-424; c.lloyd@mail.nwl.ac.uk; http://www.copernicus.org/EGS/EGS.html).

April 20-23, 1999 International Conference on Monitoring of the Cryosphere. Pushchino, Moscow region, Russia. Contact Consolidated Scientific Council on Earth Cryology, Russian Academy of Sciences (+7/095-124-5422; fax: +7/095-135-6582; kriozem@glasnet.ru).

April 25-30, 1999 Arctic Science Summit Week. Tromsø, Norway. Contact Odd Rogne at the International Arctic Science Committee (IASC) Secretariat in Oslo, Norway (+47/22-57-37-37; fax +47/22-57-37-40; iasc@iasc.no; http://www.iasc.no).

May 14-16, 1999 Visions of the North, Voices of the North. Space for Dreams, Visions, and Plans: The North, Past, Present, and Future. Temagami, Ontario, Canada. Contact Jodi Sutherland at Nipissing University in Ontario (705/474-3461 ext. 4558; visions@mail.unipissing.ca).

May 31-June 4, 1999 American Geophysical Union (AGU) Spring Meeting. Boston, Massachusetts. Contact AGU in Washington, DC (800/966-2481; fax 202/328-0566; meetinginfo@kosmos.agu.org; http://earth.agu.org/meetings). ■

Check the ARCUS Web site Calendar (http://www.arcus.org) for more...

Publications

Future Directions for the National Science Foundation's Arctic Natural Sciences Program. 1998. Polar Research Board,Washington, DC. 70 pp. $15.00 (800/624-6242; order online at http://www.nap.edu; view online at http://www2.nas.edu/prb/; National Academy Press, 2101 Constitution Avenue NW, Lockbox 285, Washington, DC 20055).

Arctic Paleo-River Discharge (APARD)—A New Research Programme of the Arctic Ocean Science Board. Ruediger Stein, editor. 1998. Berichte zur Polarforschung/Reports on Polar Research, Vol. 279, 128 pp. Ruediger Stein, Chair of the APARD Core Group (+49/471-4831-576; fax +49/471-4831-580; rstein@awi-bremerhaven.de; http://www.awi-bremerhaven.de/GEO/Arctic/index.html).

Global Environmental Change—Research Pathways for the Next Decade. 1998. Committee on Global Change Research, Board on Sustainable Development, Policy Division. National Academy Press, Washington, DC. 69 pp. (800/624-6242 or 202/334-3313; http://www.nap.edu).

Sustainable Development in the Arctic: Lessons Learned and the Way Ahead. Proceedings of the Circumpolar Sustainable Development Conference, held in Whitehorse, Yukon Territory 12-14 May 1998, published as a special issue of The Northern Review (867/668-8773; fax 867/668-8828; agraham@yukoncollege.yk.ca; http://www.yukoncollege.yk.ca/review/).

Answers from the Ice Edge: The consequences of climate change on life in the Bering and Chukchi seas. Margie Ann Gibson and Sallie B. Schullinger, editors. 1998. Arctic Network and Greenpeace USA. 32 pp. (907/277-8234; fax 907/272-6519; http://www.greenpeace.org/~climate/arctic/reports). ■

A Note from the Director of the NSF Office of Polar Programs

These are exciting times for arctic science. This was abundantly clear during the arctic science sessions at the recent American Geophysical Union (AGU) meeting. We saw significant new data from both collaborative and individual investigator experiments, learned about increasingly comprehensive models of large-scale arctic physical phenomena, and enjoyed seeing the interplay between experiment and theory spark the development of new understandings.

My colleagues in the NSF Office of Polar Programs (OPP) take pride in the accomplishments of the arctic research community and the role we have played in helping to make them possible. Our sense that the community is on the leading edge of important new science derives partly from the fact that data pointing to important new phenomena in—and interdependencies among—the physical, biological, and social sciences are now becoming available from a wide variety of platforms, instruments, and projects. The vitality and enthusiasm of the arctic research community, so evident at the AGU sessions, will inevitably push these scientific frontiers forward. Increases in NSF's 1999 Arctic Science budget will allow exploration of forefront problems, previously inaccessible because they required extensive logistics support.

Logistics involves not only research platforms and instruments, but the means to link researchers with Arctic communities. Last year NSF requested a doubling of funding for arctic logistics, and the Congress, clearly recognizing the importance of the Arctic, more than doubled the requested increase.

The opportunities afforded by these developments also present challenges to NSF and to the community. Together, we need to strike balances between support for researchers and research platforms and between support for individual investigators and large groups. We must invest our logistics funds to gain the greatest scientific return over the long term while taking advantage of arising opportunities. Most importantly, we must work together to assure a continuing flow of new talent into our enterprise. It was obvious at the AGU meeting that the arctic science community has been successful at this, and I will strongly encourage NSF's contribution to those efforts.

I believe our excellent team in OPP will meet these challenges successfully. Dr. Tom Pyle, a geologist and oceanographer who heads our Arctic Sciences Section, came to NSF three years ago with extensive experience as a sea-going researcher and as a manager of large, complex scientific and logistics programs. His experience and ability will be invaluable in charting our course through this time of growth in arctic science. Dr. Maryellen Cameron, who joined OPP as Executive Officer last year, has an outstanding two-decade-long research career in academia. This, along with the savvy gained directing programs in NSF's Directorate for Geosciences, enable her to play a key role as we respond to our new opportunities.

I'm sure I speak for all of us at NSF in saying we are delighted to be part of the efforts to advance our knowledge of the Arctic. We look forward to working with the arctic community—researchers and residents—as we tackle these challenges together. The best is yet to come!

Physicist Karl A. Erb became the Director of NSF's Office of Polar Programs in November 1998. Erb has served as Senior Science Advisor at NSF since 1993.

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