Witness The

ARCTIC

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Arctic Research at Oregon State University

A land grant university, Oregon State University was designated as Oregon's state-assisted agricultural college in 1868. Sea grant and space grant designation came later, making OSU one of only six universities to have all three titles. OSU currently enrolls 15,599 undergraduate and 3,380 graduate students in more than 200 undergraduate and 80 graduate degree programs.

With collaborative connections across the globe, OSU researchers contribute to arctic research from disciplines housed in a variety of colleges. The College of Oceanic and Atmospheric Sciences (COAS) has several researchers working on arctic projects; OSU investigators in departments as diverse as Anthropology, Geosciences, Fisheries and Wildlife, Environmental and Molecular Toxicology, Chemistry, and Bioengineering also focus on arctic research. With the growing recognition of the significance of change in the Arctic for the region and the world, the commitment to arctic research at OSU is expanding. This insert highlights recent accomplishments and current projects.

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Geosciences

Polar Ice Cores

Ed Brook (Geosciences) applies geochemical techniques to diverse problems in late Quaternary paleoclimatology; several of his projects have arctic components. NSF-supported work focused on the relative timing of millennial-scale abrupt climate change in Greenland and Antarctica uses atmospheric methane and the isotopic composition of oxygen as correlation tools to place climate records from the Siple Dome (west Antarctica) and GISP2 (Greenland) ice cores on a precise common chronology for the period from 9–57 ka. The onset of major millennial warming events in Siple Dome precedes major abrupt warmings in Greenland, and the pattern of millennial change at Siple Dome is broadly similar, though not identical, to that previously observed for the Byrd ice core (also in west Antarctica). The addition of Siple Dome to the database of well-dated Antarctic paleoclimate records supports the case for a regionally consistent pattern of millennial-scale climate change in Antarctica during the last ice age and glacial-interglacial transition.

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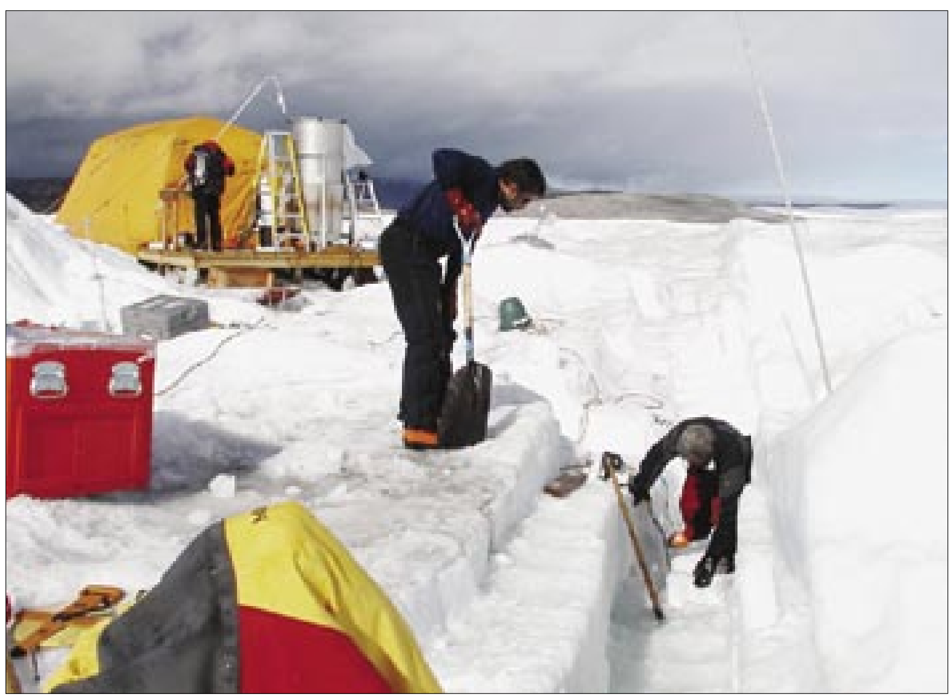

Ed Brook (leaning on shovel) next to a trench through steeply dipping ice layers at the Younger Dryas/Holocene boundary (about 11.7 ka) at the margin of the Greenland Ice Sheet at Pakitsoq, near Ilulissat on the west Greenland coast. Photo by Jeff Severinghaus, Scripps Institution of Oceanography.

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With colleagues at the University of California, San Diego, and the Danish Technical University, Brook is investigating the feasibility of extracting large volumes of ancient air from old ice outcroppings at the Greenland Ice Sheet Margin. Obtaining air samples large enough to analyze carbon-14 in atmospheric methane could resolve a major argument about the role of seafloor methane hydrates in late Quaternary climate change. Fieldwork at Pakitsoq, near Ilulissat on the west Greenland coast (photo previous page), reveals that well-preserved trace gas records from ice margin sites are recoverable. Techniques for collecting large (1–2 ton) ice samples and extracting the air onsite were developed and employed in the summers of 2002, 2003, and 2004. Sample processing for stable carbon isotopes and carbon-14 is underway.

Dating Glacial Events

During the last glaciation, outlet glaciers draining the Laurentide Ice Sheet through the Torngat Mountains of northern Labrador deposited a prominent moraine system, which suggests that ice extent along the eastern Canadian seaboard was restricted. The age of the moraines remained unknown, however, until Peter U. Clark and Ed Brook (both of the Department of Geosciences) applied cosmogenic nuclide exposure (CNE) dating to material from the site. Funded by NSF, the new CNE ages demonstrate that the moraines were deposited late during the last deglaciation, possibly in association with the Younger Dryas cold reversal.

Clark and Ph.D. student Anders Carlson, working with Gary Klinkhammer (COAS), are reconstructing the routing of continental runoff that occurred with fluctuations of the Laurentide Ice Sheet margin. By analyzing the geochemistry of foraminifera from sediment cores from Hudson Strait, the team hopes to identify geochemical signals associated with changes in surface water runoff that occurred as the ice sheet over Hudson Strait retreated.

Glacial Erosion Rates

A site of active mountain building (as evidenced by large earthquakes in 1899 and 1979), the Chugach/St. Elias mountain range in southern Alaska has been glaciated for much of the last 6 million years; its glaciers produce the largest volume of sediment from their drainage basins of any glaciers on the planet. Andrew Meigs (Geosciences), has been working on the general problem of feedback between growth of mountain belts, climate, and erosion with support from NSF and OSU. Working with four graduate students, two undergraduates, and colleagues at OSU and Virginia Polytechnic Institute and State University, Meigs has found that deformation and erosion have been concentrated on the windward, southern flank of the range, but that the rates are considerably lower on 10^5 yr and longer timescales than they are on 10^2 yr and shorter scales. The discrepancy in erosion rates in particular is apparently explained by a profound landscape and glacier response to the shift from the Little Ice Age to the present climate beginning at the start of the 20th century. Glacial retraction throughout the landscape is responsible for a short-term, but enhanced, increase in the rate of erosion over much of the mountain range. These observations are consistent with an emerging paradigm suggesting that landscape-scale geomorphic disequilibrium, perpetuated by the switching between glacial and interglacial climates that characterized the late Cenozoic, enhanced erosion rates globally throughout the Pleistocene.

OSU Geoscience graduate students Sarah Johnston (left) and Meghan Blair (right) in the northern Chugach Range, Alaska, working on sediment storage and evacuation in a 7-km long lake formed as Tana Glacier advanced across the outlet of Granite Creek. Photo courtesy A. Meigs.

Remote Sensing of Snow and Ice

A member of the science team for NASA's Multi-angle Imaging SpectroRadiometer (MISR), Anne Nolin (Geosciences) uses multi-angle and multi-spectral sensors to improve techniques for mapping ice-sheet albedo, ice-sheet roughness, and snow-covered locations with vegetation cover. Information from MISR measurements over snow and ice contributes to a number of collaborative NASA-funded projects. With Eugene Clothiaux (Pennsylvania State University), Nolin is improving arctic energy budget estimates by combining new EOS-era products from multiple satellite sensors, using MISR data to characterize surface roughness and reflectance anisotropy on the Greenland ice sheet. With OSU student Dave Selkowitz, Nolin is observing forest cover characteristics and snowpack dynamics under different climate conditions, using MISR data to simultaneously estimate snow-covered area and vegetation density. With Jeff Dozier (University of California, Santa Barbara), Tom Painter (University of Colorado), and others, Nolin is developing multi-resolution snow products for the hydrological sciences, using MISR-derived estimates of vegetation density to improve estimates of snow-covered area.

Paleoceanography and Sedimentation

In August and September 2004, an interdisciplinary team aboard the R/V *Ewing*, led by co-chief scientists Alan Mix (COAS) and John Jaeger (University of Florida), surveyed and sampled sites in Southeast Alaska fjords and open ocean to contribute to two complementary projects funded by NSF. With co-investigators Nick Pisias, Fred Prahl, Joe Stoner (all of COAS), Larry Mayer (University of New Hampshire), Ellen Cowan (Appalachian State University), Bruce Finney (University of Alaska Fairbanks), Sean Gulick (University of Texas), and Ross Powell (Northern Illinois University), the projects seek to:

- assess whether rapid climate oscillations seen in historical records are recorded in fjord and continental margin sediments;

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- determine whether climate changes since the last ice age and their biological responses are linked to changes in regional ocean conditions;
- establish whether current rapid melting of Alaskan glaciers observed over recent decades is an unprecedented anomaly associated with greenhouse warming or within the range of natural variations over the past 10,000 years;
- understand how continental margin strata accumulate at exceptionally high rates in response to interactions of tectonic uplift, climate forcing, and erosion by ice and water; and
- carry out process studies on the geologic response to rapid historical deglaciation in Glacier Bay National Park, Yakutat Bay, and Prince William Sound.

Operations included sediment coring, observing marine mammals, sampling water masses, phytoplankton, and benthic faunas to calibrate paleo-tracers, and surveying the seafloor using advanced swath bathymetry and subsurface profiling to understand sedimentation processes and history. Both projects will provide site survey information for possible future drilling under the auspices of the Integrated Ocean Drilling Program (see page 24).

Geochemistry of the Gakkel Ridge

David Graham (COAS) is part of an international team studying the petrology and geochemistry of the Gakkel Ridge in the Arctic Ocean, the slowest-spreading end-member of the global mid-ocean ridge system. During August and September 2001, the U.S. Coast Guard icebreaker *Healy*, in collaboration with the German ice-breaker *Polarstern*, carried out a high-resolution mapping and sampling expedition to the high Arctic and North Pole (see *Witness* Spring 2002).

The Arctic Mid-Ocean Ridge Expedition (AMORE) spent nine weeks in ice-covered seas producing a continuous map of the seafloor using multi-beam sonar. This map covers approximately 1100 km of the ridge, with an average width of ~25 km, at a resolution of less than 10 meters. Hydrocast sampling provided evidence of hydrothermal venting in the water column of the Arctic Ocean and the presence of vent-related biota. Seafloor rocks were recovered by dredging from over 200 localities along the Gakkel Ridge between 8°W and 85°E. A 300-km long central amagmatic zone lies between abundant, continuous volcanism in the west and large, widely spaced volcanic centers in the east. In this central magma-starved region, mantle peridotites are directly emplaced onto the seafloor along the ridge axis; the petrologic results show that the extent of melting in the upper mantle beneath ocean ridges is not a simple function of spreading rate. The basalts and peridotites sampled along the Gakkel Ridge show significant chemical and isotopic variations, due to long-lived chemical heterogeneity in the underlying mantle that is related to the tectonic history of the surrounding land masses. For more information on AMORE, see www.earthscape.org/frames/news2frame.html.

Paleomagnetics

Joseph Stoner recently joined the Marine Geology and Geophysics group in COAS. Formerly at the University of Colorado Institute of Arctic and Alpine Research, he has conducted a number of paleo-magnetic studies in arctic lake and ocean settings.

Oceanographic Research

Change and Variability in the Arctic Ocean

COAS researchers and a number of collaborators contribute to the Arctic Freshwater Initiative sponsored by NSF (see *Witness* Spring 2004). Led by Kelly Falkner, with contributions by Marta Torres and Roger Samelson (all of COAS), this group has targeted measurements of the variability of fluxes and their forcings through Nares Strait. Ultimately, the aim is to understand the relationships between the fluxes of fresh water, seawater, and ice through passages of the Canadian Archipelago and potential forcings, so that a cost-effective monitoring system can be emplaced. More details can be found on page 8 of this issue of *Witness the Arctic* and on the project web site: http://newark.cms.udel.edu/~cats.

Falkner also participates in the NSF-funded North Pole Environmental Observatory (NPEO; see *Witness* Spring 2004), led by Jamie Morison of the University of Washington. Designed to monitor change in the central Arctic Ocean, the NPEO has been in place four years, is intended to continue for at least four more years, and consists of three general components:

- instrumented buoys deployed in the ice,
- deep-sea moorings in the vicinity of the North Pole, and
- hydrographic sections at key locations in the central Arctic Ocean.

Falkner is responsible for water sampling and chemical measurements for the hydrographic program. For more information, see the NPEO web site: http://psc.apl.washington.edu/northpole.

Kelly Falkner of Oregon State University's College of Oceanic and Atmospheric Sciences (right) releasing messenger with Jamie Morison (University of Washington Applied Physics Laboratory) at a North Pole Environmental Observatory aircraft-based hydrographic station in spring 2003. Photo by Jim Haffey.

The Arctic Ocean Atmosphere, Ice, Sediment, and Water Column

The first surface ship crossing of the Arctic Ocean through the North Pole, the 1994 Arctic Ocean Section was a major joint U.S.-Canadian effort. From July to September, two icebreakers, the CCGS *Louis S. St. Laurent* and the USCGC

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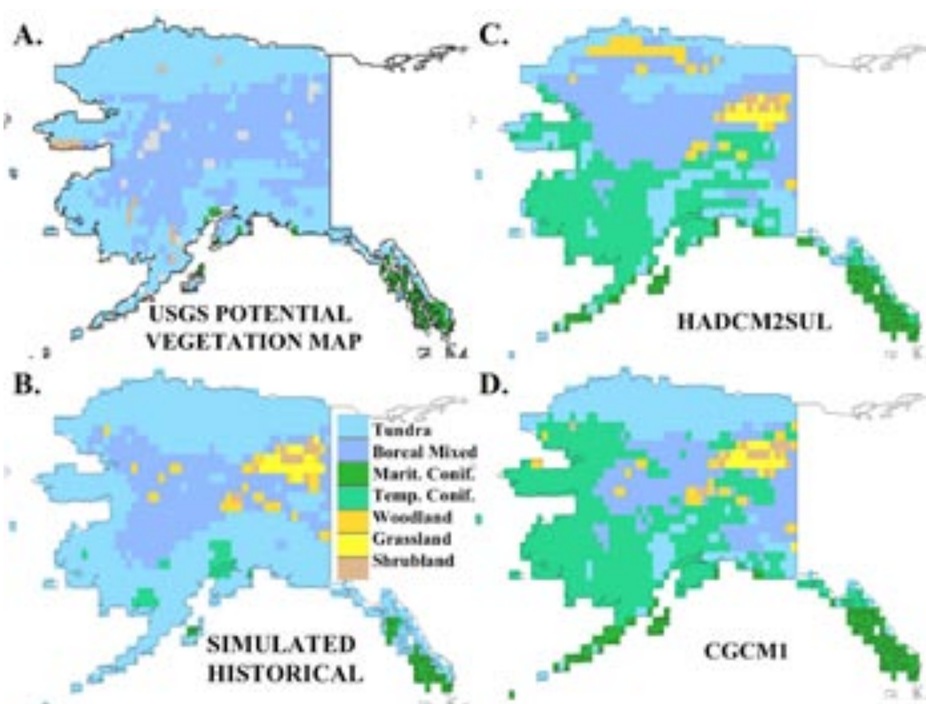
Iñupiat and western scientists plan collaborative research on contaminants in freshwater environments in northern Alaska. During an early planning meeting in Barrow, elder Joshua Nashaknik (far left) discusses good places for whitefish at several subsistence fish camps with (left to right) Jesse Ford (OSU), elder Warren Matumeak, elder James "Jake" Kignak, and translator Maasak Akpik. Not pictured: Joeb Woods, Sr. Photo by Susan Allen-Gil, Ithaca College.

from Eurasian pollution centers unknown. Against this spare background, the influence of local point sources of particulate elements can be seen easily. In contrast to particulates, semivolatile organochlorine compounds show distinctly different signatures in Alaska versus the Taimyr. These results are consistent with the global distillation model in which contaminants that volatilize in warm low latitudes later condense and are deposited in cold higher latitudes, resulting in a net poleward movement of the lighter PCB congeners.

The recent discovery of sockeye salmon *(Oncorhynchus nerka)* as an important vector of PCBs to inland lakes in southcentral Alaska brought the relative role of atmospheric deposition to aquatic foodwebs into question. It also raised the issue of whether similar processes might be influencing arctic freshwater habitats further north, where atmospheric inputs might be expected to be higher (due to lower temperatures) and biotransport by fish lower (due to differences in species composition). On the western Alaska Coastal Plain, salmon are relatively rare, but a substantial subsistence fishery targets several species of whitefish that use both marine and freshwater habitats. Funded by NSF, collaborative work with Ithaca College and local Iñupiat whitefish experts has demonstrated that differences between freshwater resident versus seagoing least cisco *(Coregonus sardinella)* and broad whitefish *(C. nasus)* are minor and that, again, contaminant burdens are relatively low. Associated work by OSU graduate student John Seigle used otolith microchemistry to investigate contemporary life histories of least cisco. Contrary to conventional wisdom that least cisco feed in brackish water during the summer, less than 10% had ever used marine habitat, although use of marine habitat was found to be common in broad whitefish.

Climate Change Modeling

Dominique Bachelet (Bioengineering) and colleagues at OSU and the U.S. Forest Service (USFS) have developed the Dynamic Global Vegetation Model (DGVM) MC1 to predict what climate change scenarios will mean in terms of vegetation growth, plant and soil processes, carbon storage or emissions, forest fire, and other important ecological effects. Funded by USFS, the model's preliminary results point toward significant changes to Alaskan ecosystems. Under a climate scenario that projects significant warming (CGCM1), the model suggests that 90% of the tundra present in Alaska in 1920 could be gone by 2100, with the only large area remaining near the north coast. Under a more conservative scenario (HADCM2SUL), the DGVM indicates that 77% of the tundra could disappear during that time. Interior boreal mixed forests could migrate towards the northeast, yielding to maritime and temperate conifer forests much like those of southeast Alaska (figure below). Because of an increase in statewide biomass with the northward advance of the temperate coniferous forest, the area burned by wildfires increases across the entire state. Insects and pathogens may also cause massive epidemics of plant disease and insect attack—in some cases causing large forest die-offs that could then lead to even more fires.



Under two scenarios of future climate, the Dynamic Global Vegetation Model (DGVM) predicts a loss of total area of tundra and a significant expansion of temperate coniferous forest in Alaska by 2100. A) Potential vegetation map (re-sampled digital map of the Major Ecosystems of Alaska, U.S. Geological Survey, approx. 1991) and simulated vegetation distribution under B) historical climate conditions 1922–1996, and under two climate change scenarios C) HADCM2SUL and D) CGCM1 for the decade 2090–2100. Figure by D. Bachelet.

Anthropology

Changes in Subsistence and Culture

Deanna Kingston (Anthropology) is currently working on four projects related to the history and culture of the Ugiuvangmiut, or King Island Iñupiat of Bering Strait. Members of the King Island community began to leave the island in the late 1950s and now live primarily in the regional center of Nome.

Kingston led the King Island component of an NSF-funded collaborative project comparing changes over the past 70 years in three northern Bering Strait societies: Little Diomede Island, King Island, and Wales. For more information, see *Witness* Spring 2004.

In a second project funded by the Pacific Walrus Conservation Fund, Kingston, Jesse Ford, and Selina Heppell (both of OSU Fisheries and Wildlife) interviewed 19 King Island walrus hunters to learn more about their knowledge of walrus biology and population.

A third project, also funded by NSF, is getting underway. Kingston and Ford have begun logistics planning for two field seasons documenting the cultural geography, biogeography, and traditional ecological knowledge on King Island. This involved helicopter trips to King Island to take aerial photographs and assess conditions on the island and in the former village for the field seasons in 2005 and 2006. Using aerial photographs taken by archaeologist Matt Ganley (Bering Straits Foundation), Kingston worked with King Island elders, Ganley, and linguist Larry Kaplan (University of Alaska Fairbanks) to document and map more than 100 placenames on King Island (see photo). In addition to Kingston, Ford, Ganley, and Kaplan, the research team includes 10–15 King Island elders, 30–40 King Island research assistants and interns, seabird biologist Kim Nelson (OSU Fisheries and Wildlife), geoarchaeologist Owen Mason (University of Alaska Anchorage), Claire Alix (University of Alaska Fairbanks), videographer David Bogan (Green Mountain Documentary), and a marine mammal biologist.

Finally, Kingston interviewed King Islanders to document the effect that moving to Nome and elsewhere has had on the culture and society of the King Island Native community. These interviews form a small part of a larger project entitled "Collocation Cultural Impact Assessment: Coastal Erosion Protection and Community Relocation, Shishmaref, Alaska," funded by the U.S. Army Corps of Engineers and directed by Peter Schweitzer (University of Alaska Fairbanks). Preliminary results of these interviews indicate that the relocation to Nome was detrimental to the King Island Native community.

Aerial photograph of King Island on 12 July 2004 from the south, looking north. The village is located in the lower center. The cold storage cave, Qaitquq, is on the lower right. Photo by Matt Ganley.

Ecosystems

Atmospheric Deposition

Staci Simonich (Departments of Environmental and Molecular Toxicology and Chemistry) is currently funded by the National Park Services Air Resource Division to study the atmospheric deposition of anthropogenic semi-volatile organic compounds to high elevation ecosystems in eight western national parks, including Denali, Noatak, and Gates of the Arctic National Parks. The goal of this research is to assess the deposition of airborne contaminants, providing regional and local information on exposure, accumulation, impacts, and probable sources. Airborne contaminants are traced through the high elevation ecosystems from the atmosphere to snow, vegetation, lake water, fish, and sediment. Other OSU researchers involved in this project include Carl Schreck (Fisheries and Wildlife) and Michael Kent (Microbiology and Fisheries and Wildlife). For more information, see the project web site: http://www2.nature.nps.gov/air/studies/air_toxics/wacap.htm.

Contaminant Biogeochemistry in Terrestial and Freshwater Ecosystems

Jesse Ford (Fisheries and Wildlife) uses a diversity of techniques to examine the sources, status, and significance of anthropogenic contaminants, including semivolatile organic compounds, elemental particulates (e.g., lead, copper), and mercury, in terrestrial and freshwater landscapes. One aspect of this work is determining relative contributions of long-range atmospheric transport, local point sources, and biotransport by anadromous fish from marine to freshwater environments.

In work funded by the U.S. Environmental Protection Agency, the moss monitoring technique was used to delineate spatial patterns of contaminant deposition in the U.S. Arctic and selected regions of the Russian Arctic. This work demonstrated that both arctic Alaska and the Taimyr Peninsula north of Norilsk have surprisingly low concentrations of particulates related to arctic haze, leaving the ultimate depositional fate of contaminants

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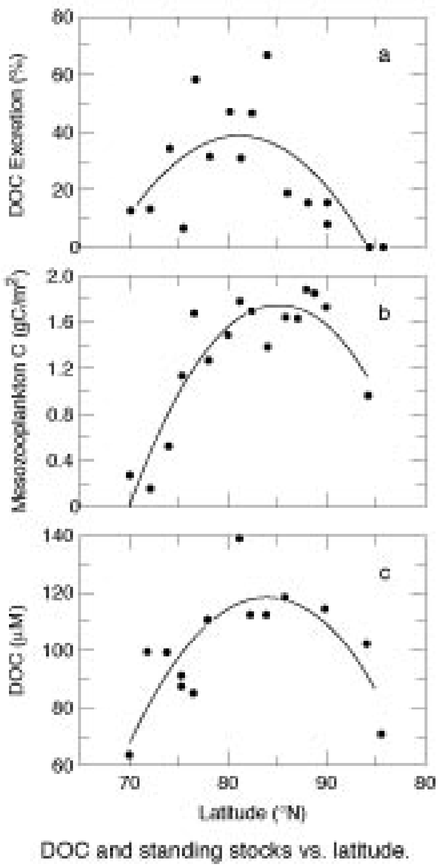

Data from the 1994 Arctic Ocean Section indicating significant cycling of organic carbon in the upper 100 m of the central Arctic Ocean. a) Percentage of phytoplankton production released as extracellular carbon. b) Zooplankton standing stocks for 1-100 m. c) Dissolved organic carbon in the surface water. Figure by P. Wheeler.

Polar Sea, entered the Arctic through the Bering Strait, proceeded across to the Makarov Basin to the North Pole, crossed the Eurasian Basin and exited through the Greenland Sea. Despite difficult ice conditions and mechanical problems, the first U.S. and Canadian surface ships to ever reach the North Pole were able to conduct successful atmospheric, ice, water column, and sediment samplings along the transect. Only one scientific program was not accommodated. P. A. Wheeler (COAS) edited the special issue of *Deep-Sea Research II* (Vol. 44 No. 8) reporting the expedition's results in three major areas:

- ocean circulation, chemistry, and geochemistry,
- biological communities and production rates (figure above), and
- sedimentary and geological processes.

Basin-scale Changes in the Arctic Ocean

Timothy Boyd (COAS) studies variability in circulation, heat, and salt content of the upper layers of the Arctic Ocean, using historical hydrographic data, as well as contemporary data collected by icebreaker and U.S. Navy submarine cruises. The submarine data were collected with Office of Naval Research (ONR) and NSF funding as part of the 1995–99 SCICEX program (see *Witness* Autumn 2001) and subsequent submarine science accommodation cruises supported by ONR. With colleagues at the University of Washington and Earth & Space Research, Boyd's analyses of the SCICEX expendable CTD (XCTD) data sets have revealed significant basin-scale changes underway in the mid-1990s to early 2000s, including:

- disappearance and subsequent recovery of the arctic cold halocline in the Eurasian Basin;
- increased temperature in the core of the Atlantic water layer through much of the Eurasian and some of the Canadian basins; and
- displacement of the boundary between Atlantic and Pacific water mass assemblies.

Funded by ONR, Boyd is processing data from the most recent submarine sampling in fall 2003. For more information, see Boyd's web site: http://boreas.coas.oregonstate.edu.

Subsistence Whaling

The annual migration of bowhead whales (*Balaena mysticetus*) past the northern shores of Alaska has provided opportunities for subsistence whaling for generations. Subsistence whaling remains key to a mixed hunting/wage economy and to maintenance of traditional lifestyles, including food, barter, art, oral history, and cultural identity. The complex system of environment-whale-human factors is vulnerable both to environmental and human generated change.

Yvette H. Spitz and Evelyn and Barry Sherr (all of COAS) are involved in a project funded by NSF to study the coupling between atmosphere, sea ice, ocean, bowhead whale, and subsistence whaling (see page 10). The project seeks to identify and understand the response and resilience of the components of this system to climate variability through four approaches:

- biological and physical ocean modeling,
- high-resolution field sampling to demonstrate presence of physical fronts and associated biological concentrations and to validate modeling,
- assessment of the resilience and vulnerability of the subsistence hunting economy and culture in Barrow, Alaska, and
- retrospective analysis synthesizing modeled ocean and climate conditions with available information on whale location, feeding, and harvest success.

Residents of Barrow butchering Captain James Itta's spring whale in 1996. Photo © Luciana Whitaker.