Witness the ARCTIC

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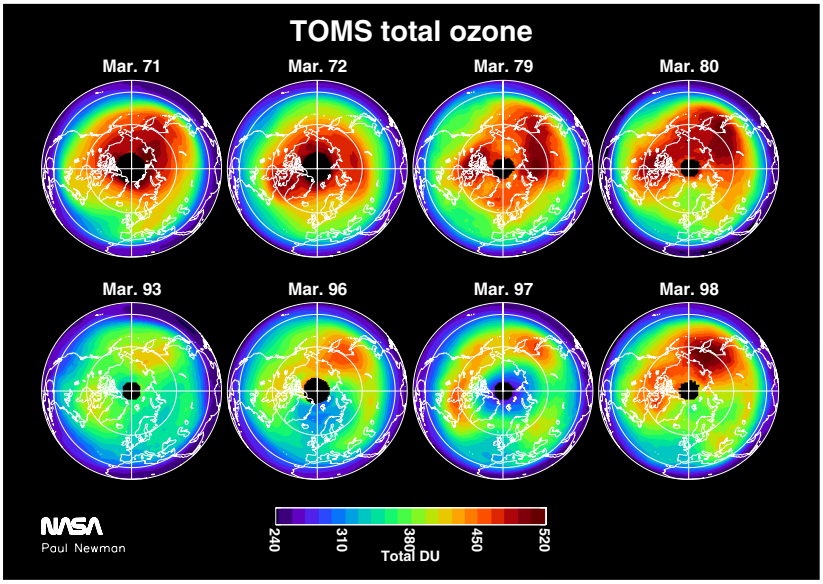
Ozone Losses Increase Possible UV Impacts in the Arctic

by Cathy Cahill and Elizabeth Weatherhead

Eskimo sunglasses made of wood, bone, or leather have been found in the archaeological assemblages of several arctic cultures. The narrow slats over the eyes protect the wearer from snowblindness. These widespread and ancient artifacts indicate that arctic indigenous people have known for generations about the harmful effects of ultraviolet (UV) radiation. Although the sun never rises far above the arctic horizon, reflections from ice and snow surfaces can allow damaging levels of UV to reach unprotected eyes and vertical surfaces such as faces, trees, and shrubs.

Ozone (O_3) in the stratosphere shields the Earth from much of the destructive UV radiation, but recent measurements in the Arctic show long-term decreases in the amount of ozone overhead—the total column ozone. Researchers have also noted a downward trend in total column ozone over the mid-latitude areas of the Northern Hemisphere in all seasons.

Before 1996, most studies of arctic ozone showed rather small impacts in comparison to the very large ozone losses recorded over Antarctica; during the winters of 1995–96 and 1996–97, however, researchers found evidence of major ozone losses over the Arctic (see figure). In addition, more frequent episodes of extremely low ozone levels, particularly during the springtime, have been reported. The interrelated issues of ozone depletion and UV exposure in the arctic environment present interesting research challenges and are likely to have serious human and ecosystem impacts.



Total Ozone Mapping Spectrometer (TOMS) satellite measurements indicate that total ozone amounts have decreased in the Arctic over the past two decades. The average total ozone in March 1997 is 21% lower than the pre-1990s March average (figure courtesy of NASA).

The Polar "Ozone Holes"

In 1985, a team of British investigators reported unusually low ozone levels over Antarctica. Research into the cause of the "ozone hole" implicated halocarbons generated by human activities, particularly chlorofluorocarbons (CFCs), in ozone depletion. The effects of CFCs have been concentrated above Antarctica, where polar stratospheric clouds (PSCs, see page 14) provide surfaces on which benign forms of chlorine are converted into reactive forms. These reactive forms of chlorine then rapidly destroy ozone in the presence of sunlight. In the Antarctic, the very cold conditions that allow PSCs to form persist through winter into spring, maintaining high levels of the reactive chlorine compounds as sunlight returns to the region. In addition, PSCs remove nitric acid and other nitrogenous compounds from the stratosphere that would otherwise moderate ozone depletion by reactive chlorine compounds.

Because the stratosphere over the Arctic isn't as cold as it is over the Antarctic, the formation of PSCs is more limited, and until recently, investigators assumed that a similar ozone hole was unlikely over the Arctic. Monitoring by a polar orbiting satellite, however, documented a decrease

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in total column ozone over the Arctic in 1993. Significant decreases continued, but with considerable interannual variability, in the Arctic into the 1990s.

The different dynamics of the arctic and Antarctic atmospheres also prevent the arctic ozone hole from reaching the magnitude of the Antarctic ozone hole. Because the southern hemisphere has very little topography, the flow of air around the Antarctic is primarily west to east. The polar vortex—the region of strong westerly winds that surrounds the Antarctic ozone hole—keeps the air over that continent from mixing with warmer air from mid-latitudes and causes the air in the center of the vortex to become cold enough for PSC formation. The topography of the Arctic generates more north to south air flow, promoting the mixing of warmer air into the polar air mass and introducing more of the nitrogen species that slow the destruction of ozone. The location of the polar vortex is determined by this flow. Warmer temperatures mean that PSCs rarely form within the arctic polar vortex during the period when the sun rises over the polar region. When PSCs are present at the "polar sunrise," as occurred in March 1997, the destruction of ozone accelerates, and a deeper ozone hole forms.

From November 1999 through March 2000, U.S., Canadian, European, Japanese, and Russian researchers collaborated on the biggest field campaign yet to measure ozone levels and changes in the arctic stratosphere. The NASA-sponsored SAGE III Ozone Loss and Validation Experiment (SOLVE) and the E.U.-sponsored Third European Stratospheric Experiment on Ozone (THESEO) made most of the measurements near Kiruna, Sweden. Additional data came from satellites and a network of high-latitude stations.

At the altitude where PSCs occur (10–25 km), ozone levels declined approximately 60% between January and mid-March 2000. In addition, PSCs persisted significantly longer in the winter of 1999–2000 than in previous winters. Several lines of evidence suggest that these results may be related to the effects of greenhouse gas emissions (*e.g.*, carbon dioxide, methane, nitrous oxide). Although accumulation of these gases low in the atmosphere warms the Earth's surface, their presence at higher stratospheric altitudes actually lowers temperatures and therefore enhances formation of PSCs.

Levels of UV Radiation in the Arctic

While stratospheric ozone fluctuations are now closely monitored, mesoscale fluctuations in UV radiation at the surface are less well understood. Accurately estimating variations in UV irradiance at the surface is particularly challenging in the Arctic, where UV levels are currently being monitored at approximately 20 locations.

How much UV reaches the surface is controlled by the amount of ozone in the atmosphere overhead, primarily in the stratosphere and to a lesser extent in the troposphere. At the low sun angles typical of high latitudes, sunlight traverses an extended path through the troposphere. UV irradiance also varies with local meteorological and surface physical conditions including cloud cover, aerosol extinction, and ground reflectivity or "albedo." For example, measurements and radiative transfer model values of UV exposure are dramatically enhanced where the surface has a high UV albedo (*e.g.*, snow) and in the presence of partial cloud cover; this combination sets up multiple reflections between clouds (with a very high UV albedo) and the surface. Aerosols (*e.g.*, particulate carbon and sulfur) also change the amount and relative proportion of direct and diffuse solar (including UV) radiation. Because UV levels are strongly affected by factors such as clouds and albedo, climate change alone will alter incident UV levels.

Impacts of UV Radiation on Humans and the Arctic Environment

The hypothesized impacts of UV radiation have not been thoroughly investigated in the Arctic. Elevated UV exposure has well-known effects on humans (*e.g.*, sunburn, snowblindness, immune suppression). Health problems related to long-term UV exposure include cataracts, skin cancer, and a number of related skin diseases.

Arctic ecosystems are particularly vulnerable to the effects of UV in spring, when ozone depletion is greatest as young organisms are developing. UV effects can affect individual species—particularly those at the base of the food web—as well as the relative abundance of species.

Certain phytoplankton species are especially sensitive to UV, and changes in their populations can ramify through marine ecosystems (see page 15). Cod, herring, pollock, salmonids, and other fish species spawn in shallow waters, where larvae can be fully exposed to ambient radiation. Elevated UV levels can damage these larvae, and a reduction in the number of larvae reaching maturity can have drastic effects on ecosystems and fisheries.

The few studies that have examined multiple impacts of other environmental stressors (*e.g.*, pollutants, climate change, and water availability) on arctic organisms and ecosystems indicate that the effects of these combined with increased UV radiation may be much more severe than the individual impacts. Many of these stressors (*e.g.*, climate change) are expected to remain significant or increase in the Arctic in the coming years.

For example, recent investigations show that UV radiation enhances the toxicity of certain chemical compounds, particularly those associated with oil spills or petroleum contamination. "Photo-enhanced toxicity" can seriously injure or kill sensitive species. Results show, for instance, that 100% of shellfish embryos that were exposed to three-day-old spill water under UV light were killed. By contrast, only 40% of the embryos exposed to the same water under fluorescent light (with low UV output) suffered fatalities.

Expectations for the Future

Although more than 160 nations subscribe to the 1987 Montreal Protocol and subsequent amendments mandating reductions of ozone-depleting chemicals, several models indicate that stratospheric ozone levels will decrease further over the Arctic for the next 10 to 20 years. Because ozone depletion in the Arctic is a function not only of man-made chemicals, but also of climate change, it is unclear whether or not, under current international legislation, arctic ozone levels will return to normal.

For more information, see relevant NASA (http://toms.gsfc.nasa.gov and http://see.gsfc.nasa.gov/edu/SEES), and NOAA web sites (www.ozonelayer.noaa.gov and www.arctic.noaa.gov/). ■

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ARCSS Committee Plans for 2002 All-Hands Meeting

In September 2000, NSF personnel met with representatives from the Arctic System Science (ARCSS) Program in Arlington, Virginia to share experiences and identify new opportunities for individual components and projects, and for the entire ARCSS Program as it moves into the more integrative, thematic approach outlined in *Toward Prediction of the Arctic System* (ARCUS 1998). The ARCSS Summit brought together representatives of the Arctic System Science (ARCSS) Committee (AC), component Science Steering Committees, Science Management Offices, Project Offices, and data management entities to discuss:

- integration among current ARCSS research efforts and with relevant NSF initiatives, including Biocomplexity in the Environment (see *Witness* Spring/Autumn 1999) and Information Technology Research;
- data management issues, including ways to recover older data and improve coordination in data sharing (see box);
- organizational structures;
- meeting coordination;
- education and outreach efforts; and
- emerging interagency and international programs pertinent to ARCSS research activities.

Summit participants will be working together to streamline communication and coordination on these issues, in part by increasing their use of Internet resources.

Following the ARCSS Summit, the AC met to advance planning for the ARCSS All-Hands meeting, tentatively scheduled for 20–23 February 2002 in Seattle. The AC discussed ways to evaluate ARCSS Program accomplishments, identify important questions that are not currently addressed in ARCSS, and articulate emerging research issues. The resulting report of ARCSS accomplishments and needs will guide the organization of the All-Hands meeting, with the goal of integrating results and questions across research components.

Working with the Science Steering Committees, Science Management Offices, and Project Offices, the AC is developing this progress report on the ARCSS Integration web site (www.arcus.org/arcss_allhands/). This evolving web site consists of:

- idea maps outlining the relationships among variables and key questions,
- status reports of progress on measuring and extrapolating variables, and
- a relational grants database linking specific ARCSS projects with variables.

For more information, see the ARCSS web site (www.nsf.gov/od/opp/arctic/system.htm) or contact Program Director Mike Ledbetter (703/292-8029; fax 703/292-9082; mledbett@nsf.gov) or AC Chair Jack Kruse (413/367-2240; fax 413/367-0092; jkruse@geo.umass.edu). ■

ARCSS Data Center Facilitates Access

Following a 1993 recommendation of the ARCSS Committee, a central ARCSS Data Coordination Center (ADCC) was established to oversee the submission, archives, access, and exchange of data generated by ARCSS-funded research. The ADCC has been located at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado, since 1994 (see *Witness* Spring 2000).

Principal investigators (PIs) funded through the ARCSS Program develop a data management plan in collaboration with the ADCC and retain exclusive use of their data for one year from its collection. After one year, the ADCC releases the data to other ARCSS investigators. Two years after collection, data become available to all other science users through the ADCC.

The Joint Office for Science Support (JOSS), at the University Corporation for Atmospheric Research, complements the ADCC by coordinating data collection and exchange efforts for selected ARCSS field programs, including SHEBA (see page 7), ATLAS (see page 5), and NATEX (see page 6), during and immediately after the field activities. JOSS (www.joss.ucar.edu/arcss) provides interim project data archive access and coordinates the transfer of data to the final archive at ADCC.

In recent months, ADCC staff have processed a backlog of more than 50 pending Directory Interchange Format (DIF) for ARCSS data sets, allowing the data to be accepted for publication on the Global Change Master Directory web site (http://gcmd.gsfc.nasa.gov), administered by NASA. Other new developments at the ADCC include:

- upgrades for the ADCC web and data server hardware that will enhance data retrieval and on-line data storage capacity,
- a redesigned searchable on-line data catalog, and
- a searchable ARCSS Address Book, with information on over 400 ARCSS investigators.

Data sets recently added to the ADCC archive include:

- SCICEX hydrographic data (see *Witness* Spring 1998),
- Previously classified optical band reconnaissance imagery of the SHEBA field site (see page 7),
- R-ARCTICNET, a regional hydrological data network from around the Arctic (available on CD-ROM).

In addition, the ADCC staff is exploring ways to use Geographic Information Systems (GIS, see page 17) to:

- georeference archived data sets,
- visualize data set locations and patterns,
- spatially combine and subset data sets, and
- integrate multiple themes inherent in the data.

For more information, see the ADCC web site (http://arcss.colorado.edu), or contact ADCC Manager Rudy Dichtl in Boulder, CO (303/492-5532; fax 303/492-2468; dichtl@kryos.colorado.edu). ■

International Collaboration in the Paleosciences: The Beringian Connection

A long history of bilateral collaboration between Russia and the U.S. in the paleosciences derives from a shared interest in the history of the Beringian subcontinent. Scientists working on both sides of the Bering Strait took immediate advantage of the changing politics of the late 1980s and early 1990s to develop joint projects. An earlier component of the ARCSS Program, Paleoclimates from Arctic Lakes and Estuaries (PALE; see *Witness* Spring 1998), was involved from its inception in cooperative studies with Russian Quaternary scientists, including work on the ecosystem, climate, and glacial histories of northeastern Siberia (western Beringia). These investigations have contributed both formally and informally to several international programs, such as BIOME 6000 (the Global Paleovegetation Project, an IGBP effort) and its arctic component PAIN (a joint European-Russian-U.S. research project co-funded by Paleoenvironmental Arctic Science [PARCS]), and CircumArctic Paleo-Environments (CAPE; the circumarctic element of IGBP-PAGES; see *Witness* Autumn 1998).

All of these efforts seek to achieve an integrated circumarctic data set, which is vital to conceptual and numerical modeling of both climate change and the likely responses of terrestrial and marine systems. Three projects are currently underway in northeastern Siberia, funded through the NSF Earth System History (ESH) Program under the PARCS or RAISE (see page 5) initiatives.

Lake El'gygytgyn (Lake E)

In 1998, Russian, U.S., and German collaborators retrieved the longest lacustrine sediment record in the Arctic to date (400,000 years) from Lake El'gygytgyn. Lake E lies in an impact crater in northeastern Siberia, outside glacial limits in uplands above present treeline. Initial seismic data indicate approximately 370 m of sediment in the basin, suggesting a possible Plio-Pleistocene age.

Field studies in 2000 have provided data important to the interpretation of the 1998 core. Detailed studies of the sedimentology and modern and downcore studies of the pollen, diatoms, and geochemistry are in progress. The pollen record clearly indicates interglacial and full-glacial extremes, but also shows periods (*e.g.*, mid-late Pleistocene) of intermediate conditions. Further, various time-series suggest that there may be correlation with the Greenland Ice Sheet Project 2 (GISP2) ice-core data (see *Witness* Spring 1997), and hence possible teleconnections with the North Atlantic.

The pollen record of the last interglacial maximum, considered to be a particularly warm period in the Arctic, is not characterized by tree pollen, suggesting that summer conditions were relatively cool in north-central Chukotka.

Participants: J. Brigham-Grette, M. Nolan, and C. Cosby (U.S.); O. Glushkova, P. Minyuk, A. Smirnov, and G. Federov (Russia); F. Niessen, B. Wagner, C. Kopsch, and M. Apfelbaum (Germany).

Paleoclimate and Paleovegetation of Western Beringia

This U.S.-Russia collaborative project examines the spatial and temporal patterns of change in late Quaternary vegetation and climates with the aim of understanding the evolution of the modern vegetation-climate system and the regional-to-global scale mechanisms responsible for past climate changes. An important contribution of this project is the integration of data from Russia and eastern Beringia (Alaska). At this larger scale, there are clearly heterogeneous patterns in regional climates and in the response of terrestrial ecosystems across Beringia to hemispheric or global-scale climatic change during the past 21,000 years. Such regional variations suggest that we should expect neither a uniform response across the Arctic to major climate forcings, nor even similarity within a single watershed, given the huge extent of many Beringian river systems.

Another key finding is that during the late Pleistocene (Karginskii) interstade—the interglacial period *ca.* 50,000–30,000 before present—rapid fluctuations between tundra and forest occurred in western Beringia, suggesting that the interval was characterized by climatic "flickering."

Although the chronology is currently not adequate to make a definite correlation with rapid climate change, these results and those from Lake E imply that there have been similar rapid climate changes in the North Pacific. This work has been supported by the Russian Foundation for Fundamental Research, PALE/PARCS, and the National Geographic Society.

Participants: P.M. Anderson, L. Brubaker, C. Mock, and P. Bartlein (U.S.); A. Lozhkin, O. Glushkova, O. Grinenko, A. Kotov, and M. Trumpe (Russia).

The Glacial and Sea Level History of Wrangel Island, Northeast Siberia

The presence of a marine-based East Siberian Ice Sheet (ESIS) during the late Quaternary is controversial, but such an ice sheet has been included in the ice-cover data used in many paleoclimate model simulations of the last glacial maximum. Modeling sponsored by PALE/PARCS confirms that an ESIS would have had a significant effect on downwind climate (*e.g.*, in the area of the Bering Land Bridge). To date, there has been little investigation of glacial geology and sea-level history along the proposed ice sheet's eastern margin that would confirm or refute its past existence. Detailed field investigations will provide the first numerical chronology of glaciation and sea-level fluctuations. During the 2000 field season, researchers collected more than 85 samples for radiocarbon, amino acid, cosmogenic isotopes, pollen, and micro- and macrofaunal identification. Marine sediment, up to 40 m above sea level and 15 km inland, was recognized on the northern tundra and may correlate with the northwestern Alaska sea-level transgressions.

Participants: L. Gualtieri, P.M. Anderson, J. Brigham-Grette (U.S.), S. Vartanyan (Russia).

For more information, see the PARCS web site (www.ngdc.noaa.gov/paleo/parcs/index.html), or contact Mary Edwards in Trondheim, Norway (+47/7359-1915; fax +47/7359-1878; mary.edwards@svt.ntnu.no) or Mike Retelle in Lewiston, ME (207/786-6155; fax 207/786-8334; mretelle@bates.edu).

RAISE Takes Steps to Improve U.S.-Russian Collaboration

The annual meeting of the Russian-American Initiative on Shelf-Land Environments in the Arctic (RAISE) International Steering Committee and Principal Investigators convened in November 2000 in Seattle, Washington. The objectives of the meeting were:

- to provide information on existing and planned U.S.-Russian collaborative research in the Russian Arctic to the Ministry for Industry, Science, and Technologies and the Academy of Sciences, agencies that empower arctic science in Russia;
- to provide information necessary for American scientists to gain permission for cooperative research in the Russian Arctic, arrange logistics, and address safety and financial requirements. The goal is to establish clear protocols for American and Russian scientists to ease access, logistics, and transport of samples for joint scientific programs; and
- to take stock of the achievements and science directions of RAISE-funded scientists, evaluating the potential to integrate their research.

The chairs of the Steering Committees of the major ARCSS projects were invited, and Terry Chapin (ATLAS/LAII; see box this page), Jackie Grebmeier (SBI; see page 9), and James Morison (SEARCH; see page 8) were able to attend the meeting. Russian participants were Vasily Zhivago (Head of the Division of Science of Earth and the World Ocean; Ministry of Industry, Science, and Technologies of the Russian Federation); Vladimir Yakukhin (Chief Expert of the Arctic, Antarctic and Marine Department, of Roshydromet); and Boris Levin (Earth Sciences Department Chief of the Russian Foundation for Basic Research). Marianna Voevodskaya provided information on the programs of the U.S. Civilian Research and Development Foundation.

Lee Cooper was elected to serve as the new Chair of the U.S. part of the RAISE International Steering Committee. Other U.S. members are Steve Forman, Sirpa Hakkinen, Bruce Peterson, Andrey Proshutinsky, Vladimir Romanovsky, and Larry Smith. Russian members of the Committee are Igor Melnikov (Co-Chair), Sergey Pryamikov (Co-Chair), Vladimir Pitulko, Nikolai Romanovskiy, and Igor Semiletov. Two positions are still vacant.

Russian members of the Steering Committee are organizing the ECOARCTIC-2001 international expedition to the western Russian Arctic in August 2001 aboard the polar research vessel *Akademik Fedorov*. Subsequent expeditions are planned for 2002 and 2003. Interested institutions and scientists are invited to participate (see www.aari.nw.ru/ecoarctic2001/program.html).

For more information about RAISE, contact Lee Cooper in Knoxville, TN (865/974-2990; fax 865/974-3067; lcooper1@utk.edu) or Vladimir Romanovsky in Fairbanks, AK (907/474-7459; fax 907/474-7290; ffver@uaf.edu).

LAII Management Emphasizes Synthesis

An important goal of the Land Atmosphere Ice Interactions (LAII) Program Science Management Office (SMO) is to promote cross-synthesis among its extended family of arctic research projects. The current major LAII projects are:

- Arctic Transitions in the Land-Atmosphere System (ATLAS), and
- the North American portion of the International Tundra Experiment (ITEX; see page 6).

The LAII SMO will now assist in the management of the Russian-American Initiative on Shelf-Land Environments in the Arctic (RAISE; see article this page) as well as smaller terrestrial projects that have been funded independently of these larger programs to investigate a range of topics relevant to LAII goals (see www.laii.uaf.edu).

The next LAII All-Hands meeting will be held in Salt Lake City, Utah 14–17 November 2001. This meeting will coincide with a meeting of the ARCSS Ocean-Atmosphere-Ice Interactions Program (see page 7), so that researchers from both programs can participate in joint discussions about topics such as land-ocean hydrologic linkages. The first two days of the LAII meeting will be devoted to separate meetings of ATLAS, ITEX, and RAISE researchers; scientists from independently funded projects will join one of these groups. During the second half of the four-day meeting, LAII researchers will meet in plenary to hear and discuss synthesis reports from each group and to plan for the future, including:

- preparation for the Arctic System Science (ARCSS) All-Hands meeting scheduled for February 2002,
- planning for LAII synthesis, and
- planning for the next edition of the *LAII Science Plan*.

As the ARCSS Program shifts from a series of research components and projects to a more thematic approach (see page 3), the arctic research community will be addressing broader, more interdisciplinary issues, such as:

- biogeochemical and hydrologic feedbacks to the climate system,
- arctic-global connections,
- detection of change in the Arctic, and
- human interactions with the arctic system.

The November 2001 LAII All-Hands meeting will be an important opportunity for LAII scientists to discuss:

- how best to integrate and synthesize current research funded under LAII, and
- how terrestrial-atmospheric research can best contribute to Arctic System Science in the future.

For more information, contact Patricia A. Anderson in Fairbanks, AK (907/474-5415; fax 907/474-6722; patricia@iarc.uaf.edu; www.cgc.uaf.edu).

ITEX Builds on First Decade, Renews Direction

The International Tundra Experiment (ITEX) held its tenth All-Scientists Workshop, *ITEX in the New Millennium,* in Abisko, Swedish Lapland in September 2000. Following progress reports and posters describing ten years of ITEX research, participants took the opportunity to assess the need and nature of continuing research directions. They addressed current issues including experimental methods, database management and data sharing, scaling up, and the relationship between ITEX and other international initiatives and funding.

The plenary coordination of these sessions, led by ITEX Chair Philip Wookey (University of Uppsala), resulted in the Abisko Accord (see box). This accord builds on the ITEX Resolution from the founding meeting of ITEX held in Michigan in December 1990 (*Arctic and Alpine Research* 23[1]:125). The new accord is seen as a blueprint and a platform for future developments in the program.

The Abisko workshop was organized by a committee chaired by Ulf Molau (Göteborg University) and hosted by Terry Callaghan, Director of the Abisko Scientific Research Station.

While at Abisko, the U.S. members of ITEX met with Program Officers Tom Pyle and Michael Ledbetter from the NSF Office of Polar Programs to discuss progress within NATEX (North American Tundra Experiment) and to stress the need for archiving and sharing of data. NATEX held an ITEX synthesis workshop on plant community change in Boulder, Colorado in February 2001. For more information, see www.lter.uaf.edu/~becru/ITEX_Workshop_Welcome.html.

The 11th meeting of ITEX is scheduled for 28 September–1 October 2001 at Finse in alpine Norway. Ørjan Totland (Agricultural University of Norway) will host the meeting. For more information, see www.nlh.no/ibn/itex2001.

For more information about ITEX, see the web sites at the Secretariat at the Danish Polar Center (www.dpc.dk/NSNITEX/Start.html) and Göteborg University (www.systbot. gu.se/research/ITEX/itex.html). ■

Abisko Accord

(25 September 2000)

Further to discussions at the 10th ITEX meeting in Abisko, Swedish Lapland, between 23-25 September 2000, the meeting participants hereby reaffirm our commitment to the continuation and further development of the International Tundra Experiment (ITEX).

We agree that:

- The original ITEX Resolution drafted at the Kellogg Biological Station, Michigan State University, USA, on 4 December 1990 remains valid.
- This Accord therefore supplements and extends (but does not replace) the 1990 Resolution.
- ITEX is a working, viable, and dynamic international program.
- We will regularly re-evaluate the methods and goals of ITEX relative to current research developments and, where necessary, respond by modifying our activities accordingly.
- The scope of ITEX includes the tundra biome in general; it is not, therefore, restricted to arctic tundra but rightfully incorporates alpine and Antarctic tundras (*inter alia* the connection between ITEX and Regional Sensitivity to Climate Change in Antarctic Terrestrial and Limnetic Ecosystems (RiSCC).

Key facets of ITEX after ten years include:

- the successful development and maintenance of an international network of research sites in the tundra biome;
- the continued use of common experiments and protocols to improve understanding of global change impacts upon biological processes in tundra ecosystems;
- the training and international exchange of young researchers (graduate and undergraduate);
- a continued focus upon biological responses to environment at the level of the species and functional group;
- increasing emphasis upon population and community dynamics and medium- to longer-term system responses to change;
- increasing emphasis upon meta-analytical techniques, development of databases, and ecological modelling; and
- initiation of advisory activities in relation to international monitoring networks and scientific agencies (such as Conservation of Arctic Flora and Fauna [CAFF] of the Arctic Council [see *Witness* Spring/Autumn 1999] and the Newsletter of the Global Change in Terrestrial Ecosystems Core Project of IGBP (International Geosphere-Biosphere Programme [GCTE News]).

We are committed to:

- retaining a flexible approach that allows for development of new research initiatives, but with a core of manipulation and monitoring activities at individual sites;
- exploring the relationship between species-specific responses to environmental change, and how these are modulated by community and site characteristics, and feedbacks on further change;
- evaluating ITEX investigations within the context of broader spatial scales, longer temporal scales, and higher trophic levels;
- exploring pragmatic approaches to long-term monitoring and measurement, designed to quantify and distinguish between (i) inter-annual variability in system state, and (ii) longer-term directional changes;
- development and implementation of an appropriate protocol for the exchange of ITEX data among participants and the broader community;
- development of thematic groups focused upon specific aspects of climate change impacts;
- development of procedures for sample collection, sharing and/or common analysis;
- regular meetings (yearly or biennial) with specific themes and progress reports;
- dissemination of data and research results to the broader community;
- development of a strong and active Steering Committee that will provide leadership and continuity and that will conduct business according to a set of by-laws. ■

SHEBA Phase III Applies Field Data to Climate Models

In 1997–98, the Surface Heat Budget of the Arctic Ocean (SHEBA) conducted a year-long field experiment in the Arctic Ocean, resulting in a comprehensive data set that documents the upper ocean, sea ice, and atmosphere in a single column of the arctic climate system (see *Witness* Spring 2000). The goals of SHEBA are:

- to improve simulations of the Arctic in global climate models, and
- to improve our capability to monitor arctic climate using satellite remote-sensing data.

Phase II of SHEBA (1997–2000) saw the establishment and initial analysis of the field data. These data are available from the Joint Office for Science Support (JOSS; see page 3).

Publications resulting from SHEBA Phases I and II have appeared in the *Journal of Geophysical Research*, *EOS*, *Journal of Climate*, and the *Bulletin of the American Meteorological Society*. Manuscripts are now under review for a special volume of the *Journal of Geophysical Research-Oceans* that emphasizes SHEBA Phase II studies. Publication is planned for 2001.

The final phase of SHEBA began in Spring 2000. Phase III consists of 17 multi-investigator projects, focused on using the SHEBA data sets to study climate feedback processes and mechanisms in the Arctic, and applying the new knowledge to improve global climate models and climate monitoring by satellite remote sensing.

Phase III principal investigators (PIs) met at the National Center for Atmospheric Research in Boulder, Colorado in October 2000 to consider how the 17 projects and the existing data sets would achieve the overall goals of SHEBA. The PIs identified opportunities to accelerate progress and enhance results, including:

- create integrated data sets to support modeling experiments;
- seek additional data sets to fill a few gaps that have been identified;
- collaborate on model intercomparison studies and single-column (ocean-atmosphere-ice) model experiments over the annual cycle;
- collaborate on case studies drawn from the SHEBA experimental period (*e.g.*, the late-July storm event, cloud/boundary layer/radiation case studies using atmospheric models);
- continue and enhance PIs' efforts to serve as ambassadors to community climate modeling programs, such as the Community Climate System Model (CCSM) Project and the Arctic Regional Model Intercomparison Project (ARCMIP), to assure that SHEBA results are incorporated into the leading climate models; and
- develop collaborative papers for publication.

SHEBA PIs will meet again in early Summer 2001 in Boulder. SHEBA data have already made important contributions to global models. The sea-ice and atmosphere components of the CCSM have been evaluated and modified partly on the basis of SHEBA data, through the activities of the CCSM Polar Climate Working Group (see www.ccsm.ucar.edu). SHEBA data are also being used in the GEWEX Cloud System Study (see http://paos.colorado. edu/~curryja/wg5/home.html) and the ARCMIP (see http://cires.colorado.edu/lynch/arcmip).

For additional information, see the SHEBA web site (http://sheba.apl.washington. edu) or contact Richard Moritz in Seattle, WA (206/543-8023; fax 206/616-3142; dickm@apl.washington.edu). ■

OAII

In the past six months, OAII has scheduled the next All-Hands meeting, updated the OAII *Prospectus and Science Plan*, and made considerable progress on the Shelf-Basin Interactions (SBI) project (see page 9), the Surface Heat Budget of the Arctic Ocean (SHEBA) project (see article this page), and the Study of Environmental Change (SEARCH; see page 8).

SEARCH has grown to become a trans-ARCSS program and is developing into a large interagency international program. The SEARCH *Science Plan* is available, and several workshops are scheduled, including two that have been funded as incubation activities under the NSF Biocomplexity Initiative.

The updated OAII *Prospectus and Science Plan* is undergoing final editing. It is posted on the OAII web site to allow for community input before publication in early 2001. The web-site version of the report will continue to be updated as comments are received.

In October 2000, the OAII Science Steering Committee (SSC) met and agreed:

- to increase outreach activities; and
- to show how aspects of OAII research could fit under NSF's Biocomplexity and Information Technology initiatives.

The next OAII All-Hands meeting will take place 14–16 November 2001 in Salt Lake City, Utah. The agenda includes:

- summaries of recent results of OAII and companion programs; and
- identification of gaps in knowledge of how the arctic system responds to and influences climate change.

This meeting will also provide information for the 2002 ARCSS-wide All-Hands meeting. Both meetings will play a crucial role in reorganizing the structure of the ARCSS Program to accommodate its growth with attention to cross-cutting thematic research questions.

New members of the OAII SSC are Hajo Eicken, Robie Macdonald, and Tom Delworth, replacing Don Perovich, Tom Weingartner, and Andrew Weaver.

For more information, see the OAII web site (http://arcss-oaii.hpl.umces.edu), or contact Lou Codispoti or Jane Hawkey at the University of Maryland's Horn Point Laboratory (410/221-8479; fax 410/221-8490; codispot@hpl.umces.edu, hawkey @hpl.umces.edu). ■

SEARCH Research Opportunities Emerging

Development of the Study of Environmental Arctic Change (SEARCH) Program has continued on several fronts, including completion of the SEARCH *Science Plan*, preparation of interagency plans for SEARCH-related activities in 2001 and 2002, and development of relations between SEARCH and international and national programs.

SSC Activities

The SEARCH Science Steering Committee (SSC) met in July and December 2000 to make organizational changes and work on the *Science Plan* (see http://psc.apl.washington.edu/search/index.html). The SEARCH SSC membership now includes Vera Alexander (University of Alaska), Lou Codispoti (Horn Point Laboratory, Maryland), Tom Delworth (Geophysical Fluid Dynamics Laboratory, New Jersey), Bob Dickson (Centre for Environment, Fisheries, and Aquaculture Science, U.K.), Hajo Eicken (University of Alaska), Jackie Grebmeier (University of Tennessee), Jack Kruse (University of Massachusetts and University of Alaska), Jamie Morison (University of Washington), Jim Overland (Pacific Marine Environmental Laboratory, Washington), Jonathan Overpeck (University of Arizona), Peter Schlosser (Lamont-Doherty Earth Observatory, New York), Mark Serreze (University of Colorado), and John Walsh (University of Illinois).

Interagency Working Group

The SEARCH Interagency Working Group (IWG; see *Witness* Spring 2000) has been meeting monthly to develop cooperative agency arrangements for SEARCH research in FY 2001 and 2002. Because overall budgets are essentially fixed for these years, the agreements focus on coordinating existing research activities, with some funds earmarked for new planning activities. The IWG meeting in January 2000 focused on an interagency plan for new research in 2003. ARCUS published a SEARCH brochure for the IWG.

Links to National Programs/Initiatives

The U.S. component of the Climate Variability and Predictability Program (CLIVAR) has formally approved making SEARCH an element of CLIVAR. A CLIVAR-SEARCH Working Group is being formed, and a description of SEARCH has been included in the CLIVAR implementation plan.

An NSF award for the SEARCH Biocomplexity Incubation activity will aid SEARCH planning efforts in the areas of biology and human dimensions. A steering group met in January 2001 to plan the first of two workshops focusing on relationships among the changing arctic environment, ecosystems, and society. In addition to members of the SEARCH SSC, the steering group includes Terry Chapin (University of Alaska), Glen Cota (Old Dominion University), and Pat Wheeler (Oregon State University).

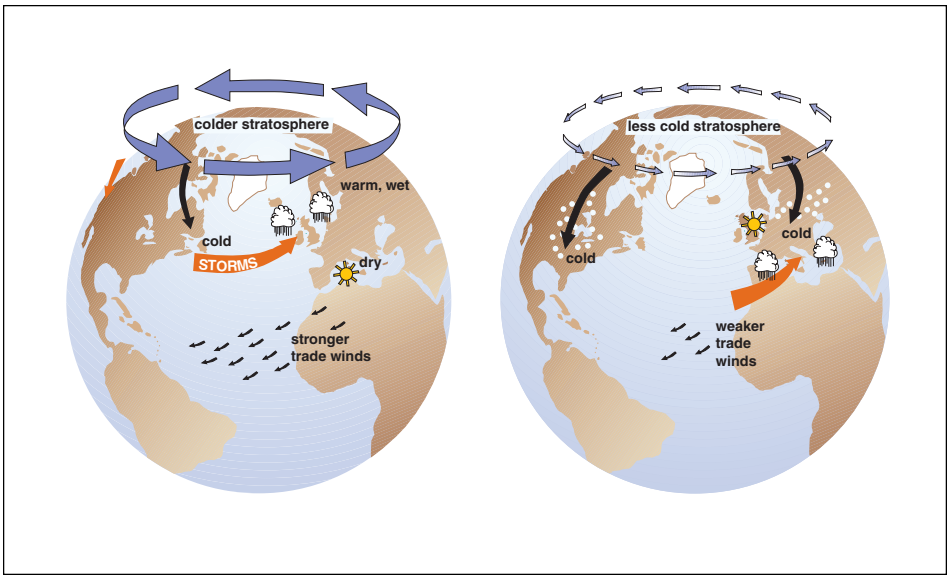
Links to International Programs

Mark Serreze and Jamie Morison attended the September 2000 Arctic Hydrology workshop in Santa Barbara, California. The hydrology research plan emerging from this effort will complement SEARCH activities and provided material for the SEARCH *Science Plan*.

Several members of the SEARCH SSC and IWG attended the Arctic and Subarctic Ocean Fluxes (ASOF; see page 23) meeting in Norway in September 2000. ASOF efforts to monitor the fluxes through the major straits connecting the Arctic Ocean to the Atlantic and Pacific will contribute to SEARCH objectives related to understanding the controls on global thermohaline circulation.

In October 2000, Mark Serreze and Jamie Morison attended the Arctic Climate System/Climate in the Cryosphere (ACSYS/CliC) meeting in Kiel, Germany. ACSYS/CliC, backed by the World Climate Research Program, shares many goals with SEARCH, *vis a vis* the relation of the arctic environment to global change. While ACSYS/CliC is more general, it has a focus on the cryosphere and shares with SEARCH the need for long-term observations. SEARCH and ACSYS/CliC have agreed to establish an agreement to cooperate to avoid duplication of effort, while ensuring that the important facets of change in the Arctic are observed.

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



The Arctic Oscillation (AO) is the dominant pattern of atmospheric variability of the Northern Hemisphere. The left panel shows conditions associated with a high AO index, while the right shows the low index state. The AO index, which is highly correlated with surface air temperatures over the hemisphere, has been rising since the mid-1960s. Developing a further understanding of the AO as an arctic-wide phenomenon of decadal and/or global change is a major objective of the SEARCH program (figures courtesy of D. Thompson, M. Wallace, and K. Dewar).

SBI Phase I Data will Guide Phase II Field Work

The overall goal of the Western Arctic Shelf-Basin Interactions (SBI) project is to improve understanding of the physical and biogeochemical connections among the arctic shelves, slopes, and deep basins that could be influenced by global change.

SBI is moving into the final year of retrospective, modeling, and opportunistic sampling studies in the Chukchi and Beaufort seas. Results of SBI Phase I that will direct the Phase II field effort include:

- Spatial and temporal gradients in water column chlorophyll, nutrients, zooplankton, and benthic fauna indicate seasonally high standing stock values in spatially concentrated regions which may be impacted by varying processes associated with changing ice conditions.
- Identified sources and pathways for the transfer of organic matter from the western shelves to arctic basins include dissolved organic carbon from rivers, transformations of shelf-derived carbon by sediments and subsequent release into halocline waters, and shelf-derived particulate and dissolved organic carbon advected from shelf to basin.
- Likely key physical processes for shelf-basin exchange include local transport across the shelf, eddies, currents along the slope boundary, and transport through canyons.
- Paleoceanographic studies of cores indicate significant variability in carbon productivity and deposition at the outer slope region during the past 1,000 to 10,000 years, indicating changes in seawater and pack-ice conditions.
- Modeling indicates that dense water is carried primarily by small-scale eddies, steered by currents and bathymetry, across the shelf and slope of the Chukchi Sea. Models also suggest past and future shifts in ice/ocean conditions coincident with varying sea-level pressure associated with Arctic Oscillation events.
- The observed interannual variability in monthly mean winter density in the Bering Strait corresponds to a variability of the equilibrium depth of the Pacific water within the Arctic Ocean halocline of 80 m.

SBI Principal Investigators convened an open meeting in February 2001 in Albuquerque, New Mexico (see http://utk-biogw.bio.utk.edu/SBI.nsf), just before the American Society of Limnology and Oceanography meeting.

More than 70 people attended the second international SBI pan-arctic meeting in Callaway Gardens, Georgia, in November 2000. The meeting included:

- short science presentations of topics relevant to the overall goals of SBI;
- group discussion on cross-cutting themes for pan-arctic SBI issues and logistical needs; and
- discussion of current and future national and international SBI studies.

The meeting agenda and abstracts are posted on the SBI web site.

An Announcement of Opportunity (AO) for SBI Phase II field work on the outer shelf-slope of the Chukchi and Beaufort seas as well as the Bering Strait region was released in early 2001 (see figure and www.nsf.gov/cgi-bin/getpub?nsf0178). Proposals are due 30 May 2001.

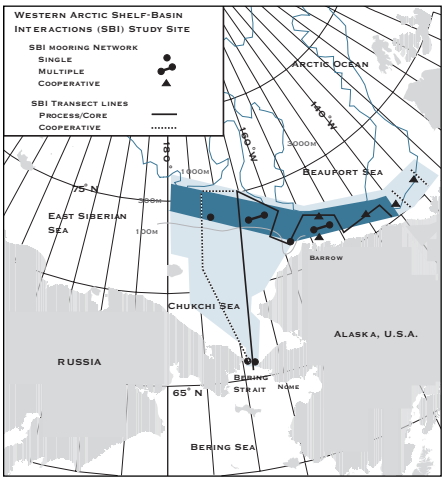
Through integrated field and modeling efforts, Phase II will investigate the effects of global change on production, cycling, and shelf-slope exchange of biogenic matter, both seasonally and spatially. Five study objectives include understanding:

- the relative importance of various physical processes in the transport, transformation, and fate of biogenic matter, water masses, and tracers through the Bering Strait, across the shelf, and into the basin interior;
- physical processes and circulation anomalies on the shelf and/or slope that support high local concentrations of benthic and pelagic biota;
- water column and ice primary productivity in relation to the biomass and diversity of primary and secondary consumers in both the water column and benthos;
- the relative importance of top-down *vs.* bottom-up controls in regulating pelagic-benthic coupling, biotic complexity, and the partitioning of carbon between lower and higher trophic levels; and
- model predictions of potential changes in the food web that would result from ice cover and hydrographic changes affecting remineralization of organic matter, changes in recycling efficiency, and biogeochemical fluxes.

The SBI Phase II *Field Implementation Plan* outlines a combination of time-series moorings and seasonal hydrobiochemical surveys in support of the major seasonal biogeochemical, biological, and physical process studies, as well as modeling efforts, at appropriate time and space scales. Mesoscale, interdisciplinary survey, and process studies conducted across the shelf and slope regions during various seasons will be critical for understanding biogeochemical and physical processes occurring over time and space scales relevant to interpreting annual and interannual changes in the system.

The SBI II field program will include four process-oriented cruises in May/June and July/August 2002 and 2004. Alternate years, 2003 and 2005, will include reduced field programs for critical time-dependent measurements essential for interpreting processes relevant to shelf-basin interactions and ecosystem response. Annual mooring turn-around/survey cruises will occur in September.

For more information, see the SBI web site (http://utk-biogw.bio.utk.edu/SBI.nsf), or contact SBI Project Office Director Jackie Grebmeier in Knoxville, TN (865/974-2592; fax 865/974-3067; jgreb@utkux.utk.edu).



Dark blue indicates the SBI intense study area, with upstream/downstream regions in lighter blue (figure courtesy SBI project office).

Tree Rings Improve Dating of Inuit Sites in Labrador

Archaeologists who are studying the convergence of environment, history, and culture among the Labrador Inuit are working to overcome the limitations of data sets with widely different time scales. An increased awareness of the richness of Labrador's detailed ethnohistorical records, and recent advances that have yielded North Atlantic paleoenvironmental records at an annual resolution, now afford archaeologists the opportunity to use both ecological and social data on the same time scale. Research in Labrador, however, is severely hampered by the paucity of well-dated archaeological sites.

Archaeologists from the Arctic Studies Center at Bowdoin College and dendrochronologists from the Tree Ring Laboratory (TRL) at the Lamont-Doherty Earth Observatory are now collaborating to:

- improve the ability of archaeologists to date their sites, and
- extend the paleoenvironmental record.

The researchers are applying the science of tree-ring analysis to the dating of wood from Inuit sod house sites in Labrador.

In Summer 2000, archaeologists and dendrochronologists, working together in the field, returned with a profoundly altered and enriched sense of the landscape and its history. Archaeological work and conversations with Inuit and settlers also yielded insights into ways that humans have used wood along the coast, and how intensive harvesting may have affected the northern range of the tree line.

More than 80 samples were collected from living trees (by coring), dead trees and stumps, and sod house walls. Analysis of disks from 25 trees at the DEG site, in inner Napaktok Bay (11 samples thus far) has extended TRL's records for the region back more than 100 years to AD 1459. Nearly all of the trees analyzed to date died between 1870 and 1890.

The archaeologists' work includes surveying the ethnohistorical literature for descriptions of intensive wood harvesting. This research is calling attention to the potential value of documenting wood-collecting practices in Nain, a Labrador community where harvesting of wood is still an important seasonal activity.

This collaborative research is co-sponsored by the NSF Arctic Social Sciences Program and the Paleoclimate Program. Additional funds are provided by the Arctic Studies Program, Bowdoin College.

For more information, contact Susan Kaplan in Brunswick, ME (207/725-3289; fax 207/725-3499; skaplan@bowdoin.edu), or Rosanne D'Arrigo and Brendan Buckley in Palisades, NY (845/365-8617; fax 845/365-8152; druidrd@ldeo.columbia.edu; bmb@ldeo.columbia.edu). ■

Yup'ik Interviews Feature Women

In June 1997, a Yup'ik woman from Gambell on St. Lawrence Island, Alaska, spoke cheerfully about her life as her hunter sons tramped in and out of another part of the house. Lucianna (not her real name), then in her 50s, described herself as one of the last in the community to have had an arranged marriage, alluded modestly to her work as a community health aide, and spoke enthusiastically about the formative years of her marriage, her family, and her domestic tasks.

Carol Jolles (Indiana University-Purdue University) interviewed Lucianna and more than 10 others as part of a project funded by the Arctic Social Sciences Program to compare Yup'ik women and families from Gambell, Alaska and a related community in Sireniki, Russia.

Because narratives of women's lives had barely penetrated the domain of Yup'ik life histories, Jolles focused on:

- the training of women for a variety of tasks;
- their contributions within their natal and marriage families, and in the larger community; and
- their work with men—in the work place, as family members engaged in subsistence work, and as their husband's work partners.

Jolles, often working with elder Elinor Oozeva as her research partner, audio-taped narrative life history interviews that are free-ranging and woven through with traditional stories. The result is a series of intimate descriptions of life in the village from the late 1930s through the 1990s. Earlier, Jolles had found that, regardless of the level of their engagement in community life, women tended to concentrate on the years before marriage when they were learning about subsistence tasks from their mothers and grandmothers. Only with encouragement did they describe their lives after marriage more fully. Jolles urged the women, for instance, to complement their narratives with detailed drawings of all the homes in which they had lived, a process which elicited further descriptions, many of which document the modernization of family life and the community.

As the research concludes, transcripts will be returned to the individuals who were interviewed. The most complete and dynamic life histories will also be edited for community use.

For more information, contact Carol Zane Jolles in Indianapolis, IN (317/278-2307; fax 317/274-2347; cjolles@iupui.edu). ■

Arctic Social Sciences Program

The NSF Arctic Social Sciences Program supports research on the dynamic cultures, economies, and social organization of northern populations, often in close collaboration with northern residents. Approximately 40 ASSP-funded projects are now studying prehistoric, historic, or modern arctic worlds. Many projects focus on the relationships between humans and environment.

For more information, see the ASSP web site (www.nsf.gov/od/opp/arctic/social.htm), or contact Program Manager Fae Korsmo in Arlington, VA (703/292-8029; fax 703/292-9082; fkorsmo@nsf.gov). ■

Aleut Responses to Catastrophic Environmental Change

The Aleut have lived on one of the world's most dynamic landscapes for at least 10,000 years. In some of the largest villages ever recorded for hunter-gatherer societies, they intensively used marine resources, developing a complex social and political fabric that is well preserved in the archaeological record. These factors make the southern Bering Sea and greater North Pacific region one of the most important areas for studying human-landscape interactions in northern regions. The NSF Arctic Social Sciences Program first funded the Lower Alaska Peninsula Project (LAPP) in 1996 to investigate the potential for using geographic information systems (GIS), remotely sensed images, and aerial photography to support archaeological and geomorphological reconnaissance of the southern Bering Sea region. The project uses multidisciplinary approaches and integrated, cross-disciplinary hypotheses to investigate both environmental and social change.

Principal investigators Herb Maschner (Idaho State University) and Jim Jordan (Antioch New England Graduate School) began by creating a spatial database of the western end of the Alaska Peninsula that included Landsat images, black and white and color infrared aerial photographs, and topographic and hydrographic data. A 1:63,360-scale digital elevation model (DEM) was generated and refined with low-altitude photography.

By 1998, Maschner and Jordan had completed an archaeological survey of the project area, including the Bering Sea shoreline, Izembek and Moffet lagoons, and the north end of Morzhovoi and Cold bays on the Pacific margin of the western Alaska Peninsula. Jordan also completed a study of the coastal geomorphology of the region, while project member Tina Dochat investigated the glacial history.

Glaciers receded from the region approximately 12,000 to 13,000 years ago. Since then, isostatic rebound (regional rebound of the earth's crust relieved of the weight of glaciers), global sea-level rise, earthquakes, volcanism, and climate have shaped the coastal landscape. Four paleoshorelines are presently recognized in the region. A barrier beach uplifted 25 m above modern sea level marks the marine limit; this was deposited more than 9,000 years ago. Subsequent shorelines are documented at 16 m (6,000 to 9,000 years old), 5–6 m (2,100 years old), and 2–3 m (500 to 1,000 years old).

Izembek Lagoon is a 200 km^2 embayment on the Bering Sea margin of the study area that supports a large portion of Alaska's migratory waterfowl. It was formed less than 400 years ago with the deposition of a narrow barrier dune system, illustrating how rapidly changes in near-shore sedimentation can affect coastal evolution. Over the past 12,000 years, volcanic eruptions also influenced terrestrial and coastal sedimentation rate and probably controlled vegetation patterns and succession both locally and regionally. Maschner and Jordan are now conducting palynological work on peat bogs in the project area to better understand postglacial climate and vegetation change.

The Aleuts established massive villages in the south Bering Sea region during the last 5,000 years, some covering nearly a square kilometer with 500 to 900 surface depressions. AMS radiocarbon dating indicates that some villages may have supported nearly 1,000 people. The site survey, together with analysis of bird, fish, and mammal remains and investigation of household organization, point to major shifts in demography, subsistence, and settlement location throughout this period.

By integrating settlement and subsistence data into the GIS and adjusting it for changing sea levels and associated intertidal zones, Maschner and Jordan were able to predict the locations of most village sites for a given time period. Coastal geomorphology and environmental change have played important roles in the distribution of prehistoric settlements. Human impacts on the landscape are being investigated through studies of plant and small mammal communities at large village sites. Faunal analysis has generated a large and important paleoecological database for fish, birds, and mammals in the region.

Episodic and dramatic cultural change in the southern Bering Sea region has been followed by long periods of relative stasis, much like punctuated equilibrium in evolutionary theory, or self-organized criticality in complex systems research. The researchers have, therefore, modeled the potential interactions of natural events (*e.g.*, earthquakes, tsunami, volcanic eruptions, rapid climate change) and social transformations (*e.g.*, migration, warfare, disease, technological innovation, demographic changes). They have, for instance, documented evidence of a large earthquake that caused subsidence of the western Alaska Peninsula approximately 2,100 years ago. GIS modeling indicates that this probably inundated sockeye salmon rearing lakes on coastal lowlands of the peninsula and established a channel between the Bering Sea and the Pacific Ocean at the head of Morzhovoi Bay. At this time, residents abandoned villages that had been established on salmon streams and concentrated at a few massive villages that were strategically located to intercept migrating salmon and sea mammals.

View from the 2000 to 4000 year old Aleut village of Adamagan east to the field camp, Big Lagoon, Morzhovoi Bay, and Mt. Frosty (photo by R. Holmer).

The village of Adamagan (see photo) is the focus of the current four-year grant, which supports investigations of prehistoric adaptations to rapid environmental change in the southern Bering Sea. The result of this work will refine models of human-landscape interactions in the past and, more broadly, will provide a better understanding of the effects of rapid and gradual environmental change on the ecology of southern Beringia.

For more information, contact Herb Maschner in Pocatello, ID (208/282-2745; fax 208/282-4944; maschner@isu.edu) and Jim Jordan in Putney, VT (802/869-2060; fax 603/357-0718; jwjordan@sover.net).

Physical Properties and Permeability of First-Year Sea Ice

The dynamics and thermodynamics of sea ice are key variables in polar ecosystems. Global change modeling requires an adequate understanding of the mechanical, electromagnetic, optical, and thermal properties of sea ice, as well as its capacity to transfer solutes through the ice sheet, to support biological activity, and to entrain and transport contaminants. The manner in which sea ice forms produces a characteristic microstructure and a unique and complex flaw structure, both of which exert major influences on all of these characteristics and processes.

In late 1999, NSF's Arctic Natural Sciences Program funded David Cole (Cold Regions Research and Engineering Laboratory), and Lewis Shapiro and Hajo Eicken (University of Alaska Fairbanks) to study the Microstructural Features and Brine Drainage Networks in First-Year Sea Ice. The researchers are investigating the very small-scale processes that occur during the formation and weathering of sea ice which exert a powerful influence on polar and ultimately global environments. Their three-year project focuses on the field collections of quantitative data on the flaw structure of the ice, theoretical considerations, and modeling.

Research on the deformation and fracture of sea ice shows a clear relationship between the details of its microstructure and its larger-scale behavior. The flaw structure, which consists primarily of liquid brine inclusions, affects:

- the permeability of the ice,
- its ability to absorb and propagate energy,
- its capacity to host biological activity, and
- its capacity to entrain and transport contaminants.

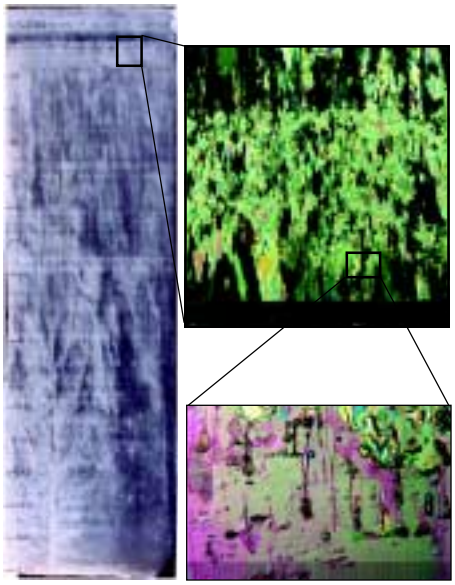
Sea-ice sheets typically consist of crystals with their c-axis—that is, the axis of hexagonal symmetry—oriented horizontally. Freezing proceeds dendritically, trapping liquid brine along specific planes within each crystal. This produces crystals that are "anisotropic"—they exhibit properties with very different values when measured along different axes. Under-ice currents give a growth advantage to crystals with their c-axis aligned with the direction of flow. As a result, large areas of aligned ice develop, and the individual crystal anisotropy is reflected in the large-scale mechanical, electromagnetic, and optical properties of the ice. Furthermore, because brine in the ice is mobile, the flaw structure evolves as the brine responds to temperature changes. Features affected in this way must be quantified as a function of time and temperature history. Features of interest to Cole, Shapiro, and Eicken include:

- details of the crystal structure (grain size variations, brine plane spacing, and c-axis fabric development in relation to under-ice currents);
- the size and shape distributions of brine and gas inclusions;
- brine drainage networks in three dimensions; and
- changes in permeability through the year, and related impacts on heat and mass transfer through the ice.

The small-scale inclusions and brine drainage features range in size from approximately 10^{-4} m to the full thickness of the ice sheet (see figure). In addition to the usual salinity, density, grain size, and fabric measurements, specialized observations include:

- the permeability measurements and associated detailed observations of drainage pathways;
- sets of orthogonal micrographs (which yield size distributions of small-scale inclusions in three dimensions);
- detailed observations of drainage pathways and their impact on the three-dimensional thermal regime; and
- vertical sections through the entire thickness of the ice sheet.

The latter provide an unparalleled view of larger-scale features such as brine drainage networks and horizontal banding. A methodology has recently been developed for measuring the *in situ* permeability at various depths within the ice sheet. These measurements are complemented with direct optical examination of the flaw structure that supports the brine flux.



The figure shows a full-thickness slab of first-year sea ice taken from the Chukchi Sea (left), a vertical thin section showing the transition from granular to columnar ice near the top of the sheet (top right), and a vertical micrograph (bottom right). The micrograph shows some interesting brine inclusions found at the granular/columnar transition. The index marks on the full thickness slab are at 0.1 m intervals, the large-scale divisions on the thin section photograph are 10^{-2} m, and the scale divisions on the micrograph are 10^{-4} m (figure by D. Cole).

Cole, Shapiro, Eicken, and UAF graduate student Karoline Frey are conducting several field trips per year to track the evolving properties of land-fast ice sheets at sites near Barrow, Alaska. One site approximately 1 km from the old Naval Arctic Research Laboratory (see *Witness* Spring/Autumn 1999) and another in nearby Elson Lagoon are instrumented to monitor the thermal regime during the growth and melt seasons; under-ice currents are measured periodically.

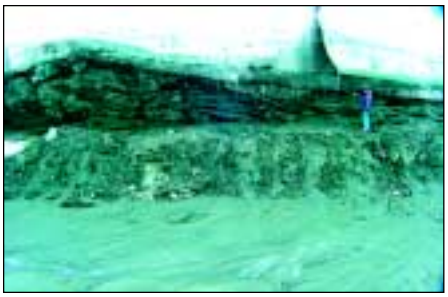
The researchers have benefited greatly from support provided by the Barrow Arctic Science Consortium (BASC; see page 25). In addition to serving as a base for field operations (*e.g.*, providing office space and field equipment), BASC's personnel have been available to collect data throughout the year and to relay information on the ice conditions which is key to optimizing the timing of principal investigators' field trips.

For more information, contact David Cole in Hanover, NH (603/646-4217; fax 603/646-4640; dmcole@crrel.usace.army.mil) and Lewis Shapiro and Hajo Eicken in Fairbanks, AK (907/474-7558; fax 907/474-7290; lews@gi.alaska.edu; hajo.eicken@gi.alaska.edu).

Matanuska Glacier Adds Ice and Debris at its Base

Scientists have long understood that glaciers grow by addition of snow on their upper surfaces. What few anticipated is that glaciers also can grow low in their ablation areas by addition of ice to their bases.

In research funded by the NSF Arctic Natural Sciences Program, Ed Evenson (Lehigh University), Dan Lawson (Cold Regions Research and Engineering Laboratory [CRREL]), Grahame Larson (Michigan State University), Richard Alley (Pennsylvania State University), and many students have demonstrated the occurrence of glaciohydraulic supercooling and basal freeze-on at the Matanuska Glacier in Alaska. At a year-round facility maintained at the glacier by CRREL in conjunction with the three universities, the researchers have been gathering data on ice velocity, water and sediment discharge, water and ice-isotopic composition, and meteorological conditions. They have also conducted summer and winter drilling, dye-injection studies, and geophysical investigations aimed at determining ice thickness, subglacial topography, the extent and thickness of freeze-on ice and sediment, and the nature and development of the subglacial hydrologic system.



Although freeze-on was long suspected at the Matanuska Glacier in south-central Alaska, it was first proved with the discovery of bomb-produced tritium in the sediment-laden basal ice. In a March 2000 field conference sponsored by NSF and the Geological Society of America, ANS researchers brought 21 scientists from around the globe to see first-hand the evidence for basal freeze-on and debris entrainment (photo by Ed Evenson).

The thermodynamics of freeze-on require high water discharge and a slope of the ground beneath the glacier bed that is sufficiently steep and contrary to the slope of the glacier surface. Under these conditions, basal water is forced to flow upward. As pressure decreases, the melting temperature rises, and supercooling, freeze-on, and associated debris entrainment occur.

Interesting observations at the Matanuska Glacier include:

- Supercooling and freeze-on occur in the summer when air temperatures remain constantly above freezing.
- Ice grows beneath the glacier as well as in front of it, producing debris-rich basal sequences and large terraces each summer that usually melt only when basal meltwater discharge decreases in the Fall.
- Thermometers suspended in water emerging from beneath the glacier record slightly subfreezing temperatures, and are often ice-covered when removed.
- Debris-rich basal ice sequences several meters thick have accreted to the bottom of the glacier in the past 50 years.
- Debris content of up to 50% by weight is common in the basal ice sequences.
- Supercooling is occurring at the Malaspina and Bering glaciers in Alaska, at several Icelandic glaciers, and elsewhere.

While this explanation solves a long-standing puzzle about debris-rich basal ice and summer terraces at the Matanuska, it also provides insights well beyond this one valley in Alaska. Other work has shown that, in many regions, glaciers are the most important erosive agents and producers of globally significant sediment and chemical fluxes. The beautiful strings of lakes left in many glacial valleys show that glaciers commonly erode overdeepenings with adverse slopes, such as the one beneath the Matanuska Glacier. Theory and observation thus indicate that, in altering the land surface, many or even most glaciers at times experience Matanuska-type basal supercooling and freeze-on of debris-laden ice. This phenomenon may help explain how Laurentide glaciers entrained and moved the voluminous debris found in the Heinrich layers of the North Atlantic, and it may have operated in many of the over-deepened basins of the Laurentide and Scandinavian ice sheets, contributing to their deposits.

The next phase of research focuses on:

- determining the thickness and distribution of basal freeze-on ice using shallow geophysical techniques, in conjunction with Greg Baker (SUNY at Buffalo);
- dating the basal ice more accurately using $^{3}H/He$, in conjunction with Thure Cerling (University of Utah);
- determining the geometry and evolution of the subglacial drainage system using dye injection into boreholes;
- identifying other glaciers exhibiting this freeze-on behavior; and
- assessing the importance of this freeze-on behavior in understanding glacial dynamics, glacial erosion and sedimentation, mountain-belt evolution, and global biogeochemical cycling.

For more information, contact Ed Evenson in Bethlehem, PA (610/758-3659; fax 610/758-3677; ebe0@lehigh.edu), Dan Lawson in Ft. Richardson, AK (907/384-0510; fax 907/384-0519; dlawson@crrel.usace.army.mil), Grahame Larson in East Lansing, MI (517/353-9485; fax 517/353-8787; larsong@pilot.msu.edu), or Richard Alley in University Park, PA (814/863-1700; fax 814/865-3191; ralley@essc.psu.edu). ■

Arctic Natural Sciences Program

The NSF Arctic Natural Sciences Program supports disciplinary research in the atmospheric sciences, biological sciences, earth sciences, glaciology, and oceanography. The program also coordinates arctic research with the NSF Directorates for Geosciences and Biological Sciences, and helps facilitate multidisciplinary, cross-disciplinary, and polar projects funded by the Office of Polar Programs (OPP).

For more information, see the ANS web site (www.nsf.gov/od/opp/arctic/natural.htm), or contact Program Directors Neil Swanberg and Jane Dionne in Arlington, VA (703/292-8029; fax 703/292-9082; nswanber@nsf.gov; jdionne@nsf.gov). ■

Clouds in Arctic Stratosphere Catalyze Ozone Loss

The second layer of the Earth's atmosphere, the stratosphere, contains high concentrations of UV-absorbing ozone. In much of the stratosphere, which extends from approximately 10 to 50 km above the surface of the Earth (depending upon latitude, season, and weather), temperature changes little with altitude, the air is dry and stable, and clouds do not form. The stratosphere over polar regions, however, deviates slightly from this picture. Because of the extreme cold, clouds do form occasionally, and these clouds set the stage for chlorine-catalyzed ozone loss as Spring arrives.

These clouds, called polar stratospheric clouds (PSCs), are unusual because they:

- exhibit the colors of mother-of-pearl,
- occur in the stratosphere at temperatures above that at which ice forms—the ice point, and
- provide the surfaces for a reaction that converts anthropogenic chlorine from a benign to a reactive state.

PSCs, through the chemical reactions they support, are precursors to the annual destruction of polar ozone (see feature story) and are required for it to proceed.

To better understand the phenomenon of ozone depletion, the NSF Arctic Natural Sciences Program has funded Terry Deshler (University of Wyoming) to collaborate with scientists from Germany, France, Italy, and Denmark to investigate the nature of PSCs. They are asking:

- What is the chemical composition of these cloud particles?
- Are the particles liquid or solid?
- What temperatures are required for the different particle types to form?
- How large are the particles?
- How much surface area is available for the conversion of chlorine to an active form?

Today we know that PSC particles can be ice, mixtures of nitric acid (HNO_3) and water (H_2O), or hydrates of nitric acid and water. Hydrates are solid particles with fixed molecular ratios for water and the other molecule (*e.g.*, solid nitric acid trihydrate [NAT] is one molecule of nitric acid and three of water).

Initial theoretical work in the 1980s suggested that PSCs were composed of nitric acid and water. Laboratory simulations then demonstrated that the solid trihydrate, NAT, was stable at stratospheric pressures and temperatures. Thus, PSCs that occurred above the ice point were thought to be NAT.

By the early 1990s, however, additional work cast doubt on this hypothesis. Field observations indicated that PSCs were often composed of liquid droplets rather than solid hydrates. Laboratory experiments indicated that NAT would not form initially until the temperature was several degrees below the ice point, even though, once formed, NAT will not evaporate until the temperature is 6° C above the ice point. Because there is so little water vapor in the stratosphere, the ice point is quite low—below -80° C. Since temperatures in the arctic stratosphere are rarely this low, the composition of many observed PSCs remained a mystery.

To address some of the uncertainties regarding PSCs, scientists from five countries combined their instruments onto one balloon gondola to provide a comprehensive PSC observation. Support for this collaboration was provided by the European Commission; the German, French, Italian, and Danish national agencies for scientific research; and the NSF Arctic Natural Sciences Program. The instrumented gondola was first flown at the end of January 2000, at which time two flights were made (see photo). Measurements included:

- particle composition using a particle mass spectrometer (German),
- optical properties using backscattersondes (Italian and Danish),
- water vapor mixing ratio using a frost point hygrometer (French), and
- aerosol size distributions using optical particle counters (U.S.).

These measurements have provided the most complete characterization of a single PSC to date. Similar measurements are planned to continue during the arctic winters of 2001 and 2002.

Although much of the data are still under analysis, the composition measurements show clearly that at least some of the PSC particles were NAT. These measurements are the first direct evidence that these solid particles occur in the stratosphere as well as in laboratory simulations.

For more information, see Voigt *et al.*, 2000, or contact Terry Deshler in Laramie, WY (307/766-2006; fax 307/766-2635; deshler@uwyo.edu).

To address some of the uncertainties regarding polar stratospheric clouds (visible overhead), scientists from Germany, France, Italy, Denmark, and the U.S. launched a balloon gondola with their combined instruments twice near Kiruna, Sweden in January 2000 (photo by Darin Toohey, University of Colorado).

Reference

Voigt, C., J. Schreiner, A. Kohlmann, P. Zink, K. Mauersberger, N. Larsen, T. Deshler, C. Kröger, J. Rosen, A. Adriani, F. Cairo, G. Di Donfrancesco, M. Viterbini, J. Ovarlez, H. Ovarlez, C. David, and A. Dörnbrack. 2000. Nitric acid trihydrate (NAT) in polar stratospheric cloud particles. *Science* 290 (5497): 1756-1758.

UV Radiation Lowers Productivity of Arctic Phytoplankton

Depletion of ozone in the stratosphere and associated increases in ultraviolet radiation (UVR) are greatest at high latitudes. While extensive studies during the past 15 years have investigated the effects of UVR on marine plankton in the Antarctic, few studies have addressed the effects in the Arctic. Findings cannot be extrapolated from one region to the other, since both oceanographic conditions and the composition of plankton species differ considerably.

The NSF Arctic Natural Sciences Program has funded field research on the effects of UVR on plankton in the waters around the Lofoten Islands of northern Norway, in collaboration with the European Union-sponsored program "The Influence of UVR and Climate Conditions on Fish Stocks: A Case Study of the Northeast Arctic Cod." Osmund Holm-Hansen (Scripps Institution of Oceanography) joined Hans Christian Eilertsen (University of Tromsø, Norway) and others aboard Norwegian research vessels in Spring-Summer 2000. The major focus of the combined research was to evaluate the potential impact of increased UVR on the food reservoirs available to grazing zooplankton and to commercially important fishery resources. Because the Lofoten Island area harbors the world's highest concentrations of spawning arctic cod (*Gadus morhua*), a thorough understanding is needed of the dynamics of the food chain that supports cod in this area, including the effects of UVR on arctic plankton.

In general, the sensitivity of phytoplankton to UVR is related to the light conditions experienced by the cells prior to the experimental incubation period. Photosynthetic rates of phytoplankton sampled from a deeply mixed (>50 m) water column are inhibited by very low levels of UVR radiation (<1 Watt/m^2). By comparison, photosynthetic rates of Antarctic phytoplankton are generally inhibited when UVR reaches ~10 to 15 Watts/m^2.

Data from two cruises in 2000 lead to the following observations:

- The ozone layer was substantially thicker in March than in May.
- Phytoplankton stocks were comparable at all samplings (*i.e.*, typical Spring diatoms *Chaetoceros socialis*, *C. debilis*, *Thalassiosira nordenskioeldii,* and the haptophycean *Phaeocystis pouchetii*).
- Clear sky conditions correlated with high frequencies of malformed *Calanus finmarchicus nauplii* and acute mortality in cod eggs and larvae maintained within a few meters of the surface.
- Bloom conditions in March 2000 exhibited high chlorophyll-a concentrations (up to 10 mg/m^3) evenly distributed from the surface to >30 m depth. By May-June 2000, bloom conditions exhibited low chlorophyll-a concentrations (1–2 mg/m^3) and depleted nutrients in the upper mixed layer (~20 m depth).
- Phytoplankton were more sensitive to UVR in March than in the May–June period, with UV-A (320–400 nm) accounting for more of the inhibition than UV-B (280–320 nm) radiation.
- *In situ* incubations of experimental samples from the relatively shallow upper mixed layer (20 m) during the May–June period showed no detectable effect of UVR below 4 m depth.

These results are interpreted as photoacclimation of the phytoplankton to elevated UVR as summer, with its long days and higher incident radiation, progresses. Ongoing studies and field plans for 2001 will focus on:

- the degree to which UVR-induced damage can be repaired or reversed by metabolic processes;
- the relative importance of direct DNA damage by UV-B radiation compared to photodynamic effects of photoproducts (*e.g.*, reactive oxygen species) that may be generated by UV-A radiation;
- the importance of mycosporine-like amino acids as protective UVR screens;
- seasonal changes in column ozone levels and impact of associated increases in UV-B radiation on phytoplankton from late winter to midsummer, particularly as it affects the food resources of grazing zooplankton and fish larvae;
- differential sensitivity of phytoplankton species to UVR and the ensuing impact on food web dynamics; and
- ecosystem effects of UVR (phytoplankton-zooplankton-fish larvae-benthos).

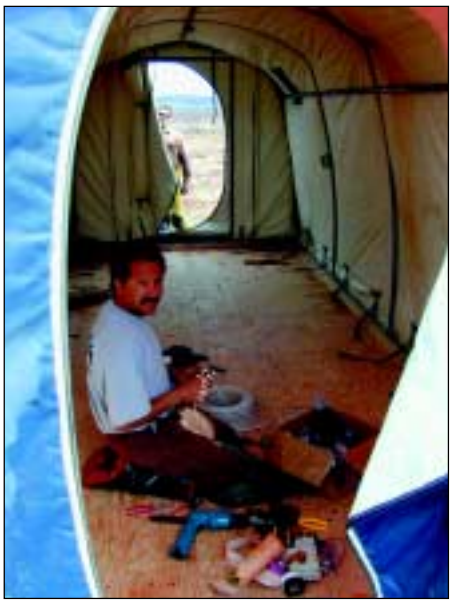
R/V Jan Mayen *outside the entrance to Austnesfjorden, one of the main spawning sites for cod in the Lofoten Island area of arctic Norway (photo by H.C. Eilertsen).*

For more information, contact Osmund Holm-Hansen in La Jolla, CA (858/534-2339; fax 858/534-7313; oholmhansen@ucsd.edu), or Hans Christian Eilertsen in Tromsø, Norway (+47/7764-4540; fax +47/7764-6020; hanse@nfh.uit.no).

VECO Polar Resources Provides Arctic Logistics

At the end of November 2000, VECO Polar Resources (VPR) completed its first year as NSF's contractor for Arctic Research Logistics Support Services (ARLSS). VPR support for scientists in Greenland, Alaska, Canada, and near the North Pole in 2000 has included:

- installing a wireless Local Area Network (LAN) with full-time internet connectivity at Summit Camp, Greenland;
- operating a camp for about 20 researchers at Council (see photo); and
- providing extensive aircraft support for researchers working in remote locations in Alaska.



Near Council on the Seward Peninsula of Alaska, Mark Begnaud and Larry Levine (background) erect a Weatherport in June 2000 for scientists supporting the Integrated Sounding System (ISS) for the National Center for Atmospheric Research (photo by Jay Burnside).

VPR is currently supporting a winter-over team of four at the Summit Camp and planning for the second contract year. Plans for 2001 include:

- further enhancements to the Arctic Program's field communications capabilities;
- expansion of VPR's range of support to include several Russia-based projects;
- development of a field safety program;
- major enhancements to VPR's web site.

The VPR team is comprised of VECO, an Alaska-based engineering and construction company; SRI International, a technical scientific communications and research company; and Polar Field Services, Inc., a scientific logistics project management group whose personnel have experience with the NSF Office of Polar Programs Antarctic Program. In collaboration with arctic researchers, other logistics providers, and local organizations, VPR offers field camp engineering services, construction and operations support, aircraft support, use of field equipment (*e.g.*, vehicles, tents, power systems, radios, satellite telephones), and services for engineering and installing radiated media field communications systems.

Until October 1999, the Snow and Ice Research Group at the University of Nebraska-Lincoln operated the Polar Ice Coring Office (PICO) under contract to OPP. Under this contract, PICO provided both science support and ice coring and drilling services. Under the new contract, ice coring services will be provided by the University of Wisconsin-Madison (www.ssec.wisc.edu/A3RI/icds/).

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

Logistics Working Group Reviews Community Input

The Arctic Research Support and Logistics Working Group (RSLWG) is supported by NSF to update and expand upon the accomplishments of the first ARCUS Logistics Working Group, sponsored by the U.S. Arctic Research Commission (see page 20) and NSF.

The major task for the RSLWG is to update the 1997 report, *Logistics Recommendations for an Improved U.S. Arctic Research Capability*, by gathering information and recommendations from the arctic research community.

The RSLWG met at Lamont-Doherty Earth Observatory in September 2000 to advance the development of the new report based on the results of an on-line community survey and discussions at an arctic logistics town meeting held in May 2000 (see *Witness* Spring 2000).

Working group members are currently developing the updated report. A draft will be available for community review in early Fall 2001 and published in late Spring 2002.

Additional discussions at the September meeting included:

- logistics issues related to emerging research initiatives,
- other relevant arctic planning and logistics efforts, and
- progress on the improved Arctic Logistics Information and Support (ALIAS) web site.

ALIAS (www.arcus.org/alias) serves as a primary access point to help the research community acquire support and logistics information for the Arctic. When fully implemented, ALIAS will be a comprehensive information source for:

- assessing the feasibility of working in a particular area,
- planning the conduct of research,
- viewing current research in a given area, including maps and publications, and
- making support and collaboration contacts for both science and logistics.

ALIAS, still under development, will be an interactive, database-driven site, allowing users to conduct complex criteria-based searches to gather information on research sites and logistics resources. Users, including researchers, research site managers, and logistics providers, will be able to submit updated site and resource information to ALIAS through an online survey.

For more information, see the ARCUS web site (www.arcus.org/rslwg/) or contact RSLWG co-chairs Peter Schlosser (845/365-8707; fax 845/365-8155; peters@ldeo.columbia.edu) and Terry Tucker (603/646-4268; fax 603/646-4644; wtucker@crrel.usace.army.mil).

Arctic Modeling Focuses on Collaborative Efforts

Modeling of the arctic atmosphere, ocean, ice, and terrestrial systems has progressed significantly over the past decade, driven in part by the movement to address research questions that appear to be keyed to global and interdisciplinary dynamics, such as:

- Why is the arctic sea ice thinning and shrinking?
- What is causing the warmer Atlantic-layer water in the Arctic Ocean?
- How will the regional climate, permafrost, and vegetation in the Arctic respond to predicted global warming?

To ensure continuing progress in arctic modeling, several recent workshops highlight the need for collaboration between observational programs (*e.g.*, field work, remote sensing) and the state-of-the-art modeling efforts that are applying the field data to simulations:

- Arctic Regional Climate Model Intercomparison Project (ARCMIP) investigators met in September 2000 at the University of Alaska Fairbanks. They will perform high-resolution atmospheric simulations and compare their results, in hopes of improving their models.
- Sea Ice Model Intercomparison Project (SIMIP) investigators also met in September 2000 in Fairbanks. They will compare thermodynamic ice model simulations with observed data to improve their models.
- Investigators involved with Phase 3 of NSF's Surface Heat and Energy Budget of the Arctic (SHEBA) program (see page 7) met in October 2000 in Boulder, Colorado. In order to improve arctic climate simulations, they are addressing collaboration between the scientists at the field camp and the modelers who will use the data for model validation and forcing. SHEBA investigators collected, and are making available, one terabyte of data from the field, from satellites, and from analyses.

Progress in arctic modeling has increased the demand for computational resources. For instance, the 18 km-resolution arctic ice-ocean model from the Naval Postgraduate School requires 2,400 processor-hours for a 100-year simulation on a massively parallel supercomputer. There are approximately 20 parallel supercomputers in U.S. centers that can perform these experiments. The Arctic Region Climate System Model (ARCSyM) requires 600 hours for a single-year simulation on a more common high-end workstation. To adequately address the most pressing climate issues, significantly more computer resources will be required than are presently available to the arctic modeling community.

Supercomputing centers in the United States (largely within the Departments of Energy and Defense) have increased their computing power tenfold in the past five years by acquiring large parallel computer systems. Adapting models to use parallel computers, however, requires considerable time and special programming skills. This has been most restrictive for individual, university-based arctic modelers, who often rely on graduate-level researchers. Some arctic modelers have made use of new atmosphere, ocean, and ice models developed for (or adapted to) parallel computers by groups associated with the larger computing centers (*e.g.*, Los Alamos National Laboratory, Argonne National Laboratory, the National Center for Atmospheric Research).

Progress in arctic modeling will continue as these new parallel architectures mature and are made accessible to a wider community that is expanding its expertise.

For more information, contact John Weatherly in Hanover, NH (603/646-4741; fax 603/646-4644; weather@crrel.usace.army.mil).

GIS Workshop Targets Improvements in Circumpolar Data Sharing

The rapidly evolving capabilities of Geographic Information Systems (GIS) provide broad new approaches to spatially related research questions. The Arctic Research Support and Logistics Program (see *Witness* Spring 2000) sponsored ARCUS to host an Arctic GIS Workshop in Seattle, Washington in January 2001, to gather input from the arctic research and GIS technology communities. More than 100 international researchers from a variety of scientific disciplines, representatives of state and federal agencies, and GIS professionals met to assess current issues and discuss and prepare recommendations to improve the use of GIS in support of arctic research.

Little of the existing georeferenced data for the Arctic is widely available to academic and agency researchers, planners, and the public, and even less is usable for manipulation and analysis. Recent advances in GIS technology, software, and internet compatibility make it feasible to share georeferenced data and associated metadata over the internet to allow map viewing, data manipulation, and analyses.

Improved spatial data sharing will benefit researchers by facilitating new interdisciplinary collaborations, innovative analyses, and enhanced outreach. Workshop participants agreed that a cooperative effort among agencies, researchers, technical experts, and nations will be needed to develop a geographic information infrastructure (GII) supporting arctic research by consistently documenting metadata, using internationally accepted data standards, and making data accessible to other users. The data standards already in place through the Federal Geographic Data Committee (FGDC) and the experience of individuals and agencies cooperating in this effort will contribute to establishing an extensive GII for arctic research.

A summary of the workshop recommendations is available on the ARCUS web site (www.arcus.org/gis/index.html). A more detailed report will be developed, circulated to the arctic research and GIS professional communities for comment, and published later this year. For more information, contact Renée Crain at ARCUS (renee@arcus.org).

Research Site Registration is Underway at Barrow

The 7,466-acre Barrow Environmental Observatory (BEO) and neighboring lands and waters encompass hundreds of research sites used for past and present studies, including ecological, geomorphic, cryospheric, atmospheric, and archaeological research. The Barrow Arctic Science Consortium (BASC) is now cataloging this history of research and developing a long-term master plan to guide the future scientific use of the BEO.

The BEO Science Management Committee (SMC), in collaboration with the Arctic Ecology Laboratory at Michigan State University (MSU), has begun to locate and mark significant research sites within and close to the BEO. In Summer 2000, MSU wildlife student Frank Lepera located 323 research sites from 23 projects using post-corrected differential GPS, and marked 223 of these with individually labeled survey caps. These registered sites include approximately 150 International Tundra Experiment (ITEX; see page 6) experimental and control chambers and 30 ARCSS/CALM (Circumpolar Active Layer Monitoring) plots. Additional sites (*e.g.*, from other federal and North Slope Borough projects) are also being added to the database. The arctic community will be asked to review the inventory of sites and suggest additions.

To enhance the operational efficiency, integrative management, and research potential of the BEO, a new metadatabase of past and present research activity in the vicinity includes:

- contact and professional details of researchers affiliated with the BEO,
- project and site information, and
- publications resulting from research.

This web-accessible database will be linked to a GIS resource and an archive of resources (*e.g.,* aerial photography, topography, soils, vegetation, wildlife).

The Ukpeagvik Iñupiat Corporation (the Barrow village corporation) established the BEO in 1992 for the purpose of protecting an area for long-term research (see *Witness* Autumn 1997). BASC manages the preserve under a cooperative agreement with NSF.

For more information, see www.arcus.org/basc/index.html or contact BEO SMC Chair Jerry Brown in Woods Hole, MA (508/457-4982; fax 508/457-4982; jerrybrown@igc.org).

AICC Sees the USCGC *Healy* through Successful Trials

Activities of the Arctic Icebreaker Coordinating Committee (AICC) during Spring and Summer 2000 were dominated by the cold water science systems testing for the new U.S. Coast Guard Cutter *Healy*. Jack Bash and John Freitag of the University-National Oceanographic Laboratory system (UNOLS; see *Witness* Spring 2000) coordinated the efforts of UNOLS technical specialists to evaluate each primary science system on the ship. Ice trials in April and May 2000 between Canada and Greenland put the *Healy* through increasingly heavy icebreaking. The vessel met or exceeded icebreaking specifications; there is not excessive milling of the ice by the props, and the vessel is responsive and maneuvers well in the ice.

The cold-water science systems tests in May-July 2000 were especially valuable because of the enthusiastic joint participation of the Coast Guard personnel who will be supporting the systems, technical experts from the UNOLS community, and seagoing scientists. Tests included:

- science acoustic equipment (*e.g.*, SeaBeam 2112 swath mapping system, ADCPs, Bathy2000 and Knudsen bathymetry systems);
- the XBT system;
- the science data network;
- the uncontaminated seawater system;
- the thermosalinograph and fluorometer;
- scientific towing with a MOCNESS multiple opening and closing net and environmental sampling system;
- the CTD/rosette system;
- winch control systems;
- laboratory environmental controls;
- communications systems;
- scientific mooring deployment and recovery; and
- coring and dredging capabilities.

Most science systems proved ready for use on funded science cruises. Plans were made to address the few deficient systems and test them with science oversight before funded science cruises begin in 2001.

All of *Healy*'s passengers have come away impressed with the professionalism, support, interest, and friendliness of the entire ship's company. Five teachers from NSF's Teachers Experiencing Antarctica and the Arctic (TEA) program thoroughly enriched the test cruises. They brought the ice trials and science systems tests to the public, via the internet, with accuracy, breadth, humor, and insight (see page 26).

Healy's commissioning ceremony took place in August 2000 in Seattle. The AICC is now working to advise NSF and the Coast Guard regarding arctic science missions on the three Coast Guard icebreakers (*Healy*, *Polar Star*, and *Polar Sea*), especially regarding the panoply of logistic considerations that are much clearer to the AICC now that testing is completed. The 2001 field season will include the first paid-science cruises for the vessel.

Ship costs for the use of *Healy* (and the two polar-class icebreakers) are no longer contained in NSF proposal budgets. Ship-use requirements must be made clear in accompanying documentation (*e.g.*, Form 831, and NSF/OPP's logistical support form for arctic research). NSF proposals to use the icebreakers should be submitted by 15 February of the year preceding the proposed cruise.

Lisa Clough succeeded James Swift as AICC Chair in January 2001.

For more information, contact Lisa Clough at East Carolina University in Greenville, NC (252/328-1834; fax 252/328-4178; cloughl@mail.ecu.edu), or the UNOLS Office (office@unols.org).

President Bush Requests 1.3% Increase for NSF Budget

Although NSF received a 13% increase in its budget in FY 2001, President Bush's FY 2002 NSF budget request is $4.5 billion, just $56 million or 1.3% above FY 2001. The expected rate of inflation for FY 2002 is 2.6%, an effective decrease in the NSF budget of 1.3%. The Research and Related Activities account would decline 0.5%, with a major cut (17.5%) in Integrative Activities, including Major Research Instrumentation.

The proposed budget for the Office of Polar Programs totals $276.57 million, increasing 1.2% over FY 2001. The U.S. Polar Research Programs budget would increase 1.5%, or $3.17 million, from $210.8 to $213.97 million, including:

- the Arctic Research Program would increase 6.4%, from $31.14 to $33.14 million;
- the Arctic Research Support and Logistics budget would remain level at $23.96 million;
- the Arctic Research Commission budget would increase 1.4%, from $1.00 to $1.02 million;
- the Antarctic Research Grants Program budget would increase 2.1%, from $36.5 to $37.25 million;
- the budget for Operations and Science Support would increase 0.3%, from $118.2 to $118.61 million.

The budget document describes two FY 2002 priorities for the Arctic Research Program:

- the Study of Environmental Arctic Change (SEARCH) program (see page 8), and
- support for merit reviewed oceanographic research using the U.S. Coast Guard Cutter *Healy* (see page 18).

The budget request proposes to expand NSF's education activities, including the President's new Math and Science Partnership Initiative, funded at $200 million. The bulk of this funding ($110 million) would be redirected from existing NSF education programs. The budget for Education and Human Resources (EHR) would increase by 11% overall. In this budget scenario, graduate student stipends will increase from an average of $18,000 per year to $20,500 per year for the academic year 2002–03.

Congressional Actions

Several recent actions by Congress indicate that the final FY 2002 budgets for the basic science agencies may increase over the President's proposed budget. By a bipartisan voice vote, the Senate on April 5 approved an amendment to the Senate Budget Resolution (H.R. 83), which would increase the funding for some basic science agencies by $1.44 billion. This vote is an important indication of what Congress may do later this year when it considers the FY 2002 appropriations bills.

Senate Amendment 211 was sponsored by seven senators led by Christopher Bond (R-MO) and Barbara Mikulski (D-MD) and would increase funding for:

- NSF by $674 million,
- DOE by $469 million, and
- NASA by $518 million.

The amendment would increase the NSF budget by 15.3%, keeping the agency on track for the proposed doubling of its budget by 2005, supported by a bipartisan group of 41 senators last year.

In related action in the House of Representatives, 13 Republican and Democratic members of the Science Committee wrote to Appropriations Committee Chairman Bill Young (R-FL), asking him to consider making funding for the science agencies a high priority, especially that for NSF. Budget Committee member Rush Holt (D-NJ) attempted to increase general science funding in the House Budget Resolution but was unsuccessful, as the House voted along party lines. Rep. Eddie Bernice Johnson (D-TX), the ranking minority member on the Research Subcommittee, introduced legislation on April 4 to authorize the doubling of the NSF budget over the period 2001–05. This bill (H.R. 1472) provides for a 15% annual increase for NSF from FY 2002–05. The Johnson bill, which has 16 Democratic cosponsors from the House Science Committee, was referred to that committee for further consideration.

Administration Reviewing NSF Needs

The Administration intends to review the needs and opportunities facing NSF over the next five years to determine whether future NSF budget increases are warranted. Results of the review, which is underway and involves a variety of different studies, will be factored into the preparation of the FY 2003 budget. The staffs of NSF and the Office of Management and Budget (OMB) will have preliminary results for review by Fall 2001.

A random survey of academic institutions and individual investigators that have received NSF grants will begin in June. The survey, considered by NSF and OMB staff to be key to future NSF funding increases, is expected to result in the recommendation that average NSF grant size and duration be increased.

Details of the OMB/NSF review can be found in the "General Science, Space, and Technology" section of the main budget document, under the heading "Management Reforms" (pages 33–35). Following are some excerpts:

- For 2003, the Administration will undertake a budgetary review to determine how best to support the NSF's budget in a sustained manner over time.
- With the assistance of U.S. academic research institutions, NSF will develop metrics to measure the efficiency of the research process and determine the 'right' grant size and duration for the various types of research the agency funds.
- NSF will develop a plan for costing, approval, and oversight of major facility projects, and also will enhance its capability to estimate costs and provide oversight of project development and construction.
- NSF will develop a five-year strategic plan for the work force and information technology needs of the agency in time for consideration of the 2003 budget.

For more information, see the following web sites: NSF (www.nsf.gov), the American Association for the Advancement of Science (www.aaas.org/spp/R&D), the American Institute of Physics (www.aip.org/gov), the Association of American Universities (www.aau.edu), the OMB (www.whitehouse.gov/omb/budget/fy2002/budget.html), or the U.S. Congress (http://thomas.loc.gov).

U.S. Arctic Research Commission Plans Visit to ANWR

The 2001 edition of the U.S. Arctic Research Commission (USARC) *Report on Goals and Objectives 2001* was published in January and will be available soon on the USARC web site. The three major goals outlined in the report are:

- support for the SEARCH Program (see page 8), to enhance the study of change in the Arctic,
- a multiagency integrated research program for the Bering Sea (see *Witness* Spring 1998), and
- a two-part health of arctic residents program, including principal causes of morbidity and mortality and environmental health concerns and recommendations.

In 2001, the Commission met in:

- Dillingham, Alaska in November to discuss issues including improved coordination in fisheries research, fish and wildlife research needs, and distance education;
- La Jolla, California in January for a tour of the U.S.S. *Salt Lake City*, a Los Angeles class submarine, and discussions of how to carry forward SCICEX research (see *Witness* Spring/Autumn 1999).
- Iqaluit, Nunavut, Canada, prior to Arctic Science Summit Week (see page 22), including the USARC's first meeting with the Canadian Polar Commission (see *Witness* Spring 2000).

The Commission also:

- conducted a workshop, in collaboration with the Navy, on Navy responses to decreased ice cover in the Arctic, and
- discussed opportunities for arctic logistics cooperation with staff from the Canadian Polar Continental Shelf Project (see *Witness* Spring 1998), the Canadian Department of Fisheries and Oceans, and the Office of Polar Programs.

The Commission plans to visit the Arctic National Wildlife Refuge (ANWR) in early June. They will visit Svalbard and Tromsø, Norway following a meeting in Arlington, Virginia on June 22.

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

Enhancing NASA's Contributions to Polar Science: New PRB Report Available

For scientists who study climate change, the Arctic and Antarctic are prime laboratories. Data that document change range from the thickness and movement of entire ice sheets and glaciers, to the timing of cloud cover, distribution of precipitation, concentrations of atmospheric gases, past weather patterns, ocean temperatures, sea levels, and salinity patterns. To track changes, such data must be gathered over periods of years. Observations at the poles, however, are extremely difficult to make—these are among the most remote, harsh, and inhospitable environs on the planet.

The National Atmospheric and Space Administration (NASA) is responsible for a number of satellites and remote sensing programs that measure conditions in the earth's polar environments. NASA compiles its raw data into polar geophysical data sets that are available to scientists studying these regions. How these data sets can be made more useful to scientists is the subject of a new report—*Enhancing NASA's Contributions to Polar Science: A Review of Polar Geophysical Data Sets*, from a committee of the National Research Council's Polar Research Board (PRB).

After approximately a year of study and deliberations, including a survey of more than 100 polar scientists who use polar geophysical data in their day-to-day research, the committee:

- identified gaps between the data available and data needed; and
- made specific recommendations for additional air, water, and land measurements that NASA should collect to enhance existing records.

In addition, the committee made the following recommendations:

- in some cases, aircraft, automated underwater vehicles, and ground-based technologies may be more appropriate than satellites for collecting data;
- make available NASA's data-set archives, some of which extend back as far as 20 years;
- make a greater effort, for comparative purposes, to integrate NASA data sets with data collected in other parts of the world; and
- better publicize the availability of data sets, make them as user-friendly as possible, and provide web links to sites that offer additional relevant information.

This study was requested and sponsored by NASA's High Latitudes Office. Authors include John Walsh, Chair (University of Illinois), Judith Curry (University of Colorado, Boulder), Mark Fahnestock (University of Maryland), David McGuire (University of Alaska Fairbanks), William Rossow (Goddard Institute for Space Studies), Michael Steele (University of Washington), Charles Vorosmarty (University of New Hampshire), and Mahlon Kennicutt (Texas A&M University). The report is available in limited quantities from the PRB in prepublication format. The published volume will be available in May 2001 from National Academy Press (800/624-6242; www.nap.edu) for $31.

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

Finland Assumes Chair of Arctic Council for Two Years

U.S. Under Secretary of State for Global Affairs Frank Loy chaired the second biennial meeting of the Arctic Council in October 2000 in Barrow, marking the culmination of the two-year period of U.S. leadership of the Council and the beginning of the Finnish chairmanship. Participants included:

- Ministers from the eight arctic member states of the Council;
- presidents of the four arctic indigenous peoples' organizations that have Permanent Participant status on the Council—the Aleut International Association, the Inuit Circumpolar Conference, the Russian Association of Indigenous Peoples of the North, and the Saami Council; and
- representatives of the Council's accredited Observers.

New Participants, Observers Welcomed

The Barrow delegates approved two new Permanent Participants—the Arctic Athabaskan Council and the Gwich'in Council International; both indigenous groups have U.S. and Canadian members. France joined Germany, the Netherlands, Poland, and the United Kingdom as an Observer country. The ministers also approved eleven new Observer organizations, bringing the total number of Observers to 21. The eleven new Observer organizations are:

- the North Atlantic Marine Mammal Commission,
- the Nordic Council of Ministers,
- the Advisory Committee on the Protection of the Sea,
- the Association of World Reindeer Herders,
- the Circumpolar Conservation Union,
- the International Arctic Social Science Association,
- the International Federation of Red Cross and Red Crescent Societies,
- the International Union for Circumpolar Health,
- the International Union for the Conservation of Nature,
- the Standing Committee of Parliamentarians of the Arctic Region, and
- the World Wide Fund for Nature.

U.S. Concludes Chair; New Agenda Set

Accomplishments of the Arctic Council during the U.S. chairmanship include:

- finalization of a framework document for the Council's Sustainable Development Program,
- progress on the U.S.-led projects on telemedicine and cultural and eco-tourism,
- progress on the Canadian-led project on the Future of Children and Youth in the Arctic, and
- progress on the Denmark/Greenland-led Survey of Living Conditions in the Arctic.

The United States also contributed to the Council's Human Health Effects Program in the Arctic Monitoring and Assessment Program and helped fund a new assessment of contaminants in the food supply of Russian indigenous communities in the Arctic.

The October 2000 Ministerial meeting set the Arctic Council agenda for 2000–02. Topping the agenda is the Arctic Climate Impact Assessment (see page 22), a comprehensive study of the impact of climate change in the Arctic. The Council will also pursue a number of projects under the newly established Arctic Council Action Plan to Eliminate Pollution of the Arctic (ACAP; see *Witness* Spring 2000), including:

- the second phase of a project to reduce PCB use in Russia, and
- a plan to reduce mercury releases from arctic states.

The Ministers also approved proposals to develop an International Circumpolar Surveillance system for infectious diseases and to initiate projects on sustainable reindeer husbandry and development in northern timberline forests. The Ministers recommended that the Council pay particular attention to proposals from the Permanent Participants directed at improving human health in indigenous communities.

Ministers held a series of roundtable discussions on:

- the impact of climate variability on arctic communities and ecosystems;
- health, education, and economic opportunities of arctic communities;
- the threat of contaminants in the Arctic and opportunities for collective action to address the problem; and
- how to improve cooperation between the Arctic Council and the many organizations and initiatives with a northern focus.

The North Slope community, including school classes, observed the Council proceedings and joined in an evening panel discussion on contaminants and the impact on human health in the arctic environment.

Priorities of the Finnish Chair

Finland now assumes the chair of the Arctic Council until October 2002. Finnish Minister of Justice Johannes Koskinen outlined his country's priorities as chair, emphasizing increased contacts with international bodies such as the United Nations and the European Union.

Finland will also work toward active political implementation of conclusions drawn from technical reports of the Arctic Council working groups, specifically on issues such as climate change, long-range transportation of contaminants, and UV radiation.

Finland plans to evaluate the structure of the Arctic Council and its working groups, expand the use of information technology (such as in the University of the Arctic and telemedicine projects), and promote eco-tourism. The Finns will also concentrate on transportation infrastructure, capacity building, gender equality, and in the words of Justice Minister Koskinen, "bringing capital closer to the Arctic Circle . . . without forgetting the need to increase sensitivity toward indigenous affairs."

The next meeting of the Senior Arctic Officials (SAO) will take place in Rovaniemi, Finland, 10–13 June 2001. Future SAO meetings will be held in Helsinki in November 2001 and Oulu in April 2002. The next Ministerial-level meeting will be held in September 2002 in Inari (Saariselkä).

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

International Arctic Coastal Dynamics Drafts Science Plan

In October 2000, the International Arctic Science Committee (IASC) sponsored an international Arctic Coastal Dynamics (ACD) workshop in Potsdam, Germany. Eleven participants from Canada, Germany, Norway, Russia, and the United States reviewed results from the November 1999 workshop held in Woods Hole, Massachusetts (see *Witness* Spring 2000) and developed a phased five-year *Science and Implementation Plan*. The overall objective of the plan is to improve understanding of the dynamics of the 200,000-km circumarctic coastal margin, where permafrost and sea ice play key roles, under the influence of environmental changes and geologic controls.

The plan consists of two interrelated components:

- a series of coordinated activities to assess and synthesize existing information; and
- proposed focused research projects and long-term observations.

This research will serve as a basis for generating and updating maps and models for predicting coastal sensitivity.

The IASC Council will consider the plan for approval at its April 2001 meeting (see article this page). The ACD Steering Committee is pursuing coordination with related programs and seeking funds.

For more information, see the ACD web page (www.awi-potsdam.de/www-pot/geo/acd.html), or contact Jerry Brown in Woods Hole, MA (508/457-4982; fax 508/457-4982; jerrybrown@igc.org) or Volker Rachold in Potsdam, Germany (+49/331-288-2144; fax +49/331-288-2137; vrachold@awi-potsdam.de).

Lead Authors Outline Arctic Climate Impact Assessment

The Arctic Council is conducting an international Arctic Climate Impact Assessment (ACIA) to evaluate and synthesize knowledge on climate variability, climate change, increased ultraviolet radiation, and their consequences (see *Witness* Spring 2000). The aim is to provide useful and reliable information to the governments, organizations, and peoples of the Arctic on policy options to meet such changes.

At an October 2000 workshop in Seattle, Washington, the ACIA Steering Committee prepared an extended outline for the assessment with the help of lead authors appointed for each of the assessment chapters. The report outline and lead authors are as follows:

The Arctic System—Gunter Weller (U.S.)

The Arctic as Part of the Global Climate System—Gordon McBean (Canada), Petteri Taalas (Finland), Erland Källén (Sweden), Vladimir Kattsov (Russia), and Betsy Weatherhead (U.S.).

- The Climate System and the Roles of Ozone and UV Processes on the Arctic and the Planet
- Past and Present Changes of Climate and UV Radiation
- Future Changes of Climate and UV Radiation—Modeling and Scenarios for the Arctic Region

Physical and Biological Systems and Their Response to Climate Change— John Walsh (U.S.), Terry Callaghan (Sweden), Jim Reist (Canada), and Harald Loeng (Norway).

- The Cryosphere and Hydrological Variability
- Terrestrial and Freshwater Ecosystems
- Arctic Freshwater Ecosystems
- Oceanic and Marine Ecosystems

Impacts of Climate and UV Changes on Humans and Their Activities—Henry Huntington (U.S.), David Klein (U.S.), Mark Nuttal (U.K.), Glenn Juday (U.S.), Arne Instanes (Norway), Jim Berner (U.S.), and fisheries lead author Hjalmar Vilhjalmsson (Iceland).

- Indigenous Perspectives on Climate Change
- Wildlife and Conservation Issues
- Subsistence Hunting, Fishing, Herding, and Gathering
- Fisheries and Aquaculture
- Forests, Land Management, and Agriculture and Land Use
- Engineered Structures
- Human Health

Contributing authors for each chapter will be identified in the near future. The ACIA is scheduled to be completed by 2004.

For more information, contact Gunter Weller in Fairbanks, AK (907/474-7371, fax 907/474-6722; gunter@gi.alaska.edu).

IASC Convenes Arctic Science Summit Week

The International Arctic Science Committee (IASC) again invited all arctic science organizations to hold their organizational meetings at the annual Arctic Science Summit Week, 22-29 April 2001, in Iqaluit, Nunavut, the capital of Canada's newest territory. The purpose of the summit, held each year in late April, is to provide opportunities for coordination, collaboration, and cooperation in all areas of arctic science and to combine science and management meetings to optimize travel and time. The summit is comprised of a series of meetings of circumarctic organizations, structured around a Joint Science Day. The focus of the third annual ASSW Science Day was "Science and Technology for Sustainable Communities," focusing on both terrestrial and marine resources. The Science Day and other venues provided opportunities for researchers, students, and others to discuss issues of common concern.

The first ASSW took place in April 1999 in Tromsø, Norway; the second in Cambridge, UK (see *Witness* Spring 2000).

For more information, see the IASC web site (www.iasc.no/) or contact IASC Executive Secretary Odd Rogne in Oslo, Norway (+47/2295-9900 fax +47/2295-9901; iasc@iasc.no).

Sverdrup Symposium Focuses on Arctic/Subarctic Oceans

Approximately 70 international scientists assembled for the H.U. Sverdrup Symposium at the Polar Environmental Centre in Tromsø, Norway in September 2000. The Norwegian Polar Institute (NPI) and the Fram Committee hosted the symposium commemorating the *Maud* expedition to the Arctic, which concluded 75 years ago. Professor H.U. Sverdrup, who later became director of Scripps Institution of Oceanography and of the Norwegian Polar Institute (see Member Insert), was responsible for the scientific aspects of the *Maud* expedition.

The symposium provided a current assessment of the role of ocean/sea-ice/atmosphere interaction in polar and subpolar climates. Presentations included:

- mixing and exchange processes,
- fluxes,
- deep water formation, and
- shelf processes.

The proceedings will be published in *Polar Research* in late 2001.

A workshop on Arctic/Sub-Arctic Ocean Fluxes (ASOF) followed the Sverdrup Symposium. The ASOF program is an international effort to measure climatically important oceanic exchanges between the arctic and subarctic seas (see *Witness* Spring 2000). Working groups addressed the following topics:

- ocean fluxes,
- shelf-basin interactions,
- deep sea processes,
- sea ice, and
- paleoclimate.

Participants also discussed methods and platforms for measurements (*e.g.*, satellites, available ice-going vessels, new technologies) and ways of achieving international funding cooperation.

The workshop was organized by Olav Orheim of Norway; the workshop report is available on the ASOF sections of the NPI (www.asof.npolar.no) and the University of Washington (http://psc.apl.washington.edu/search/ASOF.html) web sites. The workshop established the ASOF International Science Steering Group, chaired by Bob Dickson of the U.K. The Steering Group is purposely organized into two groups—ASOF-West and ASOF-East. Members of ASOF-West include Peter Rhines (Deputy Chair), John Calder, Eddy Carmack, Tom Haine, Mark Johnson, Craig Lee, Cecilie Mauritzen, Mike McCartney, Rich Pawlowicz, Simon Prinsenberg, Sergey Pryamikov, Tom Pyle, Peter Schlosser, and a to-be-determined representative from Japan. Members of ASOF-East are Jens Meincke (Deputy Chair), Harry Bryden, Eberhard Fahrbach, Bogi Hansen, Edmond H. Hansen, Peter Haugan, Michael Karcher, Harald Loeng, Jochem Marotzke, Bill Turrell, Ian Vassie, and Richard Wood.

For more information, see the NPI web site (www.npolar.no), or contact Olav Orheim in Tromsø (+47/7775-0620; fax +47/7775-0501; olav.orheim@npolar.no). ■

NSF Pursues Initiative to Coordinate Arctic Measurements

The NSF Office of Polar Programs is assessing community interest and pursuing discussions toward developing a Circumarctic Environmental Observatory Network (CEON) to maximize sharing of and access to scientific observations in the data-poor arctic environment. The CEON initiative would be an agreement to measure the same things, at the same time, in the same way—as much as possible—and to use the internet to share results in near real time. The measured variables would be defined by scientists; station managers and agency officials would be involved only in implementation and funding.

The proposed CEON network focuses on terrestrial sites (see figure), because many such research stations already exist and because the Forum of Arctic Research Operators (FARO; see *Witness* Spring/Autumn 1999) working group recommended restricting initial efforts to land stations. The CEON approach, in concept, also applies to ocean observatories. Programs such as ASOF (see above) and SEARCH (see page 8) will likely use similar approaches for ocean observatories.

For CEON to become a reality, countries with arctic interests would have to involve their own stations and contribute to maintaining or reopening selected Russian stations. Both the U.S. National Oceanic and Atmospheric Administration and NSF are interested in such joint research station programs. Germany has already made significant contributions to the infrastructure of the Arctic and Antarctic Research Institute in St. Petersburg.

NSF has asked ARCUS to work with the international arctic research community to assess interest through an online survey process and discussions at several arctic meetings and to coordinate the U.S. community's contributions to CEON's development. There is strong interest in collaborating with ENVINET, the European Network for Arctic-Alpine Multidisciplinary Research. ENVINET (www.npolar.no/envinet/index.html), funded by the European Union and managed by the Norwegian Polar Institute, is an environmental research network of 17 research stations in Northern Europe.

For more information, contact Arctic Science Section Head Tom Pyle at NSF in Arlington, VA (703/292-8029; fax 703/292-9082; tpyle@nsf.gov). ■

Potential sites for a Circumarctic Environmental Observatory Network (illustration prepared by S. Mitchell).

International News

Geography Shapes Ways of Knowing

In October 2000, the Scott Polar Research Institute (SPRI) formed a new research group to examine socio-technical changes in the Arctic and Antarctica. The new Science and Development Group aspires to examine how the interface between social and natural science structures both:

- methods of inquiry, and
- the terms in which the polar regions are broadly conceived.

Researchers at the Science and Development Group have strong disciplinary allegiances to geography, history of science, and anthropology. They are pursuing comparative studies of scientific and technological practices in different political regions of the Arctic to better understand the cultural basis of:

- research ethics,
- processes of cross-cultural consensus building, and
- the long-term prospects for sustainable management of research environments.

The roles that mapping and communications technologies—including remote sensing imagery—play in development are considered pivotal to understanding the changing political configurations and regimes of environmental management.

The group incorporates historical studies (*e.g.*, the history of fieldwork in the natural and social sciences, the formation of scientific disciplines, geographical concepts of the region) into its analysis of knowledge claims and development issues. Historical precedents can be used to understand new controversies over topics as diverse as the Icelandic human genome project or the conservation of Lake Vostok in Antarctica.

For more information, contact Michael Bravo in Cambridge, UK (+44/1223-336561; fax +44/1223-336549; mb124@cus.cam.ac.uk). ■

Education News

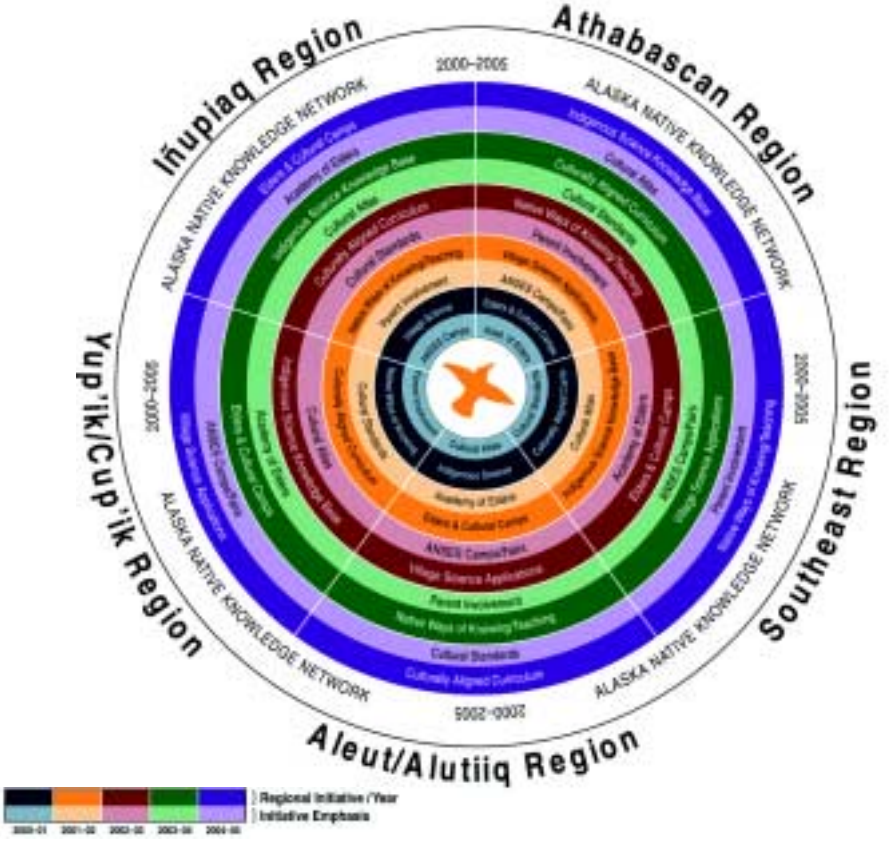
NSF Renews Funding for Alaska Rural Systemic Initiative

In September 2000, NSF funded the Alaska Rural Systemic Initiative (AKRSI) for a second five-year set of initiatives. This work, which is also supported by the Alaska Federation of Natives, began in November 2000 with guidance from Elders and support from communities, educators, and organizations across the region.

In Phase II, each of Alaska's five cultural regions will have an opportunity to implement five initiatives that were very successful in Phase I:

- Elders and Cultural Camps, emphasizing the Academy of Elders;
- Indigenous Science Knowledge Base, emphasizing the Cultural Atlas;
- Culturally Aligned Curriculum, emphasizing Cultural Standards;
- Native Ways of Knowing/Teaching, emphasizing Parent Involvement; and
- Village Science Applications, emphasizing Alaska Native Science and Engineering Society camps.

For more information, see the Alaska Native Knowledge Network web site (www.ankn.uaf.edu) or contact Sean Topkok in Fairbanks, AK (907/474-5897; fax 907/474-5615; sean@arcus.org). ■



In Phase II of AKRSI, each of Alaska's five cultural regions will have an opportunity to implement five initiatives that were very successful in the project's first five years (illustration by Paula Elmes with Ray Barnhardt).

Science Writers Tour Barrow Research Sites

In September 2000, the Barrow Arctic Science Consortium (BASC) hosted 29 journalists from across the U.S. on a three-day Barrow Science Communicators Tour. The tour, cosponsored by BASC (see *Witness* Spring/Autumn 1999) and the Alaska Press Women, preceded a convention of the National Federation of Press Women in Anchorage, Alaska. NSF provided airfare between Anchorage and Barrow, and ARCUS provided financial and logistical support.

Most of the participants were science writers with interests ranging from wildlife biology to languages, Native knowledge, health, and domestic construction. BASC scheduled tours and presentations that covered the broad spectrum of research taking place in Barrow, as well as opportunities to interview local specialists and engage local high-school students. The writers toured:

- the U.S. Department of Energy's Atmospheric Radiation Measurement site (see *Witness* Autumn 1998);
- NOAA's Climate Monitoring and Diagnostics Laboratory facility;
- the Naval Arctic Research Laboratory (see *Witness* Autumn 1997);
- the San Diego State University research aircraft that is used to measure atmospheric carbon and energy fluxes;
- the Iñupiat Heritage Center;
- Ipalook Elementary School and its Solar System (see *Witness* Autumn 1998);
- the North Slope Borough (NSB) Department of Wildlife Management and Arctic Research Facility;
- NSB Search and Rescue Facility; and
- the Barrow Utilities and Electric Cooperative underground utilidor, which delivers water in permafrost conditions.

Presentations introduced the writers to icebreaker science; wildlife contaminants research; beluga whaling, telemetry, and age estimation; snowy owl research; the use of satellite imagery to monitor sea ice; the use of optical signals to monitor functional changes in the arctic ecosystem; Iñupiat language and culture; and the reliance of North Slope science on Iñupiat traditional knowledge.

One of BASC's goals is to draw more researchers and research projects to the American Arctic. The organization recognizes that "press coverage of arctic science projects and science issues is an important way to increase recognition for the North among potential researchers in the United States and around the world."

For more information, contact BASC President Richard Glenn and Executive Director Glenn Sheehan in Barrow, AK (888/627-5724 or 907/852-4881; fax 907/852-4882; basc@barrow.com). ■

CIRES Group gets K–12 Teachers into the Field

Since 1996, the Cooperative Institute for Research in Environmental Sciences (CIRES) in Boulder, Colorado has included an outreach group that organizes Earth science education programs for teachers using a "place-based" approach. Here, learning is through inquiry about the immediate environment, and teachers and scientists work together in the field.

One of the projects run by the CIRES Outreach Program is Earthworks, an inquiry-based professional development workshop for science teachers. Secondary science teachers work with scientists to develop and conduct a week-long research project on the water, air, soils, or living organisms at the workshop's mountain site. According to Program Director Susan Buhr, "teachers gain experience with scientific inquiry themselves, so they are better prepared to go back and do real inquiry with their students."

After her week at Earthworks, Cathi Koehler (Manchester, CT) took her high-school earth science classes outside to study their soils, and then she took her own scientific curiosity to new extremes—to the summit of the Greenland ice sheet. The CIRES outreach group introduced Koehler to CIRES researcher Koni Steffen and graduate student Nicolas Cullen, and helped them apply for funding from NSF's Teachers Experiencing Antarctica and the Arctic Program (TEA; see page 26). Koehler worked with the scientists for a month at Summit, digging snow pits and monitoring clouds, sometimes in bitter arctic winds, to study the movement of energy, moisture, and reactive chemicals between surface snow and the atmosphere.

The value of her field experience was not just personal growth for Koehler. Her deepened understanding of how science works has inspired her to take her students outside to do their own field studies. She says she sees more links between Earth's many systems, applies for more grants for equipment and projects, and trades ideas with a nationwide network of creative science teachers.

The CIRES outreach group has learned much about what helps to involve scientists effectively in outreach:

- social responsibility—an interest in public or local education—and personal enjoyment are scientists' main motivations to participate in outreach;
- outreach roles for scientists—visiting classrooms, mentoring, communicating online—must make efficient use of their time;
- personal connections help CIRES staff match scientists with appropriate opportunities; and
- visible support from others in the science community encourages new scientists to participate in outreach.

CIRES is a joint research institute of the University of Colorado and the National Oceanographic and Atmospheric Administration's Boulder labs, whose affiliated researchers study topics from environmental chemistry to geophysics.

For more information, or for an Earthworks application, see the CIRES web site (http://cires.colorado.edu/~k12/), or contact Tamara Palmer in Boulder, CO (303/492-5670; fax 303/492-1149; k12@cires.colorado.edu). ■

Teachers Convey Technical and Human Aspects of Science

The National Science Education Standards emphasize the importance of providing inquiry-based experiences for students, demonstrating that science is a human endeavor, and underscoring the relevance of science to society. The centerpiece of NSF's Teachers Experiencing Antarctica and the Arctic (TEA) Program is actual field work that engages K–12 teachers in cutting-edge research in the polar regions (see *Witness* Spring 1998). The TEA Program aims to:

- immerse teachers in a research experience as a component of their continued professional development;
- offer research experiences that inform teaching practices, so that science investigations in the classroom model the real process of science;
- carry the polar research experience into classrooms in rich, engaging, and innovative ways that underscore the relevance of science to society and individuals; and
- cultivate a collaborative Polar Learning Community of teachers, students, administrators, researchers, and others, to build on the research experience.

What Do Researchers and Teachers Say?

Kelly Falkner (Oregon State University, Corvallis) was the Arctic Icebreaker Coordinating Committee's (AICC) liaison with the TEA Program for the new U.S. Coast Guard Cutter icebreaker *Healy* ship trials (see page 18). She hosted two TEAs on board and had this to say about her experience: "Early in the planning phases for ice testing of the *Healy*, the AICC recommended that an educational outreach component be included. This materialized in the form of NSF support for five teachers to participate in various aspects of testing the vessel. All of the teachers lent assistance to the on-board science activities while maintaining a web-based journal (see http://tea.rice.edu/tea_meetteachers.html#thearctic). By all accounts—from the Coast Guard to the scientists to students and the general public—the teachers' involvement was extremely successful. Not only were they able to effectively learn about and communicate the excitement of polar science to their classrooms and others, they facilitated good relations on board the ship with a great deal of insight and good humor."

Teacher Sandra Kolb worked with Terry Tucker (Cold Regions Research and Engineering Laboratory [CRREL]) on the *Healy*. She writes, "My roles and responsibilities were not only to support Terry's team in their research but also to translate this experience into daily journals for the TEA web site. I worked with students, teachers, and the public daily, addressing their questions and educational activities by e-mail. My TEA web page continues to be accessed by schools, and I present locally and nationally in classrooms and for teacher workshops. The TEA challenge for me is facilitating the implementation of enduring instructional techniques that are based on inquiry and 'learning science by doing science.'"

Teacher Tim Buckley (ahead) and CRREL researcher Terry Tucker (behind) worked side by side on the Polar Sea *in 1998. Kelly Falkner, the Arctic Icebreaker Coordinating Committee's liaison with the TEA program for the* Healy *ship trials in 2000, wrote, "The teachers' help was invaluable to the complex array of engineering and science goals that comprised the testing program. The very positive impact of these educators on the* Healy*... has led both Coast Guard personnel and scientists to recommend that teacher involvement be considered for all future arctic icebreaker missions" (photo by Aaron Putnam).*

AICC Chair Lisa Clough (East Carolina University, Greenville, NC) has also worked with TEAs aboard Coast Guard icebreakers. She writes, "I have benefited from the perspectives that teachers bring to my project (not to mention the extra hands). I can't tell you how many crew family members were thrilled to be able to go to the TEA web page and find out what's going on during a cruise. The teachers intuitively know how to explain the intricacies of science to the crew. In addition, several crew members want to explore a teaching career when they retire, and the teachers can give them a feel for what that's really going to require."

Martin Jeffries (University of Alaska Fairbanks) has been working with TEAs since Marge Porter (Woodstock, CT) first joined his research team in Antarctica six years ago. Since then, Porter has obtained additional funding to continue her work with Jeffries studying ice growth and heat flow at frozen ponds at Poker Flat, Alaska. Of his experience, Jeffries says, "I have enormous respect for the efforts that she and teachers like her make to pursue professional development opportunities that enhance their teaching strategies and enrich students' learning experiences. I have learned much about K–12 education in general, and science education in particular, and have a new appreciation for the challenges that teachers face on a daily basis. Scientific researchers have much to offer teachers and vice versa. I recommend working with a teacher (or teachers) for a mutually beneficial and professionally and personally fulfilling experience."

TEA is a partnership between teachers, researchers, students, school districts, and communities. The program is sponsored by NSF's Division of Elementary, Secondary, and Informal Education in the Directorate of Education and Human Resources and the NSF Office of Polar Programs. It is facilitated by Rice University, CRREL, and the American Museum of Natural History.

For more information, see the TEA Program web site (http://tea.rice.edu), or contact Deb Meese (603/646-4594; fax 603/646-4644; dmeese@crrel.usace.army.mil) and NSF Arctic Social Sciences Program Director and Science Education Liaison Fae Korsmo (703/292-8029; fax 703/292-9082; fkorsmo@nsf.gov).

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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

May 16–20 Fourth International Congress of Arctic Social Sciences (ICASS IV), "The Power of Traditions: Identities, Politics, and Social Sciences." Quebec City, Canada. Contact the Organizing Committee in Quebec City (418/656-7596; fax 418/656-3023; iassa.getic@fss.ulaval.ca) or Peter Johnson in Ottawa (613/562-5800 ext 1061; fax 613/562-5145; peterj@aix1.uottawa.ca).

May 23–25 ARCUS 13th Annual Meeting and *Arctic Forum*. Arlington, VA. Contact Diane Wallace in Fairbanks, AK (907/474-1600; fax 907/474-1604; diane@arcus.org; www.arcus.org/annual_meeting_01/index.html).

May 28–31 Impact of Climate Change and UV in the Russian Arctic: Arctic Climate Impact Assessment (ACIA) Workshop. St. Petersburg, Russia. Contact Odd Rogne at the International Arctic Science Committee Secretariat in Oslo, Norway (+47/2295-9900; fax:+47/2295-9901; iasc@iasc.no; www.iasc.no) or Gunter Weller in Fairbanks, AK (907/474-7371; fax 907/474-7290; gunter@gi.alaska.edu).

June 6–8 International Symposium on Climate Change and Variability in Northern Europe—Proxy Data, Instrumental Records, Climate Models, and Interactions. Turku, Finland. Contact Mia Ronks (+358/2333-6009; fax +358/2333-5730; miaron@utu.fi; http://figare.utu.fi).

July 10–13 Global Change Open Science Conference. Amsterdam, Netherlands. Contact the IGBP Secretariat in Stockholm, Sweden (+46/816-6448; fax +46/816-6405; sec@igbp.kva.se; www.sciconf.igbp.kva.se).

July 16–20 Detecting Environmental Change: Science and Society. London, U.K. Contact Catherine Stickley in London (+44/20-7679-5562; fax +44/20-7679-7565; c.stickley@ucl.ac.uk; www.nmw.ac.uk/change2001).

August 19–23 Symposium on Ice Cores and Climate. International Glaciological Society. Kangerlussuaq, Greenland. Contact the Secretary General in Cambridge, U.K. (+44/1223-355974; fax +44/1223-336543; int.glaciol.soc@compuserve.com).

August 19–21 Seventh Circumpolar University Co-Operation Conference. Tromsø, Norway. Contact the Roald Amundsen Centre for Arctic Research in Tromsø (+47/77-64-5241; fax +47/7767-6672; frits.jensen@arctic.uit.no; www.arctic.uit.no/cua/).

September 19–22 52nd AAAS Arctic Science Conference. Anchorage, AK. Contact Don Spalinger (907/267-2190; don_spalinger@fishgame.state.ak.us; http://hosting.uaa.alaska.edu/afdes/AAAS2001).

For more information, check the Calendar on the ARCUS web site (www.arcus.org/misc/fr_calendar.html).

Publications

Emergency Prevention, Preparedness and Response Working Group (EPPR). 1998. *Field Guide for Oil Spill Response in Arctic Waters.* Environment Canada, Yellowknife, NT Canada, 348 pages. $45 CAD. Contact David Tilden (867/669-4728; fax 867/873-8185; david.tilden@ec.gc.ca; http://arctic-council.org).

Arctic Environmental Sensitivity Atlas System (CD-ROM). Environment Canada, Yellowknife, NT Canada. $45 CAD. Contact David Tilden (867/669-4728; fax 867/873-8185; david.tilden@ec.gc.ca; www.mb.ec.gc.ca/pollution/spills/ed00s00.en.html).

Stein, R. (ed.) 2000. Circum-Arctic River Discharge and its Geological Record. 2000. Special issue of *International Journal of Earth Sciences* 89(3). Contact Ruediger Stein (+49/471-4831-1576; fax +49/471-4831-1580; rstein@awi-bremerhaven.de; http://e-net.awi-bremerhaven.de/GEO/APARD/NewsLetter4/APARD-NL-4.html).

Enhancing NASA's Contributions to Polar Science: A Review of Polar Geophysical Data Sets. 2001. National Research Council, Polar Research Board. National Academy Press ($31; 800/624-6242; www.nap.edu).

A Note From the ARCUS Executive Director

We have taken several important steps over the past year to improve our ability to serve the arctic research community and would like to update you on some of these activities. More information is available at www.arcus.org.

ARCUS Washington, DC Office

For several years, both the member institutions of ARCUS and the agencies engaged in arctic research have encouraged ARCUS to develop a presence in Washington, DC to facilitate communication with agencies, other federal entities, and relevant scientific organizations. In September 2000, Suzanne Bishop opened the Washington, DC office of ARCUS, representing the organization and its members to agency representatives and Congress on a wide variety of issues affecting arctic research. Suzanne, who has extensive experience in academic public relations, is available to assist arctic researchers in their efforts to advance arctic research issues at the federal level (703/979-7461; fax 703/979-7460; bishop@arcus.org).

Award for Arctic Research Excellence

The winners of the Fifth Annual ARCUS Award for Arctic Research Excellence reflect the quality of young researchers working in the Arctic and the diversity of their research. The abstracts of the winning and honorable mention student papers and a listing of all the 2001 participants can be found on the ARCUS web site. The 2001 winners are:

Interdisciplinary Research: Valerie Barber, University of Alaska Fairbanks.

Social Sciences: Dyanna Riedlinger, University of Manitoba, Winnipeg.

Life Sciences: Tim Karels, University of Toronto at Scarborough.

Physical Sciences: Luke Copland, University of Alberta, Edmonton.

The winners have been invited to present their work at the *Arctic Forum* and will receive a $500 honorarium. The announcement and entry information for the Sixth Annual ARCUS Award for Arctic Research Excellence (2002) will be distributed to the community in late summer 2001. We hope that you will look for it and encourage young researchers to submit papers to the competition.

ARCUS Annual Meeting

The ARCUS 13th Annual Meeting will be held at the Sheraton Crystal City in Arlington, VA on 23–25 May 2001. A highlight of the Annual Meeting is the interdisciplinary *Arctic Forum*, a science symposium that includes oral and poster presentations. The 2001 *Arctic Forum* will focus on interactions between physical and biological systems in the Arctic and will be held 24 and 25 May.

ARCUS Main Office Moves

The ARCUS office has a new address:

3535 College Road, Suite 101
Fairbanks, AK 99709-3710
Phone 907/474-1600
Fax 907/474-1604

Email and web addresses remain the same.

Inside

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