Launch of the Anti-Electron Sub Orbital Payload instrument from NASA's Columbia Scientific Balloon Facility in Kiruna, Sweden, in June of 2006. This balloon is made of a polyethylene film (the same type of material used to make trash bags), weighs approximately 5,000 pounds, and can carry an 8,000-pound load. Photo by Andrew McDermott.

Bartol Research Institute section continued from page 2.

complete, and the results were published in the proceedings of the 30th International Cosmic Ray Conference. A NASA proposal to refly AESOP and LEE was also recently awarded.

Spaceship Earth

With support from the Office of Polar Programs and the Solar Terrestrial Program at NSF, the Bartol Research Institute leads Spaceship Earth, a strategically located network of cosmic ray detectors (called neutron monitors) in Earth's polar regions. John Bieber is the principal investigator and his co-investigators are Paul Evenson, K. Roger Pyle, and John Clem.

Currently four countries—the U.S., Russia, Australia, and Canada—contribute to Spaceship Earth, which consists of 11 monitoring sites providing precise, real-time, three-dimensional quantity and distribution measurements of cosmic rays impacting Earth from space. The Bartol Research Institute operates 6 of the 11 monitors—one in Thule, Greenland; four in Canada (Inuvik and Fort Smith, in the Northwest Territories, Peawanuck in Ontario, and Nain in Labrador); and one at McMurdo Station in Antarctica. A station in Mawson, Antarctica, is operated by Australia, and the Apatity, Norilsk, Tiksi Bay, and Cape Schmidt stations are all located in and operated by Russia.

A cosmic ray approaching Earth first encounters Earth's magnetic field. The magnetic field repels some particles altogether and deflects others. Computers at the monitoring sites track the path of cosmic rays through the magnetic field and determine how the starting direction is related to the impact point.

The Spaceship Earth sites are located in the Arctic, subarctic, and Antarctic because cosmic rays in high latitude regions arrive from a relatively narrow range of directions (compared to low latitude sites) due to the combined effects of Earth's magnetic field and atmosphere. This makes the source direction easier for the monitors to detect.

Real-time and past data from the neutron monitors are available on the Bartol Research Institute website at: www.bartol.udel.edu/.

UD's Inuit Art Collections

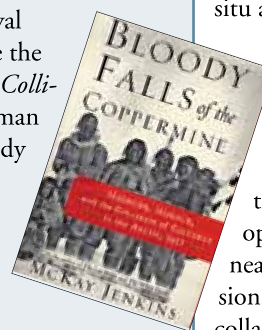
UD's collections of Inuit art and artifacts offer the public insight into the rich culture and heritage of the Inuit and serve as an important focus of research and teaching by faculty and students of the University Gallery and Center for Material Culture Studies. For more information on these world-class collections, go to: www.udel.edu/museums/.

The Frederick and Lucy S. Herman Native American Art Collection, a gift to UD in 2000, features nearly 200 Inuit drawings. Veteran collectors of American and European art, the Hermans began collecting Inuit art nearly 20 years ago, attracted by drawings that depicted a society in transition with increasing exposure to and influence from the outside world. The artwork portrays the Inuit's everyday lives and traditions over the span of three generations, including scenes of their hunts, wildlife in their environment, and their rituals, myths, and legends.

The Mabel and Harley McKeague Collection of Alaskan Inuit Artifacts, acquired by UD in 2001, includes baskets, dolls, and toys, which the McKeagues amassed while collecting vital statistics about Yup'ik communities in western Alaska for the Alaska Department of Health and Welfare from 1958 to 1964. A significant component of the collection is Mabel McKeague's notes, letters, and slides of her experiences in Alaska. The McKeagues came to know more than 2,500 villagers and visited every home in the 11 settlements they surveyed.

Sophie Nevak (left) holding a ptarmigan chick and Mabel McKeague (right) holding a sandpiper chick, in Nelson Island, Alaska, July 1962. The photographer is unknown but was possibly Harley McKeague. This photo is part of the collection given by Mr. Harley McKeague and Mr. and Mrs. John Bennick in honor and memory of Mabel and Harley McKeague.

Book Tells of Collision of Cultures in the Arctic



As part of his research for this book, author McKay Jenkins traveled to Kugluktuk, an Inuit outpost at the mouth of the Coppermine River in the summer of 2003. He witnessed first-hand a number of troubles Denny LaNauze predicted 90 years ago, including public health concerns like diabetes and alcoholism, widespread poverty, and growing disconnection from traditional ways of Inuit life.

The murder of two priests by Eskimos, the hunt for the men who killed them by Royal Northwest Mounted Police, and the subsequent trials of the men who confessed are the subject of the non-fiction book *Bloody Falls of the Coppermine: Madness, Murder and the Collision of Cultures in the Arctic in 1913*. Written by McKay Jenkins, the Cornelius A. Tilghman Professor of English at UD, and published by Random House in 2005, the book is a study of Eskimo way of life in the Arctic—where their people had lived for centuries before western civilization brought about change.

The saga begins with the two priests, Father Jean Baptiste Rouvière and Father Guillaume LeRoux, on a mission to spread Christianity near the Coppermine River, located north of the Arctic Circle. Rouvière was a gentle man and LeRoux prone to anger and impatience, but both were unable to speak the native language and unprepared for the harshness of the Arctic. Whether the priests threatened the Eskimos who shot them or whether they were killed for their guns and ammunition is still in question.

The Royal Northwest Mounted Police set out to find their fate—the 3,000-mile journey by Mounties Denny LaNauze and Wyndham Bruce as they followed the trail is a remarkable story. The book details the trial and acquittal, and then the retrial with a guilty verdict, of the killers Sinnisiak and Uluksuk. The two were released and sent home to carry the message about the importance of compliance to the British laws and judicial system to their fellow Eskimos.

Jenkins closes the book with observations LaNauze had written after his journey to bring back Sinnisiak and Uluksuk: "The advent of civilization amongst [the Eskimos] will not tend to be to their betterment," he wrote, concluding that "Indeed to us who have had the good fortune to see these people live their strenuous, healthy existence on the arctic coast, we cannot wish them better fortune than to hope that civilization may ever be kept at arms' length from them."

Geography and Climatology Research section continued from page 3.

situ autonomous buoys to improve understanding of ice on geophysical scales. Near real-time satellite-derived motion processing of the ice has been developed at UD with the near-real time transmission made possible through collaboration with the National Ice Center and the Alaska Satellite Facility. These coordinated efforts will result in inter-calibrated ice motion and thickness measurement methods, which have never before been integrated to this level of detail. Ultimately, better understanding of these processes will result in improved configuration of global climate and forecast models and possibly in new navigation tools as the Arctic Ocean opens to more shipping.

Marine and Earth Studies section continued from page 4.

Nares Strait between Greenland and Canada's Ellesmere Island. About two-thirds of this equipment was recovered in 2006 by the CCGS *Henry Larsen* in collaboration with the Canadian Institute of Ocean Sciences. The data provide a three-year time series of horizontal currents, salinity, temperature, pressure, and ice-thickness (see image on page 4). Published analyses of data from the 2003 expedition revealed that the southward flux of freshwater is concentrated in a 10-km wide subsurface boundary current along the mountainous coast of Ellesmere Island.

This experiment contributes to simultaneous tracking of the major freshwater fluxes out of the Arctic Ocean as part of the Arctic-Subarctic Ocean Flux Experiment (ASOF). For more information, see: http://newark.cms.udel.edu/~cats.

Arctic Cloud-Radiation Models

Dana Veron models the interaction between arctic clouds and solar radiation to improve understanding of their effects on Earth's climate. Assessments of modern climate cloud-radiation parameterizations using case studies from the international Surface Heat Budget of the Arctic Ocean (SHEBA) program indicate large discrepancies in model representation of both clear and cloudy sky net radiative fluxes at the surface and top of the atmosphere in the Arctic. These discrepancies are due in part to differences in model representation of aerosols and surface albedo.

Particularly, mixed-phase clouds, which contain layers of liquid and ice and commonly occur over the Arctic, may not be accounted for in some atmospheric climate models. With funding from the Department of Energy Atmospheric Radiation Measurement Program, Veron and her students have developed a new cloud-radiation model for these clouds, which more accurately represents the transmission of light through the cloud layers. Their work shows that modeling the distribution of ice patches throughout a supercooled liquid layer cloud is nearly as important as incorporating the liquid layer that typically caps such mixed-phase clouds.

Other Cryospheric Efforts

Several other researchers in the Department of Geography conduct cryospheric research around the globe:

- David R. Legates and Cort J. Willmott create global climate data sets used to test and validate model results.
- Delphis Levia specializes in snow-canopy interactions and currently chairs the Cryosphere Specialty Group of the Association of American Geographers and the Research Committee of the Eastern Snow Conference.
- Daniel Leathers conducts research on snow cover patterns in the Northern Hemisphere and their relation to climatic variations.
- Brian Hanson conducts research in glaciology, climate dynamics, and numerical modeling.
- Michael A. O'Neal works on integrated field studies with theoretical models to evaluate linkages between alpine glacier fluctuations and climate variations of the past few thousand years.

Witness the

ARCTIC

Arctic Research Consortium of the United States Member Institution — Winter 2008/2009, Volume 13 Number 1

Arctic Research at the University of Delaware

Founded as a small private academy in 1743, the University of Delaware (UD) has a long tradition of excellence—the inaugural class included three students who would later go on to sign the Declaration of Independence. Today, more than 20,000 students at campuses throughout the state and in study-abroad programs worldwide attend this research intensive, technologically advanced institution.

The state assisted, privately governed university received its collegiate charter from the state of Delaware in 1833 and was designated one of the nation's historic land grant colleges in 1867. Today, UD is also a sea grant, space grant, and urban grant institution. The Carnegie Foundation for the Advancement of Teaching, which classifies institutions based on specific attributes, has recognized UD as a university with "very high research activity"—a designation accorded to fewer than 3% of the more than 4,200 degree-granting institutions in the U.S.

University faculty conduct research and educational activities on all of the world's continents. Locally, they have access to a rich variety of natural habitats in the U.S. mid-Atlantic region, as well as exceptional facilities ranging from state-of-the-art bio-imaging labs to the R/V *Hugh R. Sharp*, which is considered one of the finest coastal research vessels in North America.

UD offers courses in a wide range of disciplines, including 4 associate's programs, 130 bachelor's programs, 110 master's programs, and 43 doctoral programs. The institution has seven colleges: the College of Agriculture and Natural Resources; College of Arts and Sciences; Alfred Lerner College of Business and Economics; College of Engineering; College of Health Sciences; College of Human Services, Education and Public Policy; and College of Marine and Earth Studies.

This insert highlights both historic and recent arctic research activities at UD.

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UNIVERSITY OF DELAWARE

This view of the University of Delaware's (UD) main campus in Newark shows Magnolia Circle in the foreground. To the left is the Hugh M. Morris Library and at the top center is Memorial Hall, which was erected in 1924 by the citizens of Delaware as the state's memorial of World War I. It is one of 16 UD buildings on the National Register of Historic Places. To the left of Memorial Hall is Mentors' Circle, a permanent and visible tribute to faculty who are distinguished by their contributions of teaching excellence and mentorship of students. Photo by Kathy F. Atkinson.

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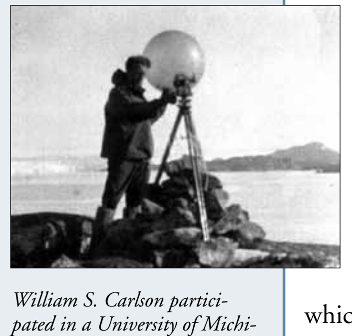
History of Arctic Research Activity at the University of Delaware

UD established its strong presence in cold regions research in the 1940s, when William Samuel Carlson, a highly accomplished arctic explorer, military strategist, and Earth scientist, became president of the institution. Carlson led two expeditions to Greenland in the late 1920s and early 1930s. Later, as commanding officer of the U.S. Army Air Forces' Arctic, Desert, and Tropic Information Center during World War II, Carlson played a critical role in developing several air transport routes through the Arctic. He also authored numerous scientific and popular publications, including the books *Greenland Lies North* (1940) and *Lifelines Through the Arctic* (1962), and was a founding member of the Arctic Institute of North America.

Among Carlson's accomplishments as president of UD from 1946 to 1950 was the creation of the university's geography program, which included "Problems in Polar Research" as one of its first seminars. This course was taught in 1955 by the famed explorer Sir Hubert Wilkins during his tenure as a visiting professor of geography at UD. Ever since Carlson's time, faculty in the UD geography department have been active in cold regions research. The late Russ Mather, founder of the department's graduate program and its long-term chairperson, conducted climate research in northern Alaska in the 1950s with his mentor, C. W. Thornthwaite. Another geographer, Joseph Sonnenfeld, conducted cultural and ethnographic studies on Alaska's North Slope during the 1950s and 1960s.

In recognition of the International Polar Year 2007–2008, UD is organizing lectures, research seminars, art exhibits, films, and receptions in honor of Carlson. Further information is available at: www.udel.edu/research/polar/.



William S. Carlson participated in a University of Michigan expedition to Greenland in 1930. He is pictured here at Mount Evans station, which he managed. The balloon that he is about to release provided information about wind speed and direction. This is only one of many such balloons released during the expedition. Photo courtesy of University of Toledo Ward M. Canaday Center.

Bartol Research Institute

Investigators at the Bartol Research Institute, a research center in the UD Department of Physics and Astronomy, conduct leading-edge physics, astronomy, and space studies, including significant projects in the Arctic related to fast-moving, super-charged particles called cosmic rays.

Cosmic rays are produced in our galaxy by supernova explosions, neutron stars, and black holes. The sun also releases these high-energy particles, mostly protons and helium nuclei, during violent events called coronal mass ejections.

The level of solar activity rises and falls over a period of approximately 11 years (activity is currently low) and influences cosmic ray intensity, which is lower when solar activity is high. This is because emissions of matter and electromagnetic fields from the sun increase during high solar activity, making it harder for galactic cosmic rays to reach Earth. Solar modulation refers to the variation in cosmic ray intensity that is correlated with solar activity.

About 1,000 cosmic rays strike each square meter of Earth's atmosphere every second. When a cosmic ray strikes an atom in the atmosphere, the collision may produce one or more new energetic particles called secondary cosmic rays. These secondary particles strike other atmospheric atoms producing still more secondary cosmic rays. The whole process is called an atmospheric cascade. If the primary cosmic ray has enough energy—greater than 500 million electron volts—the nuclear by-products of the cascade can reach Earth's surface.

Cosmic rays can interact with the sun's magnetic wind, damage electric power grids and communications satellites, threaten astronauts in space, expose airline passengers to radiation, affect radio waves and telecommunication, and may affect climate. Efforts at UD are currently underway to better understand the effects of these particles on space travel, lightning, and other phenomena.

Anti-Electron Sub Orbital Payload Project

The study of cosmic rays at Bartol Research Institute began in 1934 with the launch of several balloon flights. After a hiatus of several decades, balloon observations at the institute resumed in 1984 when the Low Energy Electrons (LEE) instrument was moved from the University of Chicago to continue a series of measurements focusing on solar modulation of cosmic electrons, which originate outside the solar system, with energies up to ~20 GeV (gigaelectron volts). The institute expanded its balloon-borne research in 1991 with funding from the National Aeronautics and Space Administration (NASA) by building the Anti-Electron Sub Orbital Payload (AESOP) instrument (see image on page 5). AESOP is carried by a 40 million cubic foot helium balloon measuring 650 feet in diameter that floats at an altitude of approximately 135,000 feet. The primary purpose of this instrument is to investigate charge-sign dependence of solar modulation, which is influenced by changing features in the large scale geometry of the Sun's magnetic field, by simultaneously measuring electron and positron (positively charged particles that are otherwise identical to electrons) fluxes near the top of the Earth's atmosphere.

In summer 2006, AESOP was launched from NASA's Columbia Scientific Balloon Facility in Kiruna, Sweden. The balloon made its way northwest across the Atlantic Ocean, over the northern tip of Iceland and Greenland's ice cap, and past Canada's Baffin Island, where it reached an altitude of 135,500 feet and a maximum cruising speed of 51 knots. After five days, it landed safely on Victoria Island, north of Canada's Northwest Territories, near the Arctic Circle. The Atlantic crossing was its longest journey so far. Data analysis is

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Geography and Climatology Research

The UD Department of Geography has a notable Ph.D. program in physical geography with a focus on climatology and land surface processes. Several faculty members are involved in national and international cryospheric programs around the globe. For more information, see: www.udel.edu/Geography/.

Permafrost Group

The UD Permafrost Group (UDPG), under the direction of Frederick "Fritz" Nelson and Nikolay Shiklomanov, oversees a global change monitoring program that includes an extensive network of permafrost observatories in the Arctic and other cold regions. With funding from the NSF Office of Polar Programs (OPP), the group is primarily focused on permafrost environments in northern Alaska but also has field projects elsewhere.

UDPG currently oversees the Circumpolar Active Layer Monitoring (CALM) program, one of several global change monitoring programs affiliated with the International Permafrost Association. Begun in 1991, CALM was initially operated as part of the International Tundra Experiment and is currently supported by the NSF Arctic Research Support and Logistics Program (see pages 5–6). The CALM program, with participants from 15 countries, observes the response of the active layer and near surface permafrost to climatic variations and trends over multi-decadal time scales at more than 160 sites in both hemispheres. Most sites in the network are located in arctic and subarctic lowlands, although 20 boreholes affiliated with CALM are in mountainous regions of the Northern Hemisphere. CALM program data, which include active layer thickness measurements, soil moisture, and soil and permafrost temperatures, are archived at the Frozen Ground Data Center (http://nsidc.org/fgdc/) in Boulder, Colorado. The CALM program encompasses numerous field experiments involving ground-penetrating radar, differential global positioning systems, and development of spatial sampling and analytic methodologies.

Since the mid-1980s, Nelson and Shiklomanov have been involved in modeling permafrost distribution and hazard potential under scenarios of climate change. Much of their work is performed in collaboration with Oleg Anisimov of the State Hydrological Institute (SHI) in St. Petersburg, Russia. Their most recent project, a collaborative undertaking between UD, SHI, University of Colorado Boulder, and University of Alaska Fairbanks that is funded by the NSF Arctic Natural Sciences Program (see pages 13–14), focuses on comparing and evaluating the performance of permafrost distribution models.

UDPG also has a long-standing interest in paleoenvironmental research. Together with Hugh French of the University of Ottawa, the group conducts research on Pleistocene permafrost throughout the mid-Atlantic and Appalachian regions.

Diver, Doug McIntosh, who is a cameraman for the Discovery Channel, gets ready to film other divers measuring and taking instrument readings associated with the lower ice surface or "ice keels" formed under pressure ridges. He is assisted by Kevin Parkhurst (at left) and Keith Van Thiel (both of whom are with the Applied Physics Laboratory Ice Station and assisted with logistics support for the SEDNA project). Photo courtesy of Robert Harris, 2007 PolarTREC teacher.

French and Nelson recently edited a long-lost (1950s and 1960s) book manuscript by Siemon W. Muller, the "father of North American permafrost science." The book, *Frozen in Time: Permafrost and Engineering Problems*, was published by the American Society of Civil Engineers and introduced at the 9th International Conference on Permafrost in Fairbanks, Alaska, in June 2008.

SEDNA Project

There are many indications that the arctic sea ice cover is undergoing significant changes affecting both extent and thickness. Cathleen Geiger (Department of Geography) and Chandra Kambhamettu (Department of Computer and Information Sciences) are co-investigators on a project funded primarily by OPP entitled Sea Ice Experiment: Dynamic Nature of the Arctic (SEDNA). Jennifer Hutchins of the University of Alaska Fairbanks is the principal investigator on the project, which also involves UD alumna Jacqueline Richter-Menge of the U.S. Army Corps of Engineers and an international team of 30 scientists.

Through a field campaign, remote sensing, and modeling, the team's primary objective is to better understand the interaction between the atmosphere, sea ice cover, and ocean, and its dynamic influence on the mass balance of ice cover. The results are being used to improve models of sea ice cover, leading to better predictions of future changes and impacts on regional and global communities.

With cooperative logistical support provided by the Office of Naval Research and OPP, the SEDNA field campaign was conducted at a temporary U.S. Navy camp built on the drifting ice pack of the Beaufort Sea during spring 2007. Robert Harris, a biology teacher at Hartford High School in Vermont, was able to spend nearly a month working with the research team north of Barrow, Alaska, through his participation in the PolarTREC program (see page 21; www.polartrec.org). The data collected during spring 2007 (see image at left) are being used to understand the new and dramatic changes developing in the Arctic.

Sea ice is unique in that it is a moving topographic surface. The researchers are working to develop a map of moving topography to visualize and measure the ice volume as it moves—an effort that requires the integration and synthesis of a wide range of data sets, many of which were collected coincidently during the project. Visual analysis of satellite data are being combined with data from in

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Marine and Earth Studies

Scientists in the UD College of Marine and Earth Studies (CMES; www.ocean.udel.edu/) conduct investigations around the globe—many CMES research efforts in the Arctic focus on climate change.

Sensitivity of Ice Caps to Climate Change

Katharina Billups studies the evolution of polar ice caps through geologic history on time scales ranging from thousands to millions of years. With funding from the NSF Marine Geology and Geophysics Program and the Petroleum Research Fund of the American Chemical Society, she investigates the geochemistry of marine sediments, which record changes in the ocean that occurred in response to the growth and decay of the continental ice sheets. She is currently examining the sensitivity of northern ice sheets to changes in external boundary conditions, such as solar radiation and tropical surface ocean hydrography, by measuring oxygen isotope ratios of benthic and planktonic foraminifera in deep ocean sediments of the subtropical North Pacific. The resulting time series will allow examination of the relationship between the subtropical surface ocean conditions and the extent of continental ice volume during past climate transitions. Ultimately, the study will contribute to a better understanding of the sensitivity of the polar ice caps to climate change.

Microbial Processes in Tundra Soils

With funding from the NSF Ecosystem Studies Program, Barbara Campbell and Thomas Hanson collaborate with University of Florida researchers to understand microbial decomposition of organic matter in tundra soils and its effects on ecosystem carbon and nitrogen balance.

Northern ecosystems are a repository for about one-third of the global carbon pool stored as soil organic carbon. Florida scientists Michelle Mack and Ted Schuur found that simulating climate change conditions via nitrogen addition to the surface of tussock tundra soils resulted in significant losses of carbon and nitrogen from deep soil layers, suggesting that a nutrient-mediated positive feedback loop could convert northern ecosystems from net sinks to net sources of atmospheric carbon and exacerbate current climate change trends.

To understand how microbes decompose organic matter in tundra soils, Campbell and Hanson collect data on microbial community structure and function in plots at the Arctic Long Term Ecological Research Site at Toolik Field Station exposed to fertilization, warming, or both for periods of time ranging from a few weeks to over 20 years. They use a molecular method that extracts ribosomal RNA gene sequences from samples to examine how microbial community structure is altered by the treatments and then correlate these measurements with community function measurements. Linked with process studies, this research helps refine models of integrated microbial and plant activities in tundra ecosystems.

An NSF Research Experience for Undergraduates supplement allowed Marcela Kokes of Lewis and Clark College in Oregon to assist with fieldwork and examine archaeal populations in these soils in 2006—she presented this work at the American Society for Microbiology General Meeting in 2007. Karen Rossmassler, a first year CMES graduate student, also assisted with fieldwork in 2007.

UD researchers prepare to deploy one of eight conductivity-temperature-depth strings from the deck of the CCGS Henry Larsen *in Kennedy Channel between Greenland and Ellesmere Island, Canada, as part of an NSF-supported project investigating arctic freshwater flux. The instruments provide time series of temperature and salinity as a function of depth. The red capsules float above the larger yellow buoys (moored at a depth of approximately 200 meters) and allow the mooring to slide smoothly through the crevices of icebergs that can have drafts of up to 150 meters. Photo courtesy of Andreas Muenchow.*

Microbial Metabolism in the Arctic Ocean

Until recently, chemolithoautotrophs, organisms that fuel their metabolism by oxidizing inorganic compounds, were not thought to be abundant in the ocean. New data suggest, however, that the importance of these microbes may be underestimated, and evidence from low-latitude oceans reveals that one type of chemolithotrophic microbe, ammonium-oxidizing archaea, may be very abundant in the deep ocean. David Kirchman and Matthew Cottrell are examining whether these microbes are common in the Arctic Ocean in an International Polar Year project funded by OPP.

They hypothesize that chemolithotrophy is key to the survival of archaea and bacteria in the Arctic Ocean, especially in winter. The project focuses on ammonium and methane oxidation because concentrations of these compounds are high in arctic coastal waters, and methane is a strong greenhouse gas with an important role in global climate change.

Field sampling during summer 2007 and winter 2008 included trips to coastal waters off Barrow, Alaska, where short-term experiments and sample preservation are being conducted in Barrow Arctic Science Consortium labs. An epifluorescence microscopy facility at UD estimates the abundance of active bacteria and archaea in samples incubated with additions of radio-actively labeled compounds consumed by the microbes. Genetic studies, co-supported by the Census for Marine Life, compare arctic microbes with those from Antarctica and other ocean regions.

Arctic Freshwater Flux

Freshwater flux into the North Atlantic Ocean impacts global thermohaline ocean circulation and, thus, climate. Andreas Muenchow collaborates with Kelly Falkner of Oregon State University on a project investigating the physics of exchange processes between the Arctic and North Atlantic Oceans funded by the NSF Arctic System Science Program.

Mooring hardware, provided by UD investment, was deployed by the USCGC *Healy* in 2003 in a 35-km wide section of

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