U.S. ANTARCTIC PROGRAM, 2004–2005

As part of the U.S. Antarctic Program, nearly 700 researchers and special participants will conduct 139 projects during the 2004–2005 austral summer, with some projects continuing through the austral winter. Supported by over 2,000 civilian contract employees and U.S. military personnel, these researchers and special participants (writers, artists, and teachers) will work at the three U.S. year-round stations (McMurdo, Amundsen–Scott South Pole, and Palmer), at remote field camps, with other national antarctic programs at locations around Antarctica, and in the waters of the Southern Ocean aboard the U.S. Antarctic Program's two icebreaking research ships—*Nathaniel B. Palmer* and *Laurence M. Gould*.

Ground crews fill a long-duration, high-altitude balloon at Williams Field, the U.S. skiway near McMurdo Station on the Ross Ice Shelf. The balloon takes advantage of the high-altitude wind currents that circle Antarctica, bringing the balloon back close to its point of origin, so that its payload can be retrieved. Instrument payload also sends data back to ground receivers. These instruments enable researchers to collect data about cosmic rays, electron precipitation from Earth's radiation belts, and other similar phenomena in near-space environments. (*NSF/USAP photo by Melanie Connor, Raytheon Polar Services Corp.*)

These projects, funded and managed by the National Science Foundation (NSF), are part of the international effort to understand the Antarctic and its role in global processes. NSF supports research that can best be performed or can only be performed in Antarctica. Besides research projects, NSF's Office of Polar Programs (OPP) and the Directorate for Human Resources support Teachers Experiencing Antarctica (TEA)/ARMADA (www.armadaproject.org). The ARMADA Project, which is administered by the University of Rhode Island's Office of Marine Programs, provides K–12 teachers with an opportunity to actively participate in ocean, polar, and environmental science research and peer mentoring. During this austral summer, as part of her professional development, Elizabeth Gibbs will work with benthic ecologist Stacy Kim of Moss Landing Marine Laboratories. Dr. Kim is studying the impact of human activities on McMurdo Sound. Another OPP program—the Antarctic Artists and Writers Program (NSF 04–558)—provides opportunities for painters, photographers, writers, and others to use serious writing and the arts to increase people's understanding of the Antarctic and America's heritage there.

The scientists conducting the projects come primarily from U.S. universities and have won NSF support by responding to the Antarctic Research Program Announcement and Proposal Guide (NSF 04–559; www.nsf.gov/pubsys/ods/getpub.cfm?nsf04559). Operational resources in Antarctica are also used to support scientists from other Federal agencies.

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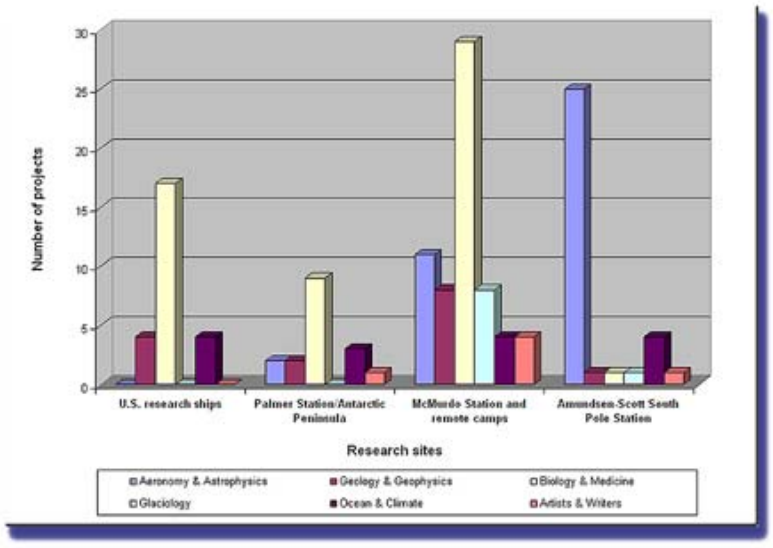
U.S. Antarctic Program Science Projects by Discipline and Research Site



During the 2004–2005 austral summer, 64 projects will be based at McMurdo Station or at remote field sites, 25 will be supported on research ships, 33 will work at Amundsen–Scott South Pole Station, and 17 will work in and around Palmer Station.

Science highlights

The following projects are among those supported during this austral summer and winter. Where appropriate, links for additional information have been added. NSF-funded science awards can also be found in the online NSF awards database. To access this information, search the database at www.nsf.gov/awardsearch/index.jsp. Each NSF award listed here, as well as in the other sections of this document, includes the award number, which can be used to do a keyword search.

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Biology and medicine

- **Long-term ecological research (LTER).** Two sites in Antarctica—one in the McMurdo Dry Valleys (NSF/OPP 98–10219) and the other along the west coast of the Antarctic Peninsula centered on Palmer Station (NSF/OPP 02–17282)—are among the world's 25 NSF-sponsored LTER sites, which are being investigated to increase our understanding of ecological phenomena over long temporal and large spatial scales. All of the other sites except one are in the United States. (http://lternet.edu; Palmer LTER, http://iceflo.icess.ucsb.edu:8080/ice_hp.php; McMurdo LTER, http://huey.colorado.edu)

- **Weddell seal population dynamics.** Weddell seals have been studied in McMurdo Sound since 1968; this constitutes one of the longest intensive field investigations of long-lived mammals anywhere. More than 16,800 animals have been tagged, and almost 162,000 resightings have been recorded. The project is a resource for understanding the population dynamics not only of Weddell seals, but also of other species of terrestrial and marine mammals. New work this season includes assessing the role of food resources in limiting the population. (NSF/OPP 02–25110; www.homepage.montana.edu/~rgarrott/index.htm)

- **Before-and-after study of a sewage outfall site.** The human impact on Antarctica is small and generally highly localized, with one measurable point being the former sewage outfall at McMurdo Station. This project collected "before" data in 2002 and earlier while the outfall was still operating and is collecting "after" data this season and next following the January 2003 completion of McMurdo's new sewage treatment plant. While organic input to the seafloor dropped immediately and dramatically, the cold water is expected to recover more slowly than temperate water would. The project seizes this unique opportunity to understand anthropogenic impacts in a polar environment. A seventh-grade science teacher has joined the team to learn firsthand how the research is done and to transfer the process and outcomes of polar science to the classroom. (NSF/OPP 01–26319; http://benthic.mlml.calstate.edu, click on Antarctic

Research, then Aspire; TEA/ARMADA, http://tea.rice.edu/tea_gibbsfrontpage.html)

- **McMurdo Dry Valleys as an analog for Martian environments.** Endolithic microbial communities (those terrestrial flora living just below the surface of rocks) inhabit harsh environments that may represent the closest analog to the environment on Mars. As part of a study of the chemical signatures of endolithic microbes in hot and cold deserts, biologists will test a unique set of portable, nondestructive instruments in the McMurdo Dry Valleys. These instruments do not need to touch the rocks that host the organisms in order to detect the subtle chemical biosignatures associated with life. The instrument suite, called SPISE3, is composed of a spectroradiometer, a portable gas chromatograph, and an ultraviolet visible light wavelengths fluorescence spectrometer and imager. The project is part of an NSF–National Aeronautics and Space Administration (NASA) collaborative program called Astrobiology Science and Technology for Exploring Planets (ASTEP). (NASA award 02–0040–0014)

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Ocean and climate systems

- **Surface carbon dioxide in the Drake Passage.** The Southern Ocean is an important component of the global carbon budget. Low surface temperatures with consequently low vertical stability, ice formation, and high winds produce a very active environment for the exchange of gaseous carbon dioxide between the atmospheric and oceanic reservoirs. The Drake Passage is the narrowest point through which the Antarctic Circumpolar Current and its associated fronts must pass. This chokepoint is an excellent site to measure the latitudinal gradients of gas exchange. The research icebreaker *Laurence M. Gould* will support a project to measure dissolved and total carbon dioxide, providing data that, with satellite images, will enable researchers to estimate the net production and export of carbon by oceanic biota. (NSF/OPP 03–38248 and NSF/OPP 03–38155; www.ldeo.columbia.edu/res/pi/CO2)

- **AnSlope, cross-slope exchanges at the Antarctic Slope Front.** What is the role of the Antarctic Slope Front and continental slope morphology in the exchanges of mass, heat, and freshwater between the shelf and oceanic regimes, particularly those leading to outflows of dense water into intermediate and deep layers near deep basins and world ocean circulation? AnSlope, a multiyear experiment, focuses on these cross-slope exchanges between the Antarctic Shelf and the deep ocean. Although scientists understand the role that cold-water masses originating in the Antarctic play in global ocean circulation and climate, the processes by which these masses enter deep ocean circulation are not well understood. The primary goal of AnSlope is to identify the principal physical processes that govern the transfer of shelf-modified dense water into intermediate and deep layers of the adjacent deep ocean, as well as to understand the compensatory poleward flow of waters from the oceanic regime. (NSF/OPP 01–25172, NSF/OPP 01–25521, NSF/OPP 01–25523, NSF/OPP 01–25084, NSF/OPP 01–25431, and NSF/OPP 01–25602; www.ldeo.columbia.edu/res/fac/physocean/anslope)

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Aeronomy and astrophysics

- **A 10-meter telescope for South Pole Station—South Pole observations to test cosmological models.** Much of the mass in the Universe is made up of dark matter, which emits little or no light or other electromagnetic radiation and makes its presence known only through the gravitational force it exerts on luminous matter. The University of Chicago will lead a consortium of six institutions to design and use a 10-meter off-axis telescope located at Amundsen–Scott South Pole Station to survey galaxy clusters. This survey will allow them to study integrated cluster abundance and its red shift evolution and will give precise cosmological constraints, completely independent of those from supernova distance and cosmic microwave background anisotropy measurements. (NSF/OPP 01–30612; http://astro.uchicago.edu/scoara/may2004workshop/TALKS/spt-carlstrom)

- **IceCube.** During the 2004–2005 austral summer, a consortium led by the University of Wisconsin–Madison will begin drilling into the ice sheet for the IceCube Observatory at the South Pole. IceCube is a neutrino telescope that will be buried 1.4 to 2.4 kilometers under the ice and will be used during the austral

summers over 5 years. The detector will consist of 4,800 optical modules deployed on 80 vertical strings. AMANDA (antarctic muon and neutrino detector array) is the prototype for this international collaborative effort. Using neutrinos as cosmic messengers, IceCube will open unexplored wavelength bands and will answer such fundamental questions as what the physical conditions in gamma ray bursts are and whether the photons originating in the Crab supernova remnant and near the supermassive black holes of active galaxies are of hadronic (derived from subatomic particles composed of quarks) or electromagnetic origin. The telescope will also be used to examine the particle nature of dark matter, aid in the quest to observe supersymmetric particles, and search for compactified dimensions. (NSF/OPP 02–36449; http://icecube.wisc.edu)

- **Cosmic microwave background (CMB) polarization measurements.** Scientists will mount QUEST, a 2.6-meter Cassegrain telescope equipped with a next-generation polarization-sensitive bolometer array, on the existing degree angular scale interferometer (DASI) platform at South Pole Station. They will use the combined system, which will operate over two austral winters, to make maps of the polarization of the CMB—the faint, relic heat from the Big Bang—which offers a snapshot of the Universe at the point where it transitioned from hot plasma to neutral gas. The statistics of the expected sky pattern for a given cosmological theory can be accurately calculated, and a host of experiments have now measured the variation of CMB's total intensity, or temperature. Taken together, these measurements have begun to reveal the origin, composition, evolution, and ultimate fate of the Universe. The QUEST system will provide measurements at an unprecedented sensitivity and angular resolution. (NSF/OPP 03–38138, NSF/OPP 03–38238, and NSF/OPP 03–38335; http://astro.uchicago.edu/dasi)

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Glaciology

- **Airborne geophysical survey of the Amundsen Sea embayment.** The Amundsen Sea embayment is the third major drainage basin of the West Antarctic Ice Sheet after the Ross and Weddell Sea embayments. Far from logistics centers, it is comparatively unstudied. However, recent satellite data and the limited amount of existing ice thickness data indicate that it has the largest ice flux in West Antarctica. Moreover, it is the only drainage basin exhibiting significant change in elevation during the era of satellite observations. The University of Texas and the British Antarctic Survey are making a comprehensive aerogeophysical survey of the embayment's major drainages—Pine Island Basin and Thwaites Glacier Basin. Geophysical maps resulting from these surveys will guide future surface-based research. (NSF/OPP 02–30197; www.ig.utexas.edu/research/projects/agasea)

- **West Antarctic Ice Sheet stability.** The Bottleneck—a unique, relatively narrow passage in the Transantarctic Mountains connecting the West and East Antarctic Ice Sheets—is located at the Ohio Range near the head of Mercer Ice Stream in West Antarctica. The glaciers in this area are sensitive to changes in snow accumulation and predominant wind direction. When compared with the record of the fluctuations of the adjacent ice sheet, the timing of alpine glacier advance will yield information that can be used to test climate reconstructions based on antarctic ice core records. In addition, the glacial record in the Bottleneck reflects the history of the interaction of the West Antarctic and East Antarctic Ice Sheets and can be used to test hypotheses regarding the collapse of the former during the Pleistocene (10,000 to 1.8 million years ago). (NSF/OPP 03–38189)

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Geology and geophysics

- **Buried ice in the western Dry Valleys, Antarctica—An analog for Martian ice?** Buried ice deposits may potentially contain a far-reaching record of Earth's atmosphere and climate extending back many millions of years. These deposits are terrestrial analogs to widespread and young buried ice on the Martian surface as identified by recent data from Mars Odyssey. Just as earlier researchers asked whether a climate record was stored in the modern ice sheets of Antarctica and Greenland, scientists are now asking whether ancient, debris-covered glaciers in the western Dry Valleys hold similar records of temperature and atmospheric change, but on time scales that are perhaps greater than those for the deepest existing ice core. The ice to be examined is over a million years old, making it by far the oldest ice yet known on Earth. A better understanding of surface processes

above buried ice will enable researchers to access a record of atmospheric and climate change that could well cover intervals that predate Quaternary time (11,000 to 1.8 million years ago). Since the conditions in the Dry Valleys are analogous to those found on Mars, extending the results could bring valuable insight into studies on the potential for life on Mars. (NSF/OPP 03–38291; http://people.bu.edu/marchant/themesBuriedIce2.htm)

- **Demonstration ocean-bottom drilling in the James Ross Basin.** Scientists will deploy a drill rig on the research icebreaker Nathaniel B. Palmer to test the feasibility of ship-based diamond coring along the antarctic continental margin. If successful, this SHALDRIL mobile system will be able to explore the no man's land between the nearshore (where the fast-ice-based Cape Roberts Project was successful) and the upper slope (where Ocean Drilling Project's Joint Oceanographic Institutions for Deep Earth Drilling Resolution becomes most efficient). (NSF/OPP 01–25922, NSF/OPP 01–25480, and NSF/OPP 01–25526; www.arf.fsu.edu/shaldril.cfm)

- **Seismograph.** The world's quietest earthquake detector is 300 meters beneath the surface of the ice sheet 8 kilometers from the South Pole. Completed in 2002, the station is detecting vibrations four times smaller than those recorded previously. Other seismographs have been there since 1957, and long-term, high-latitude data have helped prove that the Earth's solid inner core spins faster than the rest of the planet. Also, Antarctica is the continent with the fewest earthquakes, so the new station will record small regional earthquakes, leading to new insights into the Antarctic Plate. (NSF/EAR 00–04370; www.iris.washington.edu/about/GSN)

- **Magmatism in the Dry Valleys: A workshop.** The most challenging aspect of understanding magmatism is that so little of the integrated nature of the full cycle can be directly examined. Planetary magmatism is a multifaceted process involving a spectrum of interleaved chemical and physical processes responsible for the chemical transformation of the initial primitive magma into the final product. Each component can be found exposed somewhere on Earth, and each has been studied for nearly a century, but finding and studying any reasonable example of the entire process in a fully integrated context has proven singularly elusive. The Ferrar dolerites of the McMurdo Dry Valleys exhibit the three-dimensional structural evolution of an extensive magmatic system that formed 180 million years ago. This system contains all the essential features of major magmatic systems, which are seen only piecemeal elsewhere in the world. Because this unusual area is so inaccessible, geologists have chosen to hold a 2-week field workshop to introduce 20 to 25 researchers to the wonders of the McMurdo Dry Valleys, to stimulate cutting-edge research, and to delineate the unsolved problems posed by this magmatic system. This working conference will entail discussions and laboratory work at McMurdo Station and fieldwork in the Dry Valleys. (NSF/OPP 02–29306)

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Other programs

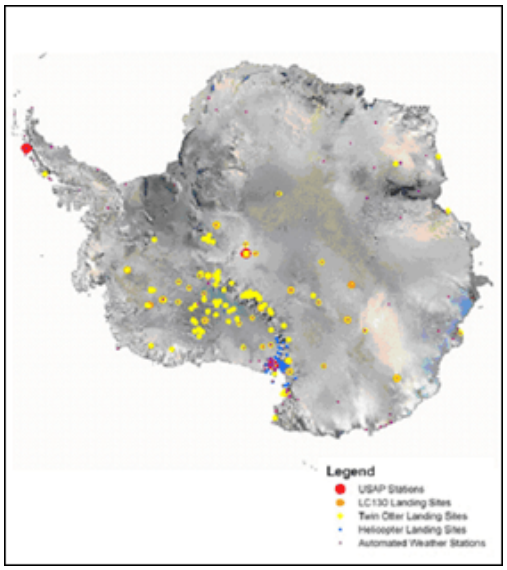
- **Antarctic Artists and Writers Program.** This program, which records the Nation's antarctic cultural heritage and extends understanding of the region and the U.S. Antarctic Program within the research community and beyond, will support the following six projects.

Artist / Writer	Project Title	Event Number
Yann Arthus-Bertrand	Mission Antarctica	W-27-M
Elena Glasberg	End as beginning: An American antarctic imaginary	W-219-M/S
Judith Nutter	Time, place, and imagination images and poems from Antarctica	W-220-P
Susan Fox Rogers	Antarctic anthology	W-216-M/S
Connie Samaras	*Vast Active Living Intelligence System:* Photographing the South Pole	W-221-S
Gabrielle Walker	*Antarctica: The Biography of a Continent*	W-223-M

- **Scouting in Antarctica.** In a nationwide competition, the Girl Scouts of the USA selected Senior Girl Scout Devon Vail of Fairbanks, Alaska, to participate in this

austral summer's field program in Antarctica. Ms. Vail, who is a biology major at the University of Alaska, will take time off from her studies to work with U.S. scientists based at McMurdo Station.

U.S. Antarctic Program, 2004–2005: Sites of Major Activities



McMurdo, Amundsen–Scott South Pole, and Palmer Stations operate year-round. During the 2004–2005 austral summer, four major field camps will operate in West Antarctica (Byrd Surface, Siple Dome, Thwaites Glacier, and Pine Island). Smaller camps will operate in the McMurdo Dry Valleys and Transantarctic Mountains regions. Six automated geophysical observatories and more than 100 automated weather stations operate year-round. The weather stations involve international collaboration with the Italian, German, Australian, and British programs. The map shows U.S. Antarctic Program locations during the 2004–2005 season. (*Data and map were prepared by Kelly Brunt, Raytheon Polar Services*.)

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U.S. Antarctic Program, 2004 – 2005

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AERONOMY AND ASTROPHYSICS

Aurora australis above the new station complex at Amundsen–Scott South Pole Station in June 2004. (*NSF/USAP photo by J. Dana Hrubes, Raytheon Polar Services, Corp.*)

On this page:

- IceCube.
- Extending the South American Meridional B-field Array (SAMBA) to auroral latitudes in Antarctica.
- Development of an autonomous real-time remote observatory (ARRO).
- Next-generation cosmic microwave background polarization measurements with the QUEST experiment on the degree angular scale interferometer (DASI).
- Dual Auroral Radar Network at South Pole Station.
- Antarctic Submillimeter Telescope and Remote Observatory (AST/RO).
- PAST: The Primeval Structure Telescope.
- Wide-field imaging spectroscopy in the submillimeter: Deploying SPIFI on the Antarctic Submillimeter Telescope and Remote Observatory (AST/RO).
- High-resolution observations of the cosmic microwave background (CMB) with the Arcminute Cosmology Bolometer Array Receiver (ACBAR).
- South Pole observations to test cosmological models: A 10-meter telescope for South Pole.

Telescopes and laboratory facilities in the "dark sector" are about 1 kilometer from the main Amundsen-Scott South Station facilities. The "dark sector" is maintained with minimal interference from extraneous light sources and other electromagnetic radiation. (*NSF/USAP photo.*)

Overview

The polar regions have been called Earth's window to outer space. Originally, this term applied to dynamic events like the aurora, staged as incoming solar plasmas encountered the Earth's geomagnetic fields. Unique properties create a virtual screen of the polar upper atmosphere on which the results of such interactions can be viewed (and through which evidence of other processes can pass). During the mid-1980s, Earth's window was extended to refer to the "ozone hole" in the polar atmosphere. As scientists have verified an annual loss of ozone in the polar stratosphere, a window previously thought closed (stratified ozone blocking the Sun's ultraviolet rays) is now known to "open," consequent to chemical cycles in the atmosphere.

For astronomers and astrophysicists, the South Pole presents unique opportunities. Thanks to a minimum of environmental pollution and anthropogenic noise, the unique pattern of light and darkness, and the properties of the geomagnetic force field, scientists staging their instruments here can probe the structure of the Sun and the Universe with unprecedented precision. Studies supported by the Antarctic Aeronomy and Astrophysics Program explore three areas of research:

- **The stratosphere and the mesosphere:** In these lower regions, current research focuses on stratospheric chemistry and aerosols, particularly those implicated in the ozone cycle.

- **The thermosphere, the ionosphere, and the magnetosphere:** These higher regions derive many characteristics from the interplay between energetically charged particles (ionized plasmas in particular) and geomagnetic/geoelectric fields. The upper atmosphere, particularly the ionosphere, is the ultimate sink of solar wind energy transported into the magnetosphere just above it. This region is energetically dynamic, with resonant wave-particle interactions and joule heating from currents driven by electric fields.

- **The galaxy and the Universe beyond, for astronomical and astrophysical studies:** Many scientific questions extend beyond the magnetosphere, including a particular interest in the Sun and cosmic rays. Astrophysical studies are conducted primarily at Amundsen–Scott South Pole Station or on long-duration

balloon flights launched from McMurdo Station. The capability of such balloons is expanding dramatically.

All research projects sponsored by this program benefit from (indeed, most require) the unique physical conditions found only in the high latitudes, yet their ramifications extend far beyond Antarctica. High-latitude astrophysical research contributes to the understanding of Antarctica's role in global environmental change, promotes interdisciplinary study of geosphere/biosphere interactions in the middle and upper atmosphere, and improves understanding of the critical processes of solar energy in these regions. Life exists in a balance on Earth because of numerous chemical and atmospheric phenomena that have developed in the specific atmosphere of this 4.6-billion-year-old spinning planet in orbit 149,637,000 kilometers from a middle-sized, middle-aged star. The 20th-century expansion of traditional astronomy to the science of astrophysics, coupled with the emerging discipline of atmospheric science (see also the Antarctic Ocean and Climate Studies Program), is nowhere better exemplified than in Antarctica.

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Background imaging of cosmic extragalactic polarization (BICEP): An experimental probe of inflation.

Andrew E. Lange and James J. Bock, California Institute of Technology; William L. Holzapfel, University of California–Berkeley; and Brian G. Keating, University of California–San Diego.

The cosmic microwave background (CMB) provides three strong but circumstantial pieces of evidence that the visible Universe was created by the superluminal inflation of a tiny volume of space, namely:

- the near isotropy (homogeneity) of the horizon,
- the flatness of space, and
- the phase-synchronicity of acoustic oscillations in the early Universe.

To better understand the origins of the Universe, we must probe this epoch of inflation directly. The most promising probe is the unique signature that the gravity wave background (GWB) imprints on the polarization of the CMB. The amplitude of this signature depends on the energy-scale of inflation.

Detection will require only modest angular resolution (about 1 degree), but long integration (about a year) on a restricted and contiguous patch of sky. The 6-month night, the extremely dry and stable weather, and the precise rotation of the sky about the zenith make South Pole Station the ideal terrestrial site for this ambitious project. A CMB polarimeter (BICEP) uniquely capable of detecting the signature of the GWB will be deployed and commissioned during 2004–2005. After BICEP is unpacked and prepared for initial cooldown, the optical loading, bandpass, and noise characteristics of the detector array and modulation systems will be tested under realistic conditions. The next steps will be erecting the groundshield, refining the pointing model of the mount, and mapping the beams of the 96 detectors before testing on galactic sources and dark fields begins.

BICEP operates simultaneously at 100 and 150 gigahertz (GHz) to both minimize and recognize confusion from polarized astrophysical foregrounds. At these frequencies, a modest (and thus relatively easy to deploy and maintain) 20-centimeter primary aperture will provide a resolution of 1 degree at 100 GHz and 0.7 of a degree at 150 GHz.

By combining a new polarization-sensitive bolometric detector technology developed for the European Space Agency's Planck satellite (to be launched in 2007) with four independent levels of signal differencing and a carefully optimized observing strategy, BICEP will reach the current limit on CMB polarization in the first hour of integration, reach the sensitivity of Planck over 1 percent of the sky in the first week, and precisely measure CMB polarization on the critical angular scales of 1 degree to 10 degrees.

Observational cosmology is enjoying a renaissance that has captured the public imagination and serves as one of the most effective vehicles for stimulating interest in

science in general. Detecting the signature of the GWB in the CMB would represent a triumph of fundamental physics and cosmology that would revolutionize our understanding of the origins of the Universe. (A–033–S; NSF/OPP 02–30438)

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The operation of an extremely-low-frequency/very-low-frequency (ELF/VLF) radiometer at Arrival Heights, Antarctica.

Antony C. Fraser-Smith, Stanford University.

We are continuing our multiyear program of monitoring extremely-low-frequency/very-low-frequency (ELF/VLF) radio noise at Arrival Heights, Antarctica. The ELF/VLF radiometer was first installed there during the austral summer of 1984–1985, and it has been in continuous operation ever since, thereby providing a record of antarctic ELF/VLF noise that is unprecedented in its continuity and duration. An identical system that has been operating at Stanford University during almost the same period provides a northern mid-latitude comparison data set. Our principal objective is to improve knowledge of the radio noise statistics at frequencies in the ELF/VLF range, and our project has already added substantially to the knowledge and understanding of these statistics on a short-term basis.

Because of the measurements made by the Arrival Heights radiometer, studies of longer term variations can be done. Simultaneously, the additional data enable the statistical reliability of shorter term variations to be improved. Because of the great difficulty involved in making long-term observations, particularly at remote locations, the Arrival Heights measurements are increasing in scientific value as the radiometer continues to operate. Since the predominant source of ELF/VLF radio noise is thunderstorms occurring in the tropics, the Arrival Heights and Stanford systems provide alternate views of this thunderstorm activity. If such activity depends on the temperature of the tropical atmosphere, as has been argued, the long-term statistical measurements of ELF/VLF radio noise made by the Arrival Heights and Stanford systems can provide independent information about global warming.

In addition, the radiometer measurements supplement those made by the automatic geophysical observatories and by other ELF/VLF measurement systems in the Antarctic, including those operated by the British Antarctic Survey. Because of its remote location, Arrival Heights has such a low background noise level that important new measurements are being made even on weak ELF signals, such as the Schumann resonances, for example. There is also the possibility that longer term observations may prove useful in studies of global change. (A–100–M; NSF/OPP 01–38126)

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Conjugate studies of ultra-long-frequency (ULF) waves and magnetospheric dynamics using ground-based induction magnetometers at four high-latitude manned sites.

Mark J. Engebretson, Augsburg College, and Marc R. Lessard, University of New Hampshire.

The Earth's magnetic field arises from its mass and motion around the polar axis, but it creates a powerful phenomenon at the edge of space known as the magnetosphere, which has been described as a comet-shaped cavity or bubble around the Earth, carved in the solar wind. When that supersonic flow of plasma emanating from the Sun encounters the magnetosphere, the result is a long cylindrical cavity, flowing on the lee side of the Earth, fronted by the blunt nose of the planet itself. With the solar wind coming at supersonic speed, this collision produces a "bow shock" several Earth radii in front of the magnetosphere proper.

One result of this process is fluctuations in the Earth's magnetic field, called micropulsations, which can be measured on time scales between 0.1 second and 1,000 seconds. It is known that magnetic variations can significantly affect power grids and pipelines. We plan to use magnetometers (distributed at high latitudes in both the antarctic and arctic regions) to learn more about how variations in the solar wind can

affect the Earth and anthropogenic systems.

We will study these solar-wind-driven variations and patterns at a variety of locations and over periods up to a complete solar cycle. Since satellite systems are now continuously observing solar activity and also monitoring the solar wind, it is becoming feasible to develop models to predict the disruptions caused by such magnetic anomalies. And while our work is geared specifically toward a better understanding of the world and the behavior of its anthropogenic systems, it will also involve space weather prediction. (A–102–M/S; NSF/OPP 02–33169)

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A search for extrasolar planets from the South Pole.

Douglas A. Caldwell, Laurance R. Doyle, and William Borucki, SETI Institute, and Zoran Ninkov, Pixel Physics, Inc.

We will operate a small optical telescope at the South Pole to search for and characterize extrasolar planets by continuously following a southern galactic star field with a charge-coupled device photometer and searching for the periodic dimming that occurs as a planet transits its parent star.

The recent discovery of many close-in giant exoplanets has expanded our knowledge of other planetary systems and has demonstrated how different such systems can be from the solar system. However, their discovery poses important questions about the effects of such planets on the presence of habitable planets. To date only one extrasolar planet—HD 209458b—has been observed to transit a parent star. This project has the potential for a 10-fold increase in the number of extrasolar planets for which transits are observed. The South Pole is an excellent location for detecting such planets because randomly phased transits can most efficiently be detected during the long winter night. Also, the constant altitude of a stellar field at the pole avoids large daily atmospheric extinction variations and allows for higher photometric precision and a search for smaller planets.

Specifically, we will establish an automated planet-finding photometer at the South Pole for two austral winters. The statistics of planetary systems of nearby solar-type stars would indicate that about 10 to 15 extrasolar planets should be detected. There is also the possibility of finding planets that have a lower mass and have not previously been detectable. Combining the transit results (which give the size of the planet) with Doppler velocity measurements (which give the mass) will allow the planetary density to be determined, thus indicating whether the planet is a gas giant like Jupiter, an ice giant like Uranus, or a rocky planet like the Earth. These data will provide basic observational information that is vital to theoretical models of planetary structure and formation. (A–103–S; NSF/OPP 01–26313)

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Dayside auroral imaging at South Pole.

Stephen B. Mende and Harald Frey, University of California–Berkeley.

We plan to operate two ground-based imagers at South Pole Station and combine their observations with simultaneous global auroral observations by the IMAGE (Imager for Magnetopause to Aurora Global Exploration) spacecraft investigating temporal and spatial effects in the ionosphere from the reconnection processes at the magnetopause. The South Pole has advantages for auroral imaging because the continuous darkness during the winter allows 24 hours of optical observations and because the ideal magnetic latitude permits observation of the dayside aurora. The reconnection (merging) region of the magnetosphere provides the most significant entry point for solar wind plasma. It is now widely accepted that the dayside region contains the footprint of field lines that participate in reconnection processes with the interplanetary field.

Although a body of literature about the auroral footprints of the dayside reconnection region has been derived from ground-based observations, it has not been possible to relate those results to simultaneous global auroral images. Global observations of proton auroras from the IMAGE spacecraft have provided direct images of the footprint of the reconnection region, showing that reconnection occurs continuously and that the spatial distribution of the precipitation follows theoretically predicted behavior as a function of

the interplanetary field. The apogee of the IMAGE spacecraft orbit is slowly drifting south, and during the austral winter of 2004, the apogee will be over the Southern Hemisphere. Thus, it will be possible to obtain simultaneous global images of the aurora by IMAGE and of the high-latitude dayside region by two ground-based imagers (electron and proton auroras) at South Pole Station.

Our main goal is to capitalize on this unique opportunity and use the IMAGE satellite as the telescope and the ground-based imagers as the microscope for these observations in an attempt to better understand substorms and related phenomena. Understanding the Earth's electromagnetic environment is key to predicting space weather and to determining how geoactive magnetic storms are. We will continue to involve students in every phase of the program, thereby encouraging some of them to start a career in upper-atmospheric research. (A–104–S; NSF/OPP 02–30428)

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A very-low-frequency (VLF) beacon transmitter at South Pole (2001–2004).

Umran S. Inan, Stanford University.

This 3-year project to establish and operate a very-low-frequency (VLF) beacon transmitter at the South Pole will measure solar effects on the Earth's mesosphere and lower ionosphere. Relativistic electrons, measured at geosynchronous orbit to have energies of more than 300 kiloelectronvolts, appear to fluctuate in response to substorm and solar activity. During such events, these highly energetic electrons can penetrate as low as 30 to 40 kilometers above the Earth's surface. At that altitude, they can wreak havoc in the atmosphere; they ionize chemical species, create x rays, and may even influence the chemistry that produces ozone.

By comparing how the South Pole VLF signal varies in both amplitude and phase when it arrives at various antarctic stations, we can calculate the extent of relativistic electron precipitation. The transmitter will also produce other data on solar proton events, relativistic electron precipitation from the Earth's outer radiation belts, and the joule heating components of high-latitude/polar cap magnetosphere/ionosphere coupling processes.

VLF data from the South Pole beacon provide a valuable complement to two other efforts: first, to other antarctic upper-atmospheric research, such as the automatic geophysical observatory program and the Southern Hemisphere coherent high-frequency radar Super4 Dual Auroral Network (SUPERDARN), and second, to ongoing satellite-based measurements of trapped and precipitating high-energy electrons at both high and low altitudes. The latter are collected by the Solar Anomalous and Magnetospheric Particle Explorer (SAMPEX). (A–108–S; NSF/OPP 00–93381)

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Austral high-latitude atmospheric dynamics.

Gonzalo Hernandez, University of Washington.

Observations of atmospheric dynamics in Antarctica help us better understand the global behavior of the atmosphere in high-latitude regions. Compared with lower latitude sites, the South Pole is a unique spot from which to observe the dynamic motion of the atmosphere. Its position on the Earth's axis of rotation strongly restricts the types of wave motions that can occur.

We will use high-resolution Fabry-Perot spectrometers at South Pole Station and Arrival Heights to make simultaneous azimuthal observations of the individual line spectra of several upper-atmospheric trace species, specifically the hydroxyl radical and atomic oxygen. The observed Doppler shift of the emission lines provides a direct measure of line-of-sight wind speed; wind field structure can also be derived from these measurements. Simultaneously observed line widths provide a direct measurement of kinetic temperature.

Our goal is to observe, characterize, and understand high-latitude mesospheric and thermospheric motions, as well as the thermal structure of these regions. In particular, we are interested in the strong coupling between the lower and upper atmosphere and the existence of persistent upper-thermospheric vertical winds.

At both South Pole Station and Arrival Heights, we make observations during the austral winter, when the instruments operate in 24-hour data-acquisition mode. At this time, station technicians perform routine maintenance and monitor operations. During the austral summer, project team members deploy to both stations to perform calibrations, maintenance, and upgrades. (A–110–M/S; NSF/OPP 02–29251)

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Studies of the polar ionosphere and magnetosphere from measurements in Antarctica and conjugate regions.

Allan T. Weatherwax, Siena College; Theodore J. Rosenberg, University of Maryland; and Louis J. Lanzerotti, New Jersey Institute of Technology.

We will continue our studies of the polar ionosphere and magnetosphere from Antarctica and nominally conjugate regions in the Arctic. Magnetometer observations, high-frequency cosmic noise absorption measurements (riometry), and auroral luminosity measurements (photometry) will form the basis of our studies, which will also involve extensive collaboration with investigators using complementary data sets.

We aim to improve understanding of the mechanisms that couple solar processes into the terrestrial environment by investigating phenomena associated with short-term environmental effects (auroras, induced electrical currents, traveling convection vortices, pulsating particle precipitation, and the origin of auroral radio emissions), as well as those associated with longer-term effects (atmospheric composition studies, stratospheric winds, space weather). The object is to understand these physical processes and how they relate to internal or external driving forces. From this may emerge an enhanced capability to predict events with negative technological or societal impacts in time to mitigate their effects.

Moreover, we will combine ground-based data sets with IMAGE (Imager for Magnetopause to Aurora Global Exploration) satellite data when the spacecraft is ideally situated at apogee in the Southern Hemisphere next year.

We will also continue to maintain the magnetometers at South Pole and McMurdo Stations, as well as imaging and broad-beam riometers and two-wavelength zenith photometers at South Pole and McMurdo Stations and imaging riometers at Iqaluit and Sondrestrom in the Arctic. In addition, we will continue to provide the systems at South Pole and McMurdo Stations for the common recording of other geophysical data and their transmission to collaborating investigators. To enhance the usefulness and timeliness of these data, we will maintain a Web site from which antarctic data sets can be accessed in near real time. Further, we will participate in, and contribute to, several major science initiatives and National Space Weather programs.

Our data can enhance many other projects. For example, astronomers have used our particle/optical data to help calibrate the "seeing" conditions at South Pole during auroral activity. Our research will also be integrated with undergraduate education at all three of the investigators' institutions. (A–111–M; NSF/OPP 03–38105)

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Polar Experiment Network for Geospace Upper-Atmosphere Investigations (PENGUIN)—A new vision for global studies.

Allan T. Weatherwax, Siena College.

Since the advent of space flight, we have witnessed the importance of understanding the Earth and its space environment. Such an understanding requires deep knowledge of the atmosphere-ionosphere-magnetosphere system—knowledge based on upper-atmosphere physical processes in the polar regions in both hemispheres. Only from the surface of Earth can many of the critical coupling processes and feedback systems that define this global system be studied with high temporal and spatial resolution.

We will investigate, from Antarctica and nominally conjugate regions in the Arctic, the multiscale electrodynamic system that comprises the space environment of Earth. Our

plan entails:

- the phased development of a new and comprehensive upper-atmosphere geophysical measurement program based on distributed autonomous instruments operating in an extreme antarctic environment,
- real-time data collection via satellites,
- a methodology to build synergistic data sets from a global distribution of Southern and Northern Hemisphere instrument arrays, and
- an analysis and data distribution/outreach program linked to modeling and computer simulation to link measurement and theory.

Over the next 5 years, we will investigate dayside phenomena such as magnetic impulse events and traveling convection vortices, substorms at the highest latitudes, auroral zone poleward boundary intensifications, and magnetic reconnection and ion flows.

We will also study the causes of space weather processes that affect technologies on Earth and in near-Earth space, including charged particle energization and loss and the effects of solar particles on the polar cap ionosphere. Having the IMAGE (Imager for Magnetopause to Aurora Global Exploration) satellite at apogee in the Southern Hemisphere will provide unprecedented opportunities for unraveling processes involved in internal and external driving forces in the global system. From such research will ultimately emerge an enhanced capability to predict the likely occurrence of events that might have deleterious effects on technology or people.

We will make our data and data acquisition tools widely available, and our research will be integrated with all levels of education from high school through postdoctoral study. Also, the development of new low-power sensors and innovative approaches to extreme environment engineering will benefit other disciplines. (A–112–M; NSF/OPP 03–41470)

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All-sky imager at South Pole.

Masaki Ejiri, National Institute of Polar Research, Japan.

The South Pole is an unparalleled platform for observing aurora during the austral winter. As a point on the Earth's rotational axis, the pole provides a unique vantage point from which to observe the airglow and discern the characteristics of acoustic gravity waves in the polar region as they vary in altitude and wavelength. Observing aurora continuously over 24 hours allows us to collect data on:

- the dayside polar cusp/cleft aurora (due to the direct entry of the solar wind);
- afternoon aurora that are closely associated with the nightside magnetospheric storm/substorm activities; and
- the polar cap aurora, which depends on the polarity of the interplanetary magnetic field.

Research has shown that these auroras develop from precipitating low-energy particles entering the magnetosphere from the solar wind.

Though data have been gathered at the South Pole with a film-based, all-sky camera system since 1965, newer technology now produces digital images and permits us to process large amounts of information automatically. Currently, we are using the all-sky-imager, a digital charge-coupled device imager monitored and controlled by the National Institute of Polar Research in Japan.

These international collaborations should enhance knowledge of the magnetosphere, the ionosphere, and upper/middle atmosphere physics. The high-frequency radar installations at Halley Bay, Sanae, and Syowa Stations provide the vector velocity of ionospheric plasma over the South Pole. These studies should provide further insight into the physics of the magnetosphere, the convection of plasma in the polar cap, and solar wind effects, specifically dayside auroral structure, nightside substorm effects, and polar cap arcs. (A–117–S; U.S./Japan agreement)

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Spaceship Earth: Probing the solar wind with cosmic rays.

John W. Bieber, William H. Matthaeus, and K. Roger Pyle, Bartol Research Institute, University of Delaware, and Evelyn Patterson, U.S. Air Force Academy.

Cosmic rays—penetrating atomic nuclei and electrons from outer space that move at nearly the speed of light—continuously bombard the Earth. Colliding with the nuclei of molecules found in the upper atmosphere, they create a cascade of secondary particles that shower down on Earth. Neutron monitors, which are deployed in Antarctica and are part of a global network of nine stationary monitors and two transportable ship-borne monitors, provide a vital three-dimensional perspective on this shower and how it varies along all three axes. Accumulated neutron-monitor records (begun in 1960 at McMurdo Station and in 1964 at Amundsen–Scott South Pole Station) provide a long-term historical record that supports efforts to understand the nature and causes of solar/terrestrial and cosmic ray variations as they are discerned over the 11-year sunspot cycle, the 22-year Hale cycle, and even longer time scales. Data from the neutron monitors in this network will be combined with data from other ground-based and spacecraft instruments in various investigations of cosmic rays in relation to the Sun and solar wind. Specific objectives include the study of acceleration and transport of solar energetic particles, the scattering of cosmic rays in the solar wind, and the use of cosmic-ray observations for space weather forecasting.

This project at McMurdo and Amundsen–Scott South Pole Stations continues a series of year-round observations recording cosmic rays with energies in excess of 1 billion electron volts. These data will advance our understanding of a number of fundamental plasma processes occurring on the Sun and in interplanetary space. At the other extreme, we will study high time-resolution (10-second) cosmic ray data to determine the three-dimensional structure of turbulence in space and to elucidate the mechanism by which energetic charged particles scatter in this turbulence. (A–120–M/S; NSF/ATM 00–00315)

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RICE: Radio Ice Cherenkov Experiment.

David Besson, University of Kansas–Lawrence.

The goals of the RICE experiment are similar to those for the larger Antarctic Muon and Neutrino Detector Array (AMANDA; see A–130–S). Neutrinos are elementary particles with no electrical charge and very little mass. They are the only particles that can elude the cosmic microwave background and penetrate, undeflected by magnetic fields, to Earth. Both RICE and AMANDA seek to measure high-energy neutrinos by detecting Cherenkov radiation, which is visible as a blue glow and results from collisions of high-energy neutrinos with ice or rock. While AMANDA aims to discover the sources, both inside and outside the galaxy, of the shower of very-high-energy neutrinos descending on (and usually passing through) the Earth, RICE is designed to detect the compact electromagnetic cascades that produce Cherenkov radiation. Radio detection is more efficient than optical-based techniques.

This season, the initiation of ice-hole drilling for the IceCube project (see A–333–S) presents a singular scientific opportunity. We will deploy radio receivers in these same holes, thereby increasing RICE's sensitivity to neutrinos by at least two orders of magnitude. Deploying three radio receiver clusters (two dual-polarization, high-bandwidth antennas per cluster per hole) will also allow us to conduct radioglaciology experiments. We will design the radio array for coincident (RICE plus IceCube) electromagnetic cascade detection, and special hardware will allow microsecond time-scale elimination of the surface anthropogenic backgrounds that have proved a problem in the past.

RICE data from the past 4 years have allowed the most detailed study of *in situ* radio detection systematics so far. This season, we will perform maintenance on the existing experiment. We will also calibrate the radio antenna and investigate radio-frequency ice response, using existing resources and infrastructure and without drilling additional holes.

Our data and results will contribute greatly to the knowledge of astrophysics and ultra-high-energy astronomy. (A–123–S; NSF/OPP 03–38219)

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A versatile electromagnetic waveform receiver for South Pole Station.

James W. LaBelle, Dartmouth College, and Allan T. Weatherwax, Siena College.

The Earth's aurora naturally emits a variety of low-frequency (LF), medium-frequency (MF), and high-frequency (HF) radio waves that are signatures of the interaction between the auroral electron beam and the ionospheric plasma. Yet some of the mechanisms that generate plasma waves are not well understood. This project focuses on several types of signals detectable at ground level, including auroral hiss, which occurs primarily at very low frequencies but often extends into the LF/MF range, and auroral roar, a relatively narrowband emission generated near or at the second and third harmonics of the electron cyclotron frequency.

We will use a versatile electromagnetic waveform receiver deployed at South Pole Station. Only recently has it been possible to conceive of an inexpensive, versatile receiver of this type for the South Pole. An antarctic location is essential for ground-based observations of LF auroral hiss because the broadcast bands usually found in the Northern Hemisphere are typically absent in Antarctica. Also, the absence of broadcast bands improves the effectiveness of automatic wave-detection algorithms.

We can use the receiver to address many issues. For example, it was recently discovered that auroral roar is sometimes modulated at frequencies between 7 and 11 hertz, a phenomenon called flickering auroral roar. This receiver will allow us to find out how common flickering auroral roar is, the conditions under which it occurs, what the frequencies are, and how the amplitude and frequency vary over time.

Between 15 percent and 30 percent of auroral hiss events are not observable at very low frequencies. The receiver will determine whether LF auroral hiss consists exclusively of relatively unstructured broadband impulses or whether it sometimes displays a fine structure similar to that of auroral kilometric radiation and whistler-mode waves in the same frequency range detected in the lower ionosphere. We will also define and test auroral roar and auroral hiss mechanisms. Despite its extensive application for communications, the LF/MF/HF band has been relatively little investigated as a source of natural radio emissions detectable at ground level.

A complete knowledge of our geophysical environment requires understanding the physics of these emissions. Further, electron beam-plasma interactions analogous to terrestrial aurora occur in many space physics and astrophysics applications. Often, the electromagnetic radiation emitted by these systems is our only source of knowledge about them. The local auroral plasma provides an opportunity to view some plasma radiation processes at close range. (A–128–S; NSF/OPP 00–90545)

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Effects of enhanced solar disturbances during the 2000–2002 solar-max period on the antarctic mesosphere-lower-thermosphere (MLT) and F regions composition, thermodynamics, and dynamics.

Gulamabas G. Sivjee and Syed Azeem, Embry Riddle Aeronautical University.

While variations in the Sun's energy affect people in obvious ways by driving the weather and the seasons, there are actually many cycles and variations of deeper interest to science, on scales from seconds to centuries to eons. One of the most basic is the 11-year cycle when the Sun's magnetic poles reverse direction (since reliable observations began, 23 of these have occurred and the last just recently peaked) and sunspots and other solar activity wax to peak levels. The National Aeronautics and Space Administration is using this opportunity to conduct its TIMED (thermosphere-ionosphere-mesosphere-energetics and dynamics) satellite study, which will focus on the region between 60 and 180 kilometers above the Earth's surface.

Taking advantage of the timing of both of these events, we will use observations in the

visible and near-infrared ranges of upper-atmospheric emissions above South Pole Station to study the heating effects of auroral electrical currents in the ionosphere, as well as planetary waves and atmospheric tides.

As it passes overhead, TIMED will provide data on the temperature, winds, and tides of the Earth's upper atmosphere, especially above the poles. But tracking satellites often have difficulty differentiating between variations in location or time. South Pole ground-based observations will be valuable in sorting out the time-location question. (A–129–S; NSF/OPP 03–37618)

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Antarctic Muon and Neutrino Detector Array (AMANDA) 2004.

Robert J. Morse, Francis Halzen, and Albrecht Karle, University of Wisconsin–Madison.

Neutrinos are elementary particles that have no electrical charge, can take one of three forms, and are believed to have very little or no mass. Coursing through the universe, they interact only rarely with other particles. The primary objective of the Antarctic Muon and Neutrino Detector Array (AMANDA) is to discover the sources, both inside and outside our galaxy, of the shower of very-high-energy neutrinos descending on (and usually passing through) the Earth. As one of the first large neutrino telescopes, AMANDA promises to make seminal contributions to astronomy.

AMANDA uses an array of photo multiplier tubes imbedded between 1 and 2 kilometers into the ice near the South Pole to create a Cherenkov detector out of the natural ice. (Cherenkov radiation, visible as a blue glow, results from collisions of high-energy neutrinos with ice or rock.) This system will detect high-energy neutrinos that have passed through the Earth. They could be made up of contributions from many active galactic nuclei, or they could be point sources coming from supernova remnants, rapidly rotating pulsars, neutron stars, individual blazars, or other extragalactic point sources. Recently, new sources of high-energy gamma rays, such as Mrk 421, have been discovered. AMANDA is designed to study just such objects, which are believed to emit copious numbers of high-energy neutrinos. To date, neutrino astronomy has been limited to the detection of solar neutrinos, plus one brief spectacular burst from the supernova that appeared in the Large Magellanic Cloud in February 1987.

The AMANDA detector has operated for more than 3 years in its final configuration of 677 optical modules on 19 strings. In steady operation, the detector collects roughly 4 neutrinos per day using fast analysis software. This year, we plan a number of upgrades to existing experiments, new staff training, very-low-frequency noise investigations, and computer upgrades in the form of filtering and monitoring software.

Also, we pioneered many of the programs that are now part of the IceCube education and outreach program (see A–333–S), including the Science in the Ice course that involves high school teachers and their students, as well as participants in the Teacher Experience in Antarctica Program. (A–130–S; NSF/OPP 03–37726)

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Measurements addressing quantitative ozone loss, polar stratospheric cloud nucleation, and large polar stratospheric particles during austral winter and spring.

Terry Deshler, University of Wyoming, and Marcel Snels, Instituto di Fisica dell'Atmosfera, Rome, Italy.

The stratospheric ozone layer provides life on Earth with an essential shield from solar ultraviolet radiation. The discovery in 1985 of large ozone losses above Antarctica each spring took the world and the scientific community by surprise. Since that time, the cause of this unprecedented ozone loss has been determined to be chlorine compounds interacting on the surfaces of clouds that formed when temperatures dropped below 78° C the previous winter [polar stratospheric clouds (PSCs)]. This interaction helps explain why ozone depletion is so severe in the polar regions. However, many details must still

be clarified before we can comprehensively model the stratospheric ozone balance.

Observations of vertical ozone profiles from McMurdo Station will add to our database of annual measurements and will be completed as stratospheric chlorine levels are peaking to provide a baseline to detect the first signs of ozone recovery. In addition, we will extend our observations of PSCs. We use balloon-borne *in situ* instruments and an optical light detection and ranging radar (lidar) to study PSCs, stratospheric aerosol, and the thermal behavior and dynamics of the atmosphere above McMurdo Station. Continuous lidar observations and comparison of lidar and *in situ* measurements provide insight into the nature of these PSCs. Specifically, measurements of the size, concentration, and optical properties of the particles that form in these clouds provide estimates of the surfaces available for heterogeneous chemistry (the activation of chlorine so it can destroy ozone), the rates of denitrification and dehydration, and particle composition.

Measurements of vertical ozone profiles and lidar aerosol profiles are archived in the database of the Network for the Detection of Stratospheric Change, a global set of high-quality remote-sounding research stations for observing and understanding the physical and chemical state of the atmosphere (see www.ndsc.ws). This project represents a collaboration between Italian researchers and the University of Wyoming. (A–131–M; NSF/OPP 02–30424 and U.S./Italian agreement)

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Measurement and analysis of extremely-low-frequency (ELF) waves at South Pole Station.

Marc R. Lessard, University of New Hampshire, and James W. LaBelle, Dartmouth College.

We aim to detect and record magnetic field fluctuations in the extremely-low-frequency (ELF) range, specifically auroral ion cyclotron waves, which have been well correlated with flickering aurora, at South Pole Station. Theory predicts that these waves modulate precipitating electron fluxes, thereby causing the flickering in luminosity emissions. Substantial evidence now supports this theory, although the excitation mechanism responsible for the ion cyclotron waves is somewhat uncertain. The most well developed theory suggests that the waves result from an electron-beam instability. In any case, the frequency of the flickering or, equivalently, the frequency of the ground-based observations of ion cyclotron waves can be used to infer the altitude of the excitation mechanism, since the wave frequency depends on the strength of the background magnetic field, which is a known quantity. As such, the information that will be acquired can be used to test models of auroral acceleration mechanisms, as well as study dispersive ELF waves, a type of wave that has been reported in the literature only a few times, but one that may provide important information on substorm onset or, perhaps, the boundaries of open and closed magnetic fields.

A first step is to identify the wave mode and to determine the location and geomagnetic conditions under which these waves can be observed. The equipment used to make these observations consists of an induction coil magnetometer and data acquisition system. The induction coil is a commercially available device, one that was originally designed for geophysical exploration. Data will be returned to Dartmouth College for analysis. (A–136–S; NSF/OPP 01–32576)

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Cosmic ray energetics and mass (CREAM).

Eun-Suk Seo, University of Maryland; Simon Swordy, University of Chicago; James Beatty and Stephane Coutu, Pennsylvania State University; Michael DuVernois, University of Minnesota; Il Park, Ewha Woman's University; and Pier Simone Marrocchesi, University of Siena.

The cosmic ray energetics and mass (CREAM) project is a joint National Science Foundation/National Aeronautics and Space Administration (NASA) endeavor that will use a series of balloon flights to study the origin of cosmic rays. The CREAM instrument is configured with state-of-the-art particle detectors to measure cosmic ray composition from protons to iron nuclei over the energy range of 1 to 10^3 tera electron volts. The goal is to observe cosmic ray spectral features and abundance changes that might signify a limit to supernova acceleration.

Particle charge measurements will be made with a timing-based detector and a pixelated silicon matrix to minimize the effect of backscatter from the calorimeter. Particle energy measurements will be made with a transition radiation detector and a sampling tungsten/scintillator calorimeter. In-flight cross calibration of the two detectors allows better determination of particle energy. Measurements of the relative abundance of secondary comic rays (e.g., B/C), as well as primary spectra, will allow us to determine cosmic ray source spectra at this high energy, where measurements are currently not available.

The instrument has been tested and calibrated with a series of beam tests. It will be integrated with a flight command data module support system that was developed for the NASA Wallops Flight Facility and is attached to the bottom of the instrument to provide CREAM with power and communications. The power system consists of 10 solar panels and 4 batteries that will provide 28 volts of power to the instrument and 5, 12, and 28 volts of (regulated and unregulated) power to the support system instrumentation. The communication interface between the science instrument and the command data module is through flight computers via an Ethernet connection. Real-time data will be down-linked continuously. All data will also be recorded to two hard drives, so anything that is not down-linked during real time can be retrieved. Other communication platforms serve as backups. (A–137–M; NSF/NASA agreement)

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Balloon-borne experiment with a superconducting spectrometer (BESS).

John W. Mitchell, National Aeronautics and Space Administration, and Akira Yamamoto, High Energy Accelerometer Research Organization (KEK), Japan.

The balloon-borne experiment with a superconducting spectrometer (BESS) investigates elementary particle phenomena in the early Universe. For further studies of low-energy antiprotons and extensive searches for antinuclei in cosmic radiation, BESS was prepared for a long-duration balloon flight in Antarctica. During a 10-day flight, an energy spectrum of cosmic ray antiprotons can be precisely measured with 10 times higher statistics, and cosmic antimatter can be searched for with greater sensitivity.

The BESS balloon payload, solar-cell array structure, and ground support equipment will be transported from the United States to William Field. Eight to ten scientists will work there from the beginning of November until the payload is recovered, after a long-duration flight, by a small plane or helicopter around the end of January. (A–140–M; NSF/NASA agreement)

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Balloon observations of MeV electron precipitation.

George Parks and David Smith, University of California–Berkeley.

We propose to prepare and fly a series of balloon payloads to study energetic electrons precipitated from the outer zone of the Earth's radiation belts into the atmosphere and then analyze the resulting data. These electrons are relativistic (kinetic energy greater than the electron rest mass) and can be responsible for damaging satellites in geosynchronous orbit. They are trapped in the Earth's magnetosphere between 4 and 6 Earth radii at the equator, which means that they hit near the Arctic and Antarctic Circles when they come down. We will address the physics of the various relativistic electron precipitation processes, their patterns in space and time, and the energy and number of electrons precipitated.

When relativistic electrons hit the atmosphere, they can produce enough ionization to create chemically important amounts of "odd nitrogen" (nitrogen dioxide and other compounds). These compounds can either destroy stratospheric ozone or else bind up and deactivate chlorine atoms that destroy ozone, thus perhaps partially protecting the ozone layer. Although their role in either case is understood to be small, it has not been well studied and may represent an important perturbation on the main chemistry.

Instruments on the balloons do not study the electrons themselves, but rather the x rays they emit when they hit the atmosphere. Balloon-borne instruments can therefore

observe all the precipitation taking place within 100 kilometers of its location or more and track the variability of the emission over time. A large balloon will fly from McMurdo Station, circumnavigating the continent in 2 to 3 weeks. It will carry several x-ray detectors, as well as instruments to detect electromagnetic fields and waves. Three small payloads will also be launched in a region of the coast below the South Atlantic, where the trapped particles bounce lowest into the atmosphere because of the shape of the Earth's magnetic field.

Improving our understanding of the physics of relativistic electron behavior is not only interesting in its own right, but may also help us better predict ozone depletion and protect satellites from radiation damage. Moreover, balloon projects have proven to be ideal training grounds for graduate students in space sciences. (A–144–E; NSF/OPP 02–30441)

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Long-Duration Balloon Program.

David W. Sullivan, National Scientific Balloon Facility.

The National Scientific Balloon Facility will launch two stratospheric balloons between December 10 and January 10. They have a volume of 40 million cubic feet and will ascend at a rate of approximately 900 feet per minute to a float altitude of 125.000 feet. All the balloons will be launched from the long-duration-balloon site near Williams Field, reach float altitude, and circumnavigate the continent between 70 degrees and 80 degrees south latitude. They will be terminated and recovered on the Ross Ice Shelf or the Polar Plateau.

When a flight is terminated, an aircraft will fly within line of sight and send a command to the payload from an onboard communication system. At the point of release, the payload will descend by parachute to a predicted impact site. Recovery operations and data analysis will then follow. (A–145–M; NSF/NASA agreement)

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Infrared measurements of atmospheric composition over Antarctica.

Frank J. Murcray, Ronald D. Blatherwick, and Pierre Fogal, University of Denver.

Using passive infrared instruments, we will measure year-round atmospheric chemistry to acquire better data for the photochemical transport models used to predict ozone depletion and climate change. The ozone hole has shown how sensitive the southern polar stratosphere is to chlorine, and although gradual healing of the hole is expected, model predictions indicate a possible delay in recovery because of the impact of global warming on the catalytic ozone destruction process.

Since most satellite instruments do not sample the polar regions in the winter, ground-based instruments can make important contributions, and the data from our instruments will also validate new satellite sensors. We are in the second year of this project. During year 1, we successfully installed and operated emission instruments at Arrival Heights and South Pole. We will install two spectrometers, one at South Pole Station and another at McMurdo Station for year-round operation, and a solar spectrometer at South Pole Station for summer operation. Also, we will collaborate with and receive data from the New Zealand National Institute for Water and Air Research, which operates a similar solar spectrometer at Arrival Heights.

During the polar night, two instruments will provide important information on nitric acid and denitrification, as well as dehydration, and high-resolution spectra from which we will derive vertical profiles, vertical column amounts of many molecules important in the ozone destruction process, and atmospheric tracers. Specifically, we will derive year-round column abundance measurements of nitric acid, methane, ozone, water, nitrous oxide, the chlorofluorocarbons (CFCs), and nitrogen dioxide. The solar spectrometers will be primarily studying the breakup of the polar vortex and photochemical recovery.

The solar instruments will provide some altitude profile information about those molecules and others. The data set we obtain will be used to determine the current state of nitrogen oxide partitioning; to measure denitrification, vapor profiles in the stratosphere, and dehydration; to determine current CFC and stratospheric chlorine

levels; and to gain more insight into vortex-related chemical and dynamic effects.

In addition, the data will allow photochemical transport modelers to compare outputs with actual measurements, especially at intermediate stages. As the recovery from ozone destruction begins, it is important to have a data set that comprehensively covers the major constituents of both the catalytic ozone destruction sequence and global warming in order to place the relative influence of the two mechanisms in perspective. (A–255–M/S; NSF/OPP 02–30370)

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Dynamics of the antarctic mesosphere–lower–thermosphere (MLT) region using ground-based radar and TIMED instrumentation.

Scott E. Palo, James P. Avery, and Susan K. Avery, University of Colorado–Boulder.

The mesosphere–lower thermosphere, which is found between 80 and 120 kilometers above the surface of the Earth, is a highly dynamic region that couples the lower atmosphere (troposphere/stratosphere) with the upper atmosphere (thermosphere/ionosphere). Of particular importance in this region are both the upward propagating, thermally forced atmospheric tides and global planetary waves. Both of these phenomena transport heat and momentum from the lower atmosphere into the upper atmosphere.

Studies in recent years have indicated that the high-latitude mesosphere–lower thermosphere has a rich spectrum of previously undiscovered planetary waves that can interact with the sun-synchronous migrating semidiurnal tide, thereby modifying its spatial and temporal structure while giving rise to the nonmigrating semidiurnal tide. Understanding the structure and variability of the semidiurnal tide is an important step toward understanding the global heat and energy balance of the mesosphere–lower thermosphere.

We will observe and model the spatial-temporal structure and variability of the semidiurnal tide, with a focus on the horizontal wind and temperature fields in the arctic and antarctic mesosphere–lower thermosphere. Previous observations have indicated that planetary waves play a significant role in the variability of the semidiurnal tide. We will therefore estimate the structure of the semidiurnal tide and the planetary waves simultaneously. These estimates will be analyzed in conjunction with both linear mechanistic and global circulation models to help interpret the observations. The data for this project will also include horizontal wind measurements from a global network of 30 ground-based meteor and medium-frequency radars. (The radar data are collected by colleagues in Australia, Canada, Japan, Russia, the United Kingdom, and the United States.) Moreover, wind and temperature measurements from the National Aeronautics and Space Administration's TIMED (thermosphere-ionosphere-mesosphere-energetics and dynamics) satellite will be combined with the radar data and incorporated into existing databases.

Teaching, training, and learning will be advanced by the inclusion in this research of graduate students, especially underrepresented minorities. All the students involved in this project will be encouraged to present their results and participate in professional meetings. (A–284–S; NSF/OPP 03–36946)

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Global thunderstorm activity and its effects on the radiation belts and the lower ionosphere.

Umran S. Inan, Stanford University.

Tracking dynamic storms is a challenge, but lightning associated with thunderstorms can provide scientists with an indirect way of monitoring global weather. This project employs very-low-frequency (VLF) radio receivers located at Palmer Station and operated in collaboration with the British and Brazilian Antarctic Programs, both of which have similar receivers. All are contributors to the Global Change Initiative.

The VLF receivers measure changes in the amplitude and phase of signals received from several distant VLF transmitters. These changes follow lightning strokes because radio (whistler) waves from the lightning can cause very energetic electrons from the Van Allen radiation belts to precipitate into the upper atmosphere. This particle precipitation then increases ionization in the ionosphere, through which the propagating VLF radio waves must travel. Because the orientations to the VLF transmitters are known, it is possible to triangulate the lightning sources that caused the changes. Once the direction of the lightning source is known, it can be subjected to waveform analysis and used to track—remotely—the path of the thunderstorms.

The data will also be correlated with data from the antarctic automatic geophysical observatory network and will be used by scientists studying the magnetosphere and the ionosphere. (A–306–P; NSF/OPP 02–33955)

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IceCube.

Francis Halzen, University of Wisconsin–Madison.

We are building the IceCube Observatory, which will be installed at the South Pole. IceCube, a neutrino telescope that will be buried 1.4 to 2.4 kilometers below the surface of the ice, will be constructed during the austral summers over the next 5 years. The detector will consist of 4,800 optical modules deployed on 80 vertical strings. AMANDA (see the Antarctic Muon and Neutrino Detector Array project, A–130–S) serves as a prototype for this international collaborative effort. This season we will to ship the remaining components, begin drilling in the ice sheet, and begin assembling and testing systems.

Using neutrinos as cosmic messengers, IceCube will open an unexplored window on the Universe and will answer such fundamental questions as what the physical conditions in gamma ray bursts are and whether the photons originating in the Crab supernova remnant and near the supermassive black holes of active galaxies are of hadronic (derived from subatomic particles composed of quarks) or electromagnetic origin. The telescope will also examine the nature of dark matter, aid in the quest to observe supersymmetric particles, and search for compactified dimensions.

Since many parts of the Universe cannot be explored using other types of radiation (protons do not carry directional information because they are deflected by magnetic fields, neutrons decay before they reach the Earth, and high-energy photons may be absorbed), IceCube will fill a gap in our knowledge and occupy a unique place in astronomical research. (A–333–S; NSF/OPP 03–31873)

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Extending the South American Meridional B-field Array (SAMBA) to auroral latitudes in Antarctica.

Eftyhia Zesta, University of California–Los Angeles.

The South American Meridional B-field Array (SAMBA) is a longitudinal magnetometer chain extending from the low to mid-latitudes. The installation of a magnetometer at Palmer Station will extend the SAMBA chain from 10 to 12 stations and allow us to study ultra-low-frequency waves and the remote sensing of mass density in the inner magnetosphere during geomagnetically active periods.

Two magnetometer stations will be deployed, one at Palmer Station and the other at Patriot Hills, a Chilean base that operates only in the summer. The Chilean Antarctic Institute will be responsible for that installation. In September 2004, we will install a system at Palmer Station that comprises:

- a magnetometer sensor,
- a magnetometer card and electronics,
- a computer to run the system,
- a 60-yard cable connecting the sensor to the electronics, and

- a global positioning system (GPS) receiver card (installed inside the computer) with an antenna and cable.

The sensor itself is mounted at one end of a 1.1-meter (m) plastic tube with a cross-sectional diameter of roughly 15 centimeters. The sensor includes a 60-m attached cable with conduit that allows the sensor to be buried in the bedrock 1 m below the surface in a magnetically quiet environment that also minimizes temperature variations. A GPS antenna will be installed as well.

Our specific goals are as follows:

- to extend the SAMBA chain to auroral latitudes and to increase the spatial resolution of the effective cusp-to-cusp chain,
- to extend the number of conjugate pairs of stations between the Northern and Southern Hemispheres, thus increasing the size of the inner magnetospheric region that can be remotely monitored,
- to establish an auroral latitude station conjugate to the Canadian Poste de la Baleine and to study the differences in substorms and general auroral activity, and
- to provide the scientific community with near-real-time data that can be used to validate models and indexes that up to now have been tuned primarily with data only from the Northern Hemisphere. (A–357–P; NSF/OPP 03–41861)

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Development of an autonomous real-time remote observatory (ARRO).

Marc R. Lessard, University of New Hampshire, and James W. LaBelle, Dartmouth College.

We will develop an autonomous real-time remote observatory (ARRO), which will be designed to accommodate at least a dozen instruments, with the goal of enabling reliable observations from several sites on the antarctic plateau. We will build two prototypes of this observatory and test them for extended periods in cold chambers on Mount Washington and at the South Pole.

Significant outstanding issues in diverse fields drive the need for a network of reliable autonomous observatories capable of operating in the polar regions. ARRO will contribute to the pursuit of a broad scientific agenda by a large group of institutions and investigators in fields ranging from solar-terrestrial physics to seismology. In solar-terrestrial physics, the geomagnetic polar cap—the region of geomagnetic field lines connected to interplanetary space—forms a key window on the interaction between the solar wind and the Earth's magnetosphere. Continued progress in understanding the Sun's influence on the structure and dynamics of the Earth's upper atmosphere depends on increasing knowledge of the role that the polar cap plays in coupling the solar wind with the magnetosphere, ionosphere, and thermosphere. Furthermore, a network of observatories at high latitudes will contribute significantly to studies of energy input into the magnetosphere, reconnection, nightside energization of particles and auroral substorms, subauroral and inner magnetospheric physics, and development of a new polar cap index of solar-terrestrial activity.

Also, because the seismic character of Antarctica is not well known, a central goal is to determine crustal and mantle structure from seismic signals. This requires a network of receiving stations. In atmospheric science, one vital object of study is nitric acid trihydrate polar stratospheric clouds, which are implicated in the annual springtime destruction of stratospheric ozone over Antarctica.

In addition, ARRO development includes several different layers of research and training. Students will be directly involved, from the initial design stages to deployment. Finally, ARRO includes significant connections to industry and Government units outside the academic community, and participation will sharpen the capabilities of these units to serve the Nation in applying technology to challenging environments of cold weather and high altitudes. (A–362–S; NSF/OPP 02–16279)

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Next-generation cosmic microwave background polarization measurements with the QUEST experiment on the degree angular scale interferometer (DASI).

Sarah E. Church, Stanford University; Clement L. Pryke, University of Chicago; and Andrew E. Lange and James J. Bock, California Institute of Technology.

We intend to deploy QUEST, a 2.6-meter Cassegrain telescope equipped with a next-generation polarization-sensitive bolometer array, to South Pole Station and operate it over two austral winters. We will mount the telescope on the existing degree angular scale interferometer (DASI) platform and reuse large parts of the DASI infrastructure and control system. We will use the combined QUEST/DASI (or QUaD) system to make maps of the polarization of the cosmic microwave background (CMB) with unprecedented sensitivity and angular resolution.

The CMB—the faint, relic heat from the Big Bang—offers a snapshot of the Universe at the point where it transitioned from hot plasma to neutral gas. The statistics of the expected sky pattern for a given cosmological theory can be accurately calculated, and a host of experiments have now measured the variation of the total intensity, or temperature, of the CMB. Taken together, these measurements have begun to reveal the origin, composition, evolution, and ultimate fate of the Universe.

The polarization of the CMB results from bulk motions of material at the time of the plasma–neutral gas transition. Several experiments are either running or under construction to improve measurements of CMB polarization. QUaD has raw sensitivity similar to that of the European Space Agency's planned Planck satellite (to be launched in 2007) and in fact shares much of the same technology. However, while Planck plans to survey the whole sky, QUaD will go extremely deep on small patches selected for extremely low foreground contamination. QUaD's maps will have dramatically higher signal-to-noise per pixel and will prove crucial to disentangling the cosmic signal from instrumental and foreground effects.

The enterprise of modern cosmology is one with which almost everybody can identify. QUaD project members communicate with the public in both formal and informal settings. Outreach and education related to the project will be disseminated through established structures and mechanisms, which reach out to local and distant K–12 schoolteachers and students to inform and to help attract women and minorities to science. Also, graduate and undergraduate education and research will be integrated into QUaD construction and data analysis. (A–366–S; NSF/OPP 03–38138, NSF/OPP 03–38238, and NSF/OPP 03–38335)

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Dual Auroral Radar Network at South Pole Station.

William Bristow and John Hughes, University of Alaska–Fairbanks.

The Super Dual Auroral Radar Network, or SuperDARN, is an international collaborative experiment for observations of plasma motions in Earth's upper atmosphere. By observing ionospheric plasma motions, many geophysical processes ranging from E-region plasma instabilities, to the relationships between auroral luminosity and electric fields, to the global-scale convective response to changes in the solar wind and the interplanetary magnetic field can be studied. Each of these contributes to the overall goals of space physics: developing an understanding of the coupling of energy from the solar wind into Earth's upper atmosphere and its effects on people or the systems they have created.

SuperDARN covers nearly 15 hours of local time in the Northern Hemisphere and close to 12 hours in the Southern Hemisphere. The continuous monitoring of convective flows requires radar observations that circumscribe the magnetic poles.

We will construct a radar instrument at Amundsen–Scott South Pole Station. The data we derive will be used to study a variety of topics, including the responses of global convection to solar wind and interplanetary magnetic field changes; plasma entry into, and exit from, the polar cap and the accompanying response of the magnetotail;

magnetospheric cusp response to changes in the solar wind; mesospheric winds; and thermospheric gravity waves. In addition, by establishing global-scale coverage in the Southern Hemisphere, we can address questions about conjugacy and the differences caused by the asymmetry of solar illumination.

The SuperDARN network has proven to be among the most powerful tools available for space physics research. The ability to observe global-scale convection with good temporal and spatial resolution allows us to address some of the most interesting and important outstanding questions of space physics.

In addition, as a radar network, SuperDARN fosters international collaboration, especially with the Italian Instituto de Fisica dello Spazio Interplanerario and the French Laboratoire de Physique et Chimie de l'Environnement. The cooperative scientific effort fostered under this program will have broad societal impacts and will also contribute to the education of future scientists.(A–369–S; NSF/OPP 03–37635)

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Antarctic Submillimeter Telescope and Remote Observatory (AST/RO).

Antony A. Stark and Adair P. Lane, Smithsonian Institution Astrophysical Observatory; Christopher K. Walker, University of Arizona; and Jacob Kooi and Richard Chamberlin, California Institute of Technology.

Astronomy is undergoing a revolutionary transformation, where for the first time we can observe the full range of electromagnetic radiation emitted by astronomical sources. One of the newly developed and least explored bands is the submillimeter, at frequencies from about 300 gigahertz up into the terahertz range. Submillimeter-wave radiation is emitted by dense gas and dust between the stars, and submillimeter-wave observations allow us to study the galactic forces acting on that gas and the star formation processes within it in unprecedented detail.

The Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) is a 1.7-meter, single-dish instrument that has been operating since 1995 in several submillimeter bands. It has made position-position-velocity maps of submillimeter-wave spectral lines with arcminute resolution over regions of sky that are several square degrees in size. AST/RO provides a valuable complement to the planned arrays, which are inefficient when observing large areas because of their small field of view. AST/RO can observe molecular clouds throughout the fourth quadrant of the Milky Way and the Magellanic Clouds to locate star-forming cores and study in detail the dynamics of dense gas in our own galaxy. AST/RO studies are showing how molecular clouds are structured, how newly formed stars react back on the cloud, and how galactic forces affect cloud structure. Also, these studies:

- have shown that the structure of molecular clouds is affected by their heavy element content and their proximity to spiral arms,
- have examined the gradient of heavy elements in the galaxy, and
- have recently produced extensive, high-sensitivity maps of several atomic and molecular transitions toward the Galactic Center and an unbiased survey of molecular and atomic gas in the fourth quadrant of the Galaxy.

Essential to AST/RO's capabilities is its location at Amundsen–Scott South Pole Station. Most submillimeter radiation is absorbed by irregular concentrations of atmospheric water vapor before it reaches the Earth's surface. The desiccated air over South Pole Station allows an accurate intercomparison of submillimeter-wave power levels from locations on the sky separated by several degrees. This is essential to the study of submillimeter-wave radiation on the scale of the Milky Way and its companion galaxies.

This season we will use recently installed receivers in the terahertz frequency band [SPIFI (the South Pole Imaging Fabry-Perot Interferometer), TREND] to map highly excited lines of carbon monoxide and other molecules toward star-forming regions in the Milky Way and nearby galaxies, as well as emission from ionized nitrogen (the second strongest line emitted from the interstellar medium) toward the Galactic Center. We will begin a survey of atomic and molecular lines from the Lupus and Chameleon clouds, which are being intensively studied at infrared wavelengths with the Spitzer Space Telescope. The data will be made freely available. (A–371–S; NSF/OPP 01–26090)

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PAST: The Primeval Structure Telescope.

Jeffrey B. Peterson, Carnegie-Mellon University.

We propose to build the Primeval Structure Telescope (PAST) and use it to locate and study the era of formation of the earliest luminous objects. The primeval structure we will detect contained the first stars, supernova explosions, and/or black holes. All these objects were strong sources of ultraviolet (UV) radiation, so they ionized the material surrounding them. It is this ionization that we will sense and study.

For decades, the study of the first collapsed objects was largely a theoretical exercise, since almost no data from red shift higher than 5 were available. The high red shift Universe, where the first ionizing objects resided, was inaccessible to observation. That changed suddenly in February 2003, when satellite data provided evidence that the Universe was ionized very early, before age 200 million years. To ionize the Universe at the then-prevailing density of hydrogen would have required a very strong UV flux, which means that the first UV-effusive objects were likely formed much earlier than many cosmologists had thought. Early ionization means that the Universe was more violent, structured, and interesting in its youth than had been believed.

The PAST will be a sparse array of 1,000 antennas that will span several square kilometers of ice surface adjacent to South Pole Station. The regions of sky that we will observe are available 24 hours a day, so for very deep integrations, this means about three times the effective mapping speed of a mid-latitude telescope.

The PAST array will image and spectrally resolve hyperfine emission of neutral hydrogen at red shifts from 6 to 35. As the primeval energy release developed, bubbles of ionization temporarily eliminated this emission. These bubbles were essentially the aggregate Stromgren spheres of protogalaxy groups and clusters. We will image these bubbles in three dimensions, allowing us to study their evolution and merging and pin down when the first bright objects were formed. Currently, it is not clear how many periods of ionization the Universe has passed through. At each transition between ionized and neutral, in either direction, PAST can create snapshots of the structure of the Universe.

During the first year, we will design the telescope, produce prototypes, and test them at the South Pole. During year 2, we will fabricate the telescope and install it. In year 3, the telescope will be operated over the winter. Year 4 is dedicated to continued observations and data analysis (we will release all data within 1 year of collection). (A–375–S; NSF/OPP 03–42448)

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Wide-field imaging spectroscopy in the submillimeter: Deploying SPIFI on the Antarctic Submillimeter Telescope and Remote Observatory (AST/RO).

Gordon J. Stacey, Cornell University.

SPIFI (South Pole Imaging Fabry-Perot Interferometer), the first direct detection imaging spectrometer for use in the submillimeter band, was designed for use on the 1.7-meter Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) at the South Pole in the far-infrared and submillimeter windows. After having developed and extensively field-tested SPIFI, our primary scientific goals are to:

- image the inner regions of the galaxy, in particular submillimeter lines that characterize excitation conditions in the Central Molecular Zone (CMZ), and trace the dynamics of the gas. Questions to be answered are, among others, Can we trace neutral gas flowing through the CMZ? Are there shocks from cloud-cloud collisions in this flow? What is the connection between the CMZ molecular clouds and the circumnuclear ring?

- map the Large Magellanic Cloud and Small Magellanic Cloud in these lines. The low metalicity environment in these dwarf galaxies may mimic that of protogalaxies, so that investigating the interaction between star formation and

the interstellar matter in these galaxies is key to understanding the star formation process in the early Universe.

- characterize and map the physical conditions of the interstellar matter in nearby galaxies. These data are unique and will be essential to understanding the relationships between density waves, bar potentials, and galaxy-wide star formation.

These projects can be undertaken only with the high sensitivity and mapping capabilities of the SPIFI AST/RO combination. SPIFI is much more sensitive than the best heterodyne receivers, which do not have the sensitivity or (often) the bandwidth, to detect the broad, weak lines from galaxies or the spatial multiplexing capability necessary for wide-field mapping projects. We plan to gradually upgrade SPIFI by a factor of 10. We will also make modest optical and cryogenic modifications to improve it in ways important to successful polar operations. The result will be better spatial resolution, with a wider field of view, and a large improvement in system sensitivity. Moreover, the new cryogenic system will require servicing only every 5 days instead of the current 40 hours. This is helpful for outdoor polar operations. This new system also reduces helium consumption (by a factor of 2) and therefore reduces cost. (A–377–S; NSF/OPP 00–94605)

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High-resolution observations of the cosmic microwave background (CMB) with the Arcminute Cosmology Bolometer Array Receiver (ACBAR).

William L. Holzapfel, University of California–Berkeley.

We will continue our observations with the Arcminute Cosmology Bolometer Array Receiver (ACBAR), a 16-element 230-micro-Kelvin bolometer receiver designed to produce high-resolution images of the cosmic microwave background (CMB) in 3-millimeter wavelength bands. Mounted on the 2.1-meter Viper telescope at the South Pole, ACBAR has sensitivity that rivals balloon-borne experiments and angular resolution that they cannot hope to achieve. Making full use of the excellent atmospheric conditions during the austral winter at the South Pole, ACBAR is producing images of CMB radiation with sensitivity and resolution that exceed the capabilities of even the European Space Agency's proposed Planck satellite (to be launched in 2007).

Observations of the CMB provide a unique window on the early Universe; moreover, these data play a key role in transforming cosmology into a precise science. In particular, small angular-scale observations of the CMB are a new frontier about which comparatively little is known. On these angular scales, contributions from secondary anisotropies introduced by intervening structures are expected to become dominant. For example, the scattering of photons by hot gas bound to clusters of galaxies results in a spectral distortion of the CMB known as the Sunyaev-Zel'dovich Effect (SZE). Observations of the SZE can provide important new constraints on theories of how the Universe grew.

The unique capabilities of ACBAR, which was deployed to the South Pole in December 2000, allow it to address a broad range of science focused on measuring primary and secondary CMB anisotropies. Our observations and analysis will help realize the full potential of this powerful instrument for the study of cosmology. Four institutions will continue to collaborate in the maintenance and operation of ACBAR and Viper and participate in the data analysis.

The results will serve as a vital complement to the large-scale Microwave Anistropy Probe (MAP) spacecraft data set and provide an essential check of the fine-scale excess power reported by other single-frequency experiments. The novel instrumentation, observation techniques, and analysis developed for ACBAR are generally applicable to future ground-based millimeter astronomy experiments. In addition, this project has provided hands-on research experience to several undergraduate and graduate students. (A–378–S; NSF/OPP 02–32009)

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South Pole observations to test cosmological models: A 10-meter telescope for South Pole.

John E. Carlstrom, University of Chicago; Antony A. Stark, Smithsonian Institution Astrophysical Observatory; John Ruhl, Case Western Reserve University; Joseph J. Mohr, University of Illinois–Urbana-Champaign; and William L. Holzapfel, University of California–Berkeley.

One of the most important discoveries in cosmology is that apparently much, if not most, of the mass in the Universe is made up not of stars and glowing gas, but of dark matter, which emits little or no light or other electromagnetic radiation and makes its presence known only through the gravitational force it exerts on luminous matter. There is some indication that dark matter may in fact not even be baryonic (baryons are subatomic particles that are built from quarks and interact via strong nuclear force). Just what fraction of the mass is in the form of noninteracting nonbaryonic particles is of great interest to cosmologists and physicists.

The University of Chicago will lead a consortium of six institutions to design and use a 10-meter off-axis telescope at Amundsen-Scott South Pole Station to survey galaxy clusters. One of the members of the team will deploy for 2 weeks in January 2005 to examine work done on foundations for the telescope and shield. A survey of galaxy clusters will allow us to study integrated cluster abundance and its red shift evolution and will give us precise cosmological constraints that are completely independent of those from supernova distance and cosmic microwave background (CMB) anisotropy measurements.

Measuring the mass in baryons along with the total mass in a region of the Universe that could be considered a fair sample would provide a crucial direct determination of the dark matter content. In recent years, just such a test-bed has been found in massive clusters of galaxies, which contain large amounts of gas (baryons) in the form of a highly ionized gas atmosphere that emits x rays. Nearly all of the baryons in the clusters are believed to be in the hot phase (millions of degrees), and so it is likely that we are truly measuring the baryonic mass in the cluster.

In addition to emitting x rays, the hot cluster gas also scatters CMB radiation. This scattering, called the Sunyaev-Zel'dovich Effect (SZE), is measurable using radio telescopes. The SZE is important to the study of cosmology and the CMB for two main reasons:

- The observed hotspots created by the kinetic effect will distort the power spectrum of CMB anisotropies. These need to be separated from primary anisotropies in order to probe inflation properties.
- The thermal SZE can be measured and combined with x-ray observations to determine the values of cosmological parameters, in particular the Hubble constant. (A–379–S; NSF/OPP 01–30612)

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Palmer Station supports U.S. and cooperative research in the Antarctic Peninsula region. Scientists work at the station laboratory and on nearby islands. (*NSF/USAP photo by Jeffrey Kietzmann, Raytheon Polar Service Corp.*)

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Overview

Antarctica is a place like no other; as an intriguing habitat, it is a scientist's dream. It is a land where water is scarce—truly a desert—despite having more than two-thirds of the world's freshwater supply trapped in ice. Though it borders the world's major oceans, the Southern Ocean system is unique in the world, a sea where average temperatures do not reach 2 °C in summer, where even the water is so unusual that it can be identified thousands of kilometers away in currents that originated here. As the Earth, tilted on its rotational axis, makes its elliptical journey around the Sun each year, the Sun "sets" in April, not to be seen again until September. And the ice—an unimaginable, incomparable vastness of ice—appears in a dozen different varieties, at times and in places several thousand meters thick; there are two major ice sheets that change all the time. (The eastern sheet is larger than most countries.)

RPSC science technician Zan Stine works in the laboratory at Palmer Station. The majority of the science conducted at Palmer Station is biology, oceanography or aeronomy. The labs at all three U.S. stations are fully equipped to facilitate scientific research. (*NSF/USAP photo by Kristan Hutchinson, Raytheon Polar Services Corp.*)

Adaptations and behavior developed in response to these extreme conditions provide insight into the intricacies, as well as the fundamental processes, of evolution. These extremes have also driven the development of ecosystems simple enough to reveal wonderfully clear pieces of the web of life on Earth.

The Antarctic Biology and Medicine Program funds research to improve understanding of antarctic ecosystems and life forms—their physiology, genetics, behavior, adaptations, and relationships. Projects range across all organizational levels, from the molecule, gene, cell, and organism to relationships within communities and ecosystems, to the level of global processes and the biosphere. This is another area of inquiry where scientific goals and benefits extend far beyond learning about flora and fauna in the high latitudes. Support is focused on the following areas:

- **Marine ecosystem dynamics:** Among the research topics are understanding the

natural variability of marine ecosystems, correlating the structure and function of the marginal ice-zone ecosystem with oceanic and atmospheric processes, exploring the sources of nutrition and their influence on prey and on primary production, and examining the role of marine phytoplankton in carbon-dioxide cycling.

- **Terrestrial and limnetic ecosystems:** Organisms in ice-free areas and in perennially ice-covered lakes show remarkable adaptations to extreme environments. The fact that relatively few species thrive here facilitates the study of ecosystem dynamics and the interpretation of experiments, although much more remains to be learned about adaptive mechanisms and evolutionary processes.

- **Population biology and physiological ecology:** At the next level, looking at relationships among organisms, studies have focused on the variability and dynamics of populations of krill and other zooplankton. Ecological relationships among and between fish species, marine mammals, and birds have also been the subject of much research, with many issues still to be further explored. Advances in genetic testing now permit scientists to establish relationships that were previously unverifiable between individuals and species in the wild. As organized programs of antarctic science enter their fifth decade (some have been in existence even longer), data sets and ongoing observations are elucidating anthropogenic as well as natural changes.

- **Adaptation:** Antarctic extremes present a fundamental research opportunity; topics include low-temperature photosynthesis and respiration, enzymatic adaptations, and adaptive physiology, such as the development of antifreeze compounds in fish and modifications to the circulatory system in seals. There is also continuing interest in the response of organisms to increased ultraviolet-B radiation from the ozone hole (as well as its impact on them). Here, too, new molecular DNA advances have had a profound impact on the types of studies that can be mounted.

- **Human behavior and medical research:** Antarctica's extreme climate and terrain impose a spartan and unconventional existence on scientists and others who live and work there. As people are subjected to social, psychological, and physiological stresses (exacerbated during the winter isolation), opportunities for research arise. Studies focus on epidemiology, thermal regulation, immune system function, individual behavior, and group dynamics.

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Impact of solar radiation and nutrients on biogeochemical cycling of dimethylsulfoniopropionate and dimethylsulfide in the Ross Sea, Antarctica.

Ronald P. Kiene, University of South Alabama, and David J. Kieber, College of Environmental Science and Forestry (Syracuse), State University of New York.

Areas of the Southern Ocean have spectacular blooms of phytoplankton during the austral spring and early summer. One of the dominant species, the haptophyte *Phaeocystis antarctica*, is a prolific producer of the organic sulfur compound dimethylsulfoniopropionate (DMSP), and *Phaeocystis* blooms are associated with some of the world's highest concentrations of DMSP and its volatile degradation product, dimethylsulfide (DMS). Sulfur, in the form of DMS, is transferred from the oceans to the atmosphere and can affect the chemistry of precipitation and influence cloud properties and, possibly, climate. DMSP and DMS are also quantitatively significant components of the carbon, sulfur, and energy flows in many marine food webs, although very little information is available on these processes in high-latitude systems.

We will study how solar radiation and iron cycling affect DMSP and DMS production by phytoplankton and the subsequent use of these labile forms of organic matter by the microbial food web. Four interrelated hypotheses will be tested in field-based experiments and *in situ* observations:

- that solar radiation, including enhanced ultraviolet-B due to seasonal ozone depletion, plays an important role in determining the net ecosystem production of DMS in the Ross Sea,

- that development of shallow mixed layers promotes the accumulation of DMS in

surface waters because of enhanced exposure of plankton communities to high doses of solar radiation,

- that DMSP production and turnover represent a significant part of the carbon and sulfur flux through polar food webs, and
- that bloom development and resulting nutrient depletion (e.g., iron) will result in high production of DMSP and high DMS concentrations and atmospheric fluxes.

Results from this study will greatly improve understanding of the underlying mechanisms controlling DMSP and DMS concentrations in polar waters, thereby improving our ability to predict DMS fluxes to the atmosphere from this important climatic region.

We actively engage high school, undergraduate, and graduate students in our research and are involved in formal programs that target underrepresented groups. The information gained from this research will also be used to teach undergraduate and graduate courses. (B–002–N and B–266–N; NSF/OPP 02–30497 and NSF/OPP 02–30499)

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Response of terrestrial ecosystems along the Antarctic Peninsula to a changing climate.

Thomas A. Day and Jeffrey M. Klopatek, Arizona State University–Tempe.

The striking increases in air temperatures and ultraviolet-B (UV–B) radiation documented along the west coast of the Antarctic Peninsula over the past 50 years represent a profound climatic change, arguably larger than that experienced by any other region on Earth during this time. Along with these well-documented changes, annual precipitation and the depth of the winter snow pack also appear to be increasing along the Peninsula. These rapid changes in climate provide a unique opportunity to examine the effects of climate change on terrestrial ecosystems.

Building on past work that focused on the impact of warming and UV–B radiation on terrestrial vascular plants on the Peninsula, we will examine how climate change alters nutrient (carbon and nitrogen) pools and cycling among plants, litter, and soils in vascular-plant-dominated communities, with the overall goal of predicting long-term effects on plant productivity. We will use two complementary approaches.

In the first approach, we will study shorter term responses to climate change by manipulating temperature, water availability, and UV–B exposure of vascular-plant microcosms over three growing seasons. We will assess how these manipulations influence plant growth and primary productivity, carbon dioxide fluxes, litter quality and decomposition, pools and turnover rates of carbon and nitrogen, and the structure of soil microbial and arthropod communities. These realistic environmental manipulations will allow us to accurately assess the effects of different future warming scenarios, as well as the effects of solar UV–B radiation.

In the second approach, we will examine longer term responses to warming by measuring pools of carbon and nitrogen in plants, litter, and soils in plant communities along transects that represent gradients of long-term temperature regimes. Analyzing the results from short-term warming manipulations in the context of patterns found along these gradients will make it possible to develop a conceptual model of warming impacts over time.

The broader impacts of this project include:

- recruiting and training undergraduate students from underrepresented minorities;
- disseminating findings to the general public; and
- contributing to society at large by improving our understanding of how climate change affects plant productivity and ecosystem carbon storage, as well as whether ecosystem responses to climate change will mitigate or promote continued buildups of greenhouse gases. (B–003–P; NSF/OPP 02–30579)

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Antifreeze proteins in antarctic fishes: Integrated

studies of freezing environments and organismal freezing avoidance, protein structure-function and mechanism, genes, and evolution.

Arthur L. DeVries and Chi-Hing Cheng, University of Illinois–Urbana-Champaign.

This project includes ongoing and new studies on the role of antifreeze glycoproteins (AFGPs) and a new antifreeze-potentiating protein (AFPP) in the freezing avoidance of antarctic fishes and their eggs and larvae. The specific areas of research to be investigated are:

- the rate of uptake of endogenous ice by ice-free specimens;
- the structure of AFPP and the mechanism whereby it potentiates the antifreeze activity of the large AFGPs, but not the small ones;
- the structure-function elucidation of eel pout AFPP through directed-evolution methodologies;
- the mechanism of freezing avoidance in embryos and young larval fish, and the temporal aspects of AFGP and AFPP expression during embryogenesis;
- comprehensive analyses of the antifreeze capacity at both the protein and gene levels across the suborder Notothenioidei;
- the evolution of the AFGP gene family and gene locus;
- the evolution of AFPP; and
- the origin of the Patagonotothen lineage (nonantarctic notothenioids and close relatives of the endemic antarctic notothenioid species).

The extreme cold and icy conditions of the McMurdo Sound arise from its association with the massive Ross Ice Shelf and the influence of cold shelf water. To elucidate the relationship between the McMurdo environment and ice exposure in the local fish population, we will conduct parallel physical measurements of the depth and extent of ice formation in various microenvironments in the sound and will complete biological experiments to determine ice load in fish at these locations by measuring the number of ice crystals in their spleens, as well as the rate of ice entry. These studies will ascertain the relationship between the degree of environmental extremes and the ice load in fish.

This project is associated with extensive international collaboration, and our findings may have broad implications for agriculture, food science, and cryomedicine. Public outreach and training of graduate and undergraduate students are integral components of the work. (B–005–M; NSF/OPP 02–31006)

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Energetics of protein metabolism during development of antarctic echinoderms.

Donal T. Manahan and Robert E. Maxson, University of Southern California.

Larval forms are dominant in the life history of marine invertebrates. In Antarctica, energy budget calculations have shown that larval stages of echinoderms can survive without food for several months to years. This has led to speculation that energy metabolism is more efficient in these forms and that this enhanced efficiency might be unique to life in extreme cold.

Our recent work on the biochemical bases of developmental physiology in antarctic marine invertebrates has indicated that contrary to expectations of low metabolism and low rates of macromolecular synthesis in the cold, embryos and larvae of an antarctic sea urchin have high rates of protein synthesis and low rates of metabolism. This apparent paradox was resolved with our recent finding that the cost of protein synthesis in this sea urchin is 1/25th that reported for other animals. This is the highest efficiency for protein synthesis reported for an animal and has important implications for the physiology of growth and development in cold environments. We now propose to investigate this unique biochemical efficiency of protein synthesis in detail.

We have three major objectives:

- We will test the generality of our recent findings by measuring metabolism and protein synthesis during the development of other antarctic echinoderm species.
- We will directly test the hypothesis that growth efficiencies will be high in such organisms by measuring the physiology of protein growth efficiencies in larvae.
- We will seek to explain the unique high efficiency of protein synthesis in antarctic sea urchin embryos in specific molecular terms by studying each of the component processes. We will supplement these measurements of whole population protein synthesis with measurements based on selected individual proteins (histones).

Understanding metabolic efficiency in polar organisms will help resolve long-standing questions about temperature compensation and adaptations to food limitation in polar regions. Our approach will emphasize the cellular and subcellular levels of biological analysis in order to test the hypothesis that there is a new biochemistry for protein synthesis in these organisms. (B–006–M; NSF/OPP 01–30398)

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Patterns and processes: Dynamics of the Erebus Bay Weddell seal population.

Robert A. Garrott and Jay J. Rotella, Montana State University–Bozeman, and Donald Siniff, University of Minnesota–Twin Cities.

The Erebus Bay Weddell seal (*Leptonychotes weddellii*) population study in eastern McMurdo Sound was initiated in 1968 and represents one of the longest intensive field investigations of a long-lived mammal in existence. Over nearly 36 years, a total of 16,809 animals have been tagged, with 161,994 resighting records logged in the database. This study is a valuable resource for understanding the population dynamics not only of Weddell seals, but also of other species of both terrestrial and marine mammals. We are pursuing two lines of investigation that combine the long-term database with new field initiatives.

The continuity of the demographic data will be maintained by annually marking all pups born, replacing lost or broken tags, and performing censuses. We will combine these new data with the existing database and perform a progressively complex series of demographic analyses that will allow us to test specific hypotheses about population regulation and evaluate previously determined temporal and spatial patterns of variation in vital rates among colonies.

The primary new field initiative is an intensive study of the mass dynamics of both pups and adult females to assess annual variation in marine resources and the potential role in limiting or regulating the population. In addition to collecting data on body mass dynamics, we will use satellite imagery to develop an extended time-series of sea ice in McMurdo Sound. (The extent of sea ice affects both regional primary productivity and availability of haul-out areas.) Increased primary productivity may increase marine resources, which would be expected to have a positive effect on foraging efficiency, leading to increased body mass. Understanding the mechanisms that limit or regulate Weddell seal populations and the specific linkages between climate, oceans, ice, and antarctic food webs can make important contributions to the knowledge of pinniped population dynamics, as well as the theoretical understanding of populations, communities, and ecosystems.

Such knowledge can be readily applied to enhance the ability of natural resource managers to effectively maintain assemblages of other large mammal species and the ecological processes they facilitate. Continuation of this long-term study may also contribute to understanding the potential impact of human activities such as global warming and the commercial exploitation of antarctic marine resources. (B–009–M; NSF/OPP 02–25110)

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Community dynamics in a polar ecosystem: Benthic recovery from organic enrichment in the

Antarctic.

Stacy L. Kim, Moss Landing Marine Laboratories/San Jose State University.

The Antarctic is considered one of the most pristine habitats on the planet. Humans occupy only a tiny portion of the continent. Though the human footprint in Antarctica is small and generally highly localized, there are areas where anthropogenic contamination is severe. For example, past practices at McMurdo Station have resulted in a few highly contaminated marine areas, such as the one near the sewage outfall. High levels of organic enrichment have radically altered the local benthic community. The altered community and surrounding undisturbed communities have been well described over a 10-year period.

In February 2003, a sewage treatment plant was completed at McMurdo Station, and the organic input to the seafloor dropped markedly. On the basis of existing information on community recovery dynamics in polar ecosystems from ice-mediated disturbances (icebergs and anchor ice) and in temperate ecosystems from organic-loading, we predict that recovery will begin immediately. However, growth and reproduction are often slow in antarctic species. Thus, complete recovery may extend over a much longer period than in temperate areas. In addition, slow microbial processes at low polar temperatures have allowed a large pile of organic material to build up at the outfall site, and some changes may be the result of burial rather than organic enrichment. Finally, the size of the disturbance is unusual; small organic inputs such as seal feces and dead fish are common, but large sewage outfalls are not. Thus, the outfall and new treatment plant provide a unique opportunity for a large-scale experiment on recovery.

Our experiments will elucidate the roles of organic enrichment, burial, and disturbance size in benthic community recovery dynamics. We will compare the rates observed with those predicted from a meta-analysis of recovery from organic disturbance in a variety of habitats, and contrast the role of organic loading with burial and patch size. Our integrated approach will further the understanding of anthropogenic impacts in polar environments. We continue to communicate the excitement of scientific research to students of all ages, not only by involving graduate and undergraduate students directly in our field and lab research, but also to K-12 students via classroom and community presentations and web interactions from the field (B–010–M; NSF/OPP 01–26319)

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Biogeochemistry of Victoria Land coastal ponds: Role in terrestrial ecosystem organic carbon dynamics and structure.

Maria Uhle, University of Tennessee, and Peter T. Doran, University of Illinois–Chicago.

Since 1993, structure, processes, and functional linkages in the antarctic terrestrial ecosystem have been the focus of the Long-Term Ecological Research site in the McMurdo Dry Valleys. This ecosystem has a modern component linking organic carbon dynamics between the soils, glaciers, streams, and ice-covered lakes, plus a legacy to ancient glacial events that deposited paleo-organic carbon. The soil reservoir contains 72 percent of the seasonally unfrozen and biologically available organic carbon within Taylor Valley, and a substantial fraction may be recalcitrant carbon derived from ancient climatic events.

One potentially large source of labile, and hence bioavailable, organic carbon that has not been investigated is the many small ponds found in most areas of the McMurdo Dry Valleys, especially near the coast. These ponds have a relatively large surface area, and they seem to generate a significant amount of stranded microbial mat as they shift position. Their transient nature renders the organic matter vulnerable to transport and possibly represents a significant source of modern, labile carbon in the ecosystem. A preliminary estimate suggests that the coastal pond reservoir may constitute at least 11 percent of the carbon in the McMurdo Dry Valleys soil reservoir. Therefore, these ponds may significantly affect the carbon cycle and must be considered in developing a carbon budget for this polar desert.

We will determine the extent of the coastal pond reservoir, assess how productive it is, and determine whether it is a source or sink within organic carbon dynamics and the overall structure of the terrestrial ecosystem. We will focus on understanding the biogeochemistry of these ponds in terms of the factors affecting organic carbon

production and nutrient cycling.

We should derive a more detailed understanding of the linkages between modern ecosystem components, develop insights into the biogeochemical cycling within polar desert ecosystems, and, possibly, identify mechanisms that help sustain life in extreme environments. We will also involve predominantly African-American K–5 students from Knoxville, Tennessee, city schools. These students will be involved in question-and-answer sessions over the Internet, and older students will design experiments and be introduced to the scientific method. Science and math classes will use data analysis to develop analytical skills and place them in a relevant context. (B–011–M; NSF/OPP 02–30237)

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Remotely operable microenvironmental observatory for antarctic marine biology research.

Samuel S. Bowser, New York State Department of Health, and Anthony D. Hansen, Magee Scientific Company.

Research diving over the past two decades has yielded important insights into the ecological importance of giant (larger than 1 millimeter) foraminifera in McMurdo Sound. Unfortunately, the *in situ* behavior of these single-celled organisms and their interactions within the food web can be observed only in "snapshots" during summer dives, when algal production is at a maximum under 24-hour light. Much would be learned by observing foraminifera over extended periods, to study mobility, response to food availability, and other directed behaviors. It would be valuable to be able to extend observations to the winter months in order to study these organisms in the dark, with no algal production, and to experimentally manipulate *in situ* conditions and observe the behavioral response.

Research diving requires costly support and cannot provide extended observation of individual organisms. Moreover, the logistical requirements, costs, complexities, and risks of winter diving at remote locations in Antarctica are prohibitive. However, human diving is not required to make long-term *in situ* observations. Technology and communications have advanced to the point where it is feasible and practical to install video macro- and microview cameras in a submersible enclosure; they can transmit both live and sequential time-lapse images over the Internet to a remote user throughout the year. Such an instrumentation platform could then be used for experimental manipulation of the environment.

We intend to develop a submersible, remotely operable underwater observatory for the study of foraminifera and associated benthic fauna. This observatory would be connected to a shoreline unit by fiberoptic cable and linked by radio to the Internet for year-round access. The design and operation of this observatory will function as a technology template to meet other year-round antarctic research requirements by means of telescience rather than personnel deployment. (B–015–M; NSF/OPP 02–16043)

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Cultural emergence and health in Antarctica.

Timothy D. Dye and Nancy Chin, University of Rochester.

The emergence of a long-term population in space will, in many ways, parallel the emergence of a sustained population in Antarctica, where development has expanded beyond the initial population of scientific and military personnel and now includes support staff and construction personnel. Experts speculate that a similar mix of residents may emerge as space populations develop. Such organizational and cultural merging in restricted environments undoubtedly creates new cultural landscapes (ethnoscapes) that could influence health and health behavior. Because of the extreme environment, health risks and health care are particularly important. The study of cultural emergence in Antarctica as an analog to space could prove useful in the development of models of health and health behavior in an isolated confined environment (ICE) and could help planners better structure these environments to reduce health risks and identify factors that predispose people to those risks.

We aim to:

- model the emergence of cultural stages in ICE ethnoscapes as experienced by both short- and long-term populations;
- identify those elements of ICE ethnoscapes that are specific to an individual season and those that are repeated;
- relate how the temporal and content stages of ICE ethnoscapes interact with risk, behavior, and injury; and
- demonstrate the utility of electronic and distance-based assisted ethnography in the conduct of social research in ICE environments of Antarctica and, possibly, in space.

We will begin with key informant interviews and focus groups conducted throughout the United States with people who have spent at least one season on the ice in the past 3 years. The purpose is to elucidate the behaviors, risks, and health events that residents face, particularly in the emergence of ethnoscapes. The next phase has us residing in Antarctica for an extended period and conducting participant observation and interviews at two different sites. This phase will include the Self-Disclosure Technique (SDT), an anthropological method for identifying the conceptual structure of a cultural event. SDT will be used to describe cultural dynamics in occupational, recreational, spiritual, and other group activities. Fieldwork will involve both short- and long-term residence. The data will be processed, and models will be tested for validity with informants on the ice.

This research could contribute to the development of screening procedures for long-term residence in ICEs and context-sensitive explanatory models of culture and injury risk, as well as illustrate the utility of distance-based ethnography. (B–027–M; NSF/OPP 01–25893)

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Genomic networks for cold-adaptation in embryos of polar marine invertebrates.

Adam G. Marsh, University of Delaware.

Although the cold ocean ecosystems comprise 72 percent of Earth's biosphere by volume, they remain sparsely inhabited and relatively unexploited, particularly the metazoan phyla. Consequently, the few animals that can exist at this border of intracellular freezing are ideal for exploring genomic-level processes of environmental adaptation. Understanding life at the margin will convey significant insights into the processes essential for survival under intense selection pressures.

Our study of adaptive mechanisms in genomic networks focuses on a system that faces a formidable challenge at cold temperatures: embryonic development of two antarctic echinoderms, the seastar *Odontaster validus* and the sea urchin *Sterechinus neumayeri*, at sea water temperatures of -1.8°C. We will quantify temperature effects on gene expression and protein turnover networks during early development by using a Bayesian network analysis (a method of statistical analysis) to identify clusters of genes and proteins whose levels of expression are associated in fixed, synergistic interactions. Ultimately, the question to be addressed is whether it is more or less difficult (complex) for an embryo to develop in an extreme environment. To answer this question, we will decipher network topologies and subnet structuring to uncover gene connectivity patterns associated with embryonic development in this polar environment. We also intend to interest students in the developing field of environmental genomics by increasing the awareness of career opportunities within the field and increasing the racial diversity of those attracted to it.

Working in a remote, extreme environment such as Antarctica is always a challenge, but the adventurous nature of the work can be used to establish educational and outreach components of high interest to both undergraduate students and the public. We will bring the experience of working in Antarctica to a larger audience by

- incorporating environmental genomics into a new bioinformatics curriculum being developed at the University of Delaware,
- implementing an intern program to involve minority undergraduates in summer research in the United States and then to bring them to Antarctica to participate

in research, and

- creating a K–12 education program that will bring the excitement of working in Antarctica to the classrooms of thousands of children (in the United States and around the world) through a program produced in conjunction with the Marine Science Public Education Office at the University of Delaware. (B–029–M; NSF/OPP 02–38281)

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Geographic structure of Adélie penguin populations: Demography of population expansion.

David G. Ainley, H.T. Harvey and Associates; Nadav Nur and Grant Ballard, Point Reyes Bird Observatory; and Katie Dugger, Oregon State University.

We are investigating the mechanisms responsible for the geographic structuring, the founding of new colonies, and the recent population expansion of the Adélie penguins (*Pygoscelis adeliae*) of Ross and Beaufort Islands. Similar expansion has been occurring throughout the Ross Sea, where 30 percent of the world's population of this species resides, and is in some way related to ameliorating climate. Thus far we have been examining:

- the relative importance of resources that constrain colony growth (the amount of nesting habitat versus access to food);
- aspects of natural history that might be affected by exploitative or interference competition among neighboring colonies (breeding success and foraging effort);
- climatic factors that influence the latter, especially extent and concentration of sea ice; and
- behavioral mechanisms that influence colony growth as a function of initial size and location, emigration, and immigration.

Only the Beaufort Island colony is nesting space limited, and we have shown how the extent and concentration of sea ice affect diet, foraging effort, and winter survival. In addition, the large colony at Cape Crozier affects the foraging patterns of penguins at the smaller ones, all within range, and, perhaps, ultimately their size. The rate and direction of emigration also appear to be constrained by sea-ice conditions, with reasonable concentrations of ice favoring the growth of smaller colonies where foraging competition is minimal. The arrival of the large icebergs, B–15A and C–16, following the 2000 season has provided an unusual opportunity, a natural experiment, to investigate the factors encouraging emigration and/or its absence (philopatry).

We will use eight cohorts of marked penguins from each colony to assess juvenile survival, recruitment age, and age-specific fecundity and subsequent survival. These data will be compared with another demographic study, the only one for this species, conducted at Cape Crozier during the 1960s and 1970s, when populations were declining.

Information will be related to sea ice as quantified by satellite images. Global climate is changing the fastest in the polar regions. The Adélie penguin is tied to sea ice, a primary factor in rapid polar climate change (less sea ice, less reflection of solar energy). The extreme sensitivity of these penguins to climate change has often been noted. Understanding the demographic mechanisms behind this sensitivity will contribute greatly to knowledge of the effects of climate change on antarctic marine organisms. (Additional information can be found on our Web site: www.penguinscience.com.) (B–031–M; NSF/OPP 01–25608)

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Occupation history and diet of Adélie penguins in the Ross Sea region, Antarctica.

Steven D. Emslie, University of North Carolina–Wilmington.

We will build on previous studies to investigate the occupation history and diet of Adélie penguins (*Pygoscelis adeliae*) with excavations of the many abandoned and active penguin colonies in the Ross Sea region: specifically, the Victoria Land coast from Cape Adare to Marble Point. Some of these sites have been radiocarbon-dated and indicate that Adélie penguins have occupied them for 13,000 years. The material we will recover, as demonstrated from previous investigations, will include penguin bones, tissue, and eggshell fragments, as well as abundant remains of prey (fish bones, otoliths, squid beaks) preserved in ornithogenic soils (formed from bird guano). These organic remains will be quantified and subjected to radiocarbon analyses to obtain a colonization history of the penguins in this region. Identification of prey remains in the sediment will allow us to assess penguin diet.

We will collaborate with New Zealand scientists to analyze other data from these sites (ancient DNA) and will interpret past climatic conditions from published ice-core and marine-sediment records. These data will be used to test the hypothesis that Adélie penguins respond predictably to climate change, past and present. In addition, we will test the hypothesis that these penguins alter their diet in accordance with climate, sea-ice conditions, and other marine environmental variables along a latitudinal gradient. Graduate and undergraduate students will be involved, and a Web site will be developed to report results and maintain educational interaction between project personnel and students at local middle and high schools in Wilmington, North Carolina. (B–034–M; NSF/OPP 01–25098)

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Cold body temperature as an evolutionary shaping force in the physiology of antarctic fishes.

Bruce D. Sidell, University of Maine.

Notothenioid fishes that dominate the fish fauna surrounding Antarctica have been evolving for 10 to 14 million years at a nearly constant body temperature of roughly 0°C. Many unusual physiological characteristics of these fishes are adaptations to life at cold body temperatures or physiological or biochemical features that are permitted by life at cold body temperatures but that would be deleterious in other environments.

We have three main objectives:

- to identify in antarctic fishes the amino acid substitutions in the fatty acid–binding pocket of fatty acyl coenzyme A synthetase (FACS) that explain its substrate specificity. Fatty acids are a major source of energy metabolism in antarctic fishes, and FACS catalyzes this metabolism.
- to produce a rigorous biochemical and biophysical characterization of the intracellular calcium-binding protein, parvalbumin, from the white axial musculature of antarctic fishes. Parvalbumin plays a pivotal role in facilitating the relaxation phase of fast-contracting muscles and is a likely site of strong selective pressure. Preliminary data indicate strongly that the protein from antarctic fishes has been modified to function at cold temperatures.
- to conduct a broad survey of the pattern of cardiac myoglobin expression in the suborder Notothenioidei. Previous work has indicated a variable pattern of presence or absence of myoglobin (Mb), an intracellular oxygen-binding protein, in the hearts of *Channichthyidae* (icefish). Because Mb has physiological value in species that express it, this part of the project will survey for the presence of cardiac Mb in as many notothenioid species as possible.

We will perform a combination of shipboard collection and laboratory experimentation (cloning and site-directed mutagenesis of FACS). Full-length cDNA clones for antarctic fish parvalbumin(s) will be obtained, permitting the deduction of primary amino acid sequence. These data will yield insight into structural elements that permit the protein from notothenioid fishes to function at very cold body temperatures.

Both modified and wild-type FACS will be produced using a cultured expression system, and the protein products will be isolated and subject to enzyme kinetic analyses. These experiments may permit us to determine the specific amino acid substitutions that explain both substrate specificity and the preservation of catalytic rate of notothenioid FACS at cold temperatures. (B–036–L; NSF/OPP 01–25890)

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Investigations on deterioration in the historic huts of Antarctica.

Robert A. Blanchette, University of Minnesota.

During the first two decades of the 20th century, Europeans mounted a handful of expeditions in hopes of reaching (and claiming) the geographic South Pole. Base camps established in the McMurdo Sound region by Scott at Hut Point and Cape Evans and by Shackleton at Cape Royds were abandoned once the expeditions were over, leaving behind thousands of artifacts, as well as the huts the explorers built for shelter and storage. Over the intervening 90 years, the extremes of the polar environment have actually protected some of the artifacts from rapid decay, but conservators have recently become concerned about the serious degradation of what is an important historical, archaeological site.

Some of the gravest threats are as follows:

- Wood in contact with the ground is being destroyed by a fungus. Also, various molds and cellulose-degrading fungi are attacking artifacts made of leather, textiles, and other organic materials.
- Exterior wood is being degraded by nonbiological processes as well, including salt, ultraviolet radiation, and wind erosion.
- Chemical damage within the huts is apparent, and the soils on the site are contaminated with aromatic hydrocarbons from petroleum products.

We plan to identify the biological and nonbiological agents responsible for the deterioration, study the mechanisms and progressive sequence of the events taking place, test methods to be used to control future deterioration, determine the extent of environmental pollutants in soils at the historic sites, and evaluate chemical spills within the huts. The goal is to provide the scientific data conservators need to help protect these important sites for future generations. But the project should also shed light on these unique deterioration processes, as well as augment scientific understanding of the biology of antarctic microorganisms and the biodiversity of microbes present in this unusual environment. (B–038–E; NSF/OPP 02–29570)

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Foraging behavior and demography of *Pygoscelis* penguins.

Wayne Z. Trivelpiece, National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center.

Seabird research conducted at Admiralty Bay, King George Island, in the Antarctic Peninsula region has documented annual variability in the life history parameters of the population biology of three related penguin species: the Adélie, the gentoo, and the chinstrap (*Pygoscelis adeliae*, *P. papua*, and *P. antarctica*, respectively). This long-term study has collected more than 25 years of data on these three related species, including survival and recruitment, population size and breeding success, and diets and foraging ecology.

We will extend the research linking penguin demography and foraging ecology to variability in the antarctic marine ecosystem. A major focus will be on the population biology data for the Adélie and gentoo penguins and the distribution and trophic interactions among the three species during the breeding season and the nonbreeding, winter period. Recent studies using satellite tags and time-depth recorders to examine postfledging foraging have provided the first detailed data on the wintering distributions of Adélie and chinstrap penguins in the Antarctic Peninsula.

Specific topics include an examination of the size and sex of krill captured by penguins feeding chicks and krill collected concurrently by net hauls in the adjacent marine environment and the length-frequency distribution of krill collected from penguin diet samples. The winter survival of breeding adults and the recruitment of young (2- to 4-year-old) prebreeding penguins to their natal colony will be compared with the extent of

sea ice in the winter before the breeding season. These variables are expected to be positively correlated for the Adélie but negatively correlated for the chinstrap penguin. Detailed studies of adult gentoo penguins, which do not disperse widely from their natal colony, will be conducted using satellite tags.

The data we gather on the impact of environmental variation on the structure of upper-trophic-level predators such as the *Pygoscelis* penguins will improve our understanding of the structure and function of the Antarctic. (B–040–E; NSF/OPP 01–25985)

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Interannual variability in the Antarctic–Ross Sea (IVARS): Nutrients and seasonal production.

Walker O. Smith, Virginia Institute of Marine Sciences.

During the past few decades, oceanographers and other scientists have found significant variations in Southern Ocean biogeochemical processes from year to year. Some of the more significant of these interannual variations are the extent and concentration of the ice, the composition of herbivore communities, and the distribution and reproductive success of birds and marine mammals.

Even though phytoplankton production is central to the food web, surprisingly little is known about how it varies from year to year or what role these variations may play. The production system in the Ross Sea consists predominantly of two major functional groups: diatoms and *Phaeocystis antarctica*, a colonial haptophyte. In this project, we will collect time-series data and assess the interannual variations of phytoplankton in the southern Ross Sea.

The Ross Sea provides a unique setting for such an investigation. We can build on a de facto, already ongoing time-series because so many studies have been conducted there in the past decade. Also, it has been established that there are fewer species there (relative to some other sites) and that seasonal production is as great as anywhere in the Antarctic. Most important, seasonal production of the total phytoplankton community (as well as its two functional groups) can be estimated from late summer nutrient profiles.

Interannual variations in seasonal production (and of the two major taxa of producers) may be an important factor in the growth and survival of higher trophic levels within the Ross Sea food web. They also shed light on the natural variability of the suite of biogeochemical processes in the region. Having a scientific handle on that baseline of change is important because of efforts to model how climate may change in the future. As climate changes, so certainly will biology be profoundly affected, and to model and evaluate such change we need to place it in the context of natural interannual variability. (B–047–M; NSF/OPP 00–87401)

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Long-term data collection at select Antarctic Peninsula visitor sites.

Ron Naveen, Oceanites, Inc.

The Antarctic Site Inventory Project has collected biological data and site-descriptive information in the Antarctic Peninsula since 1994. This research has provided data on sites visited by tourists on shipboard expeditions in the region. Our aim is to obtain data on the population of several key species of antarctic seabirds that might be affected by the cumulative impact of visits to the sites. We will focus on two heavily visited Antarctic Peninsula sites: Paulet Island, in the northwestern Weddell Sea, and Petermann Island, in the Lemaire Channel near Anvers Island. We selected these sites because both rank among the 10 most visited sites in Antarctica each year in terms of numbers of visitors and zodiac landings, both are diverse in species composition, and both are sensitive to potential environmental disruptions from visitors.

We will collect data over 5 years on two important biological parameters for penguins and blue-eyed shags:

- breeding population size (number of occupied nests) and

- breeding success (number of chicks per occupied nest).

Our main focus will be Petermann Island, which we selected for intensive study because of its visitor status and location near Palmer Station. This will allow us to compare data with the Palmer Long-Term Ecological Research Program.

We will collect demographic data in accordance with the standard methods established by the Convention for the Conservation of Antarctic Marine Living Resources Ecosystem Monitoring Program, and the information we gather will thus be comparable to similar data sets being compiled by the research programs of other Antarctic Treaty nations. While separating human-induced change from change resulting from a combination of environmental factors will be difficult, this work will provide a first step toward identifying potential impacts. The long-term data sets we compile will contribute to a better understanding of biological processes in the entire region and will also contribute valuable information to be used by Antarctic Treaty nations as they address environmental stewardship issues in Antarctica. (B–086–P; NSF/OPP 02–30069)

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Distribution and ecology of ammonia-oxidizing bacteria in the Palmer Long-Term Ecological Research study area.

James T. Hollibaugh, University of Georgia.

We propose to investigate the distribution, phylogenetic affinities, and aspects of the ecology of ammonium-oxidizing bacteria in the Palmer Long-Term Ecological Research (LTER) study area. Ammonia oxidation is the first step in the conversion of regenerated nitrogen to dinitrogen gas via denitrification, a three-step pathway mediated by three distinct guilds of bacteria. Although important to the global nitrogen cycle, ammonia oxidation and the overall process of nitrification-denitrification have received little attention in polar oceans where they are significant and where the effects of climate change on biogeochemical rates are likely to be pronounced.

Our goals are to:

- obtain more conclusive information on the composition of antarctic ammonia oxidizers,
- begin characterizing their ecophysiology and ecology, and
- obtain cultures of the organism for more detailed studies.

We will characterize water column and sea ice assemblages of ammonia-oxidizing bacteria phylogenetically and quantify different kinds in various samples. We will also measure nitrification rates across the LTER study area in water column, sea ice, and sediment samples, determining grazing rates and evaluating the sensitivity of these bacteria to ultraviolet light. In addition, we will assess the significance of urea nitrogen as a source of reduced nitrogen to these bacteria. Finally, we will evaluate the response of nitrification over temperature ranges appropriate to the polar regions.

Our work will provide insights into the ecology of ammonia-oxidizing bacteria and the knowledge needed to model how water-column nitrification will respond to changes in the polar ecosystems accompanying global climate change. (B–114–L; NSF/OPP 02–34249)

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Microbial diversity and function in the permanently ice-covered lakes of the McMurdo Dry Valleys, Antarctica.

John C. Priscu, Montana State University–Bozeman; Brian D. Lanoil, University of California-Riverside; Michael T. Madigan, Southern Illinois University-Carbondale; and Steven J. Giovannoni, Oregon State University.

We plan to study prokaryotic organisms in the permanently ice-covered lakes of the McMurdo Dry Valleys in order to identify and characterize novel organisms and elucidate those aspects of their genome and metabolism that are critical to understanding their role in biogeochemical cycles. We will use molecular tools in concert with conventional and high-throughput culturing techniques to define representative prokaryotic groups responsible for the contemporary geochemical gradients existing in these lakes.

The McMurdo Dry Valleys form the driest and coldest ecosystem on Earth and, until relatively recently, have been thought to harbor little life. A primary reason for establishing a microbial observatory for these lakes is to understand not only how the environment controls the diversity of organisms, but also how diversity itself controls the way ecosystems function. The McMurdo Dry Valley lake systems lend themselves to answering this question in a unique way. Given their isolation, the lack of higher life forms, and their evolutionary history, these lakes offer a unique experimental arena to search for novel microorganisms and to study the interplay of microbial diversity and ecosystem function.

The results we derive will be significant to the growing body of literature in biodiversity, biotechnology, geobiology, polar ecology, and astrobiology. We will work with existing and new programs to archive the phylogenetic and physiological data we collect so that anyone who is interested can access it easily over the Internet. Strong linkages will be made with the highly visible education, outreach, and human diversity programs supported by the National Science Foundation's Office of Polar Programs and the McMurdo Long-Term Ecological Research Program to yield a project that will have a broad impact on society. (B–195–M; NSF/OPP 02–37335, NSF/MCB 02–37576, NSF/MCB 02–37434, and NSF/MCB 02–37689)

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Diving physiology and behavior of emperor penguins.

Paul J. Ponganis, Scripps Institution of Oceanography, University of California-San Diego.

The emperor penguin, *Aptenodytes forsteri*, is the premier avian diver and a top predator in the antarctic ecosystem. The routine occurrence of 500-meter dives during foraging trips is a physiological and behavioral enigma. We will attempt to determine how and why emperor penguins dive as deeply and long as they do by examining four major topics: pressure tolerance, management of oxygen stores, end-organ tolerance of diving hypoxemia/ischemia, and deep-dive foraging behavior. These subjects are relevant to the role of the emperor as a top predator in the antarctic ecosystem and to critical concepts in diving physiology, including decompression sickness, nitrogen narcosis, shallow water blackout, hypoxemic tolerance, and extension of aerobic dive time.

We will test the following hypotheses:

- Prevention of nitrogen narcosis and decompression sickness in emperor penguins is due to inhibition of pulmonary gas exchange at depth.
- Shallow water blackout does not occur because of greater cerebral hypoxemic tolerance and, in deep dives, because of resumption of pulmonary gas exchange during the final ascent.
- The rate of depletion of blood oxygen stores is a function of the depth of the dive and the heart rate.
- The aerobic dive limit reflects the onset of lactate accumulation in locomotory muscle, not total depletion of all oxygen stores.
- Elevation of tissue antioxidant capacity and free-radical scavenging enzyme activities protect against the ischemia and reperfusion that routinely occur during diving.
- During deep dives, the antarctic silverfish, *Pleuoragramma antarcticum*, is the primary prey.

In addition to evaluating these hypotheses, we will cooperate with U.S. and foreign organizations such as the National Institute of Polar Research in Japan, Centro de Investigaciones del Noroeste in Mexico, National Geographic, University of Texas Southwestern Medical Center, and Sea World. Our work will be featured in National

Geographic television documentaries that will provide unique educational opportunities for the general public.

Development of state-of-the-art technology (e.g., blood oxygen electrode recorders, blood samplers, and miniaturized digital cameras) will lay the groundwork for future research. Moreover, during our planned fieldwork at several Ross Sea colonies, we will continue to evaluate the effects of the B–15 iceberg on the breeding success of emperor penguins by taking population censuses. (B–197–M; NSF/OPP 02–29638)

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Monitoring the human impact and environmental variability on Adélie penguins at Palmer Station, Antarctica.

William R. Fraser, Polar Oceans Research Group.

The potential consequences of antarctic tourism on Adélie penguins (*Pygoscelis adeliae*) have been debated for more than 20 years. However, the rapid proliferation of these activities since 1970, particularly on the Antarctic Peninsula, has not only forced an extension of these questions to wildlife populations in general, but also colored them with a sense of urgency and controversy that has polarized opinions. The key concern is that continued increases in these activities will eventually overcome the ability of research to address critical issues in a timely and biologically meaningful manner. This is a valid concern, since studies to examine human impacts have either not been implemented at critical sites or are limited in scope because of logistic and experimental constraints.

Understanding how tourism might affect Adélie penguins rests fundamentally on the need to quantify and understand the natural variability manifested by breeding populations over spatial and temporal scales. However, although it is generally recognized that without these data it will be difficult to critically assess any localized changes from tourism, this ecosystem approach is expensive and complex and is not likely to be justified by the need to understand tourist impacts.

We will continue a tourist monitoring program underway at Palmer Station as part of a large ecosystem-scale study. Palmer Station mirrors current patterns in tourism and tourist-wildlife interactions in the western Antarctic Peninsula. It also provides unique opportunities for research on human impacts, including the presence of long-term databases that document environmental variability over time and space in both marine and terrestrial habitats, as well as the ability to examine potential tourist impacts as part of controlled experiments.

Our research is expected to capitalize and expand on two key findings to date. One is the discovery of a previously unrecognized source of variability in the Adélie penguin population resulting from interactions between landscape geomorphology and changing patterns of snow deposition due to climate warming. The other is the observation that penguins breeding in less desirable landscapes may be more susceptible to cumulative impacts induced by the presence of human activity.

These findings have important implications for understanding interactions between climate change and ecosystem response, and for detecting, mitigating, and managing the consequences of human activities such as tourism. (B–198–P; NSF/OPP 01–30525)

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Effects of foraging on the lipid biochemistry of freely diving Weddell seals.

Michael A. Castellini, University of Alaska–Fairbanks, and Lorrie D. Rea, University of Central Florida.

Our primary goal is to quantify the dynamics of lipid uptake and use in a naturally foraging mammalian carnivore by examining freely diving Weddell seals (*Leptonychotes weddellii*) in Antarctica. This species, in this environment, offers a unique opportunity—one that may not be possible in any other system—to follow the biochemistry and physiology of nutrient use in a large carnivore.

To our knowledge, the *in vivo* nutritional biochemistry of foraging in a free-ranging, large mammalian carnivore has never been attempted. While such studies can be conducted in laboratories or zoos, they are necessarily limited to captive animals whose feeding times and diets are determined and constrained.

For several decades, the Weddell seal has been the focus of studies using isolated holes through the sea ice near McMurdo Station to study natural diving physiology. In that system, the seal has access to a single ice hole where it routinely returns to breathe, sleep, and digest. Using blood-sampling catheters, we have been able to collect serial samples whenever the seal returns to the surface between diving bouts. During such experiments on diving physiology, these seals actively caught and digested their prey, but any observations on nutritional chemistry were incidental and not part of the study design.

Like all seals, Weddell seals rely primarily on lipid metabolism for their daily energy demands. Therefore, we will examine the kinetics of lipid uptake and use during active foraging bouts. We will obtain blood samples from freely diving animals during these bouts; use labeled, traced experiments to quantify lipid turnover rates; and separate the lipid pool into its various components.

In addition, we will compare adults with pups, which are biochemically adapted for massive and rapid lipid use while nursing. This project is unique to Antarctica and will provide an insight into mammalian biochemistry never before possible. These data will be important not only to antarctic ecosystem studies, but also to the entire field of lipid metabolism in mammals and to the study of carnivore biology. (B–199–M; NSF/OPP 01–30417)

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Interactive effects of ultraviolet radiation and vertical mixing on phytoplankton and bacterial productivity of Ross Sea *Phaeocystis* bloom.

Wade H. Jeffrey, University of West Florida, and Patrick J. Neale, Smithsonian Institution.

Ultraviolet (UV) radiation influences plankton in the near-surface waters of most ecosystems. In particular, the Southern Ocean is affected in the austral spring, when UV radiation is enhanced by ozone depletion. While progress has been made in estimating the impact of UV radiation on bacteria and phytoplankton in the Southern Ocean, important issues remain to be resolved. Little is known, for example, about responses in systems dominated by the colonial haptophyte *Phaeocystis antarctica*, which dominates spring blooms in the southern Ross Sea. The presence of open water at a far southerly location, well within the ozone hole in the spring, and of continuous daylight, with implications for DNA repair, make the Ross Sea of intense interest.

A number of studies suggest that vertical mixing can significantly modify the impact of UV radiation. However, the limited measurements of turbulence intensity in the surface layer that have been done have not been integrated with parallel studies of the effects of UV radiation on phytoplankton and bacterioplankton. To address these issues, we will focus on vertical mixing and UV radiation in the Ross Sea and characterize phytoplankton and bacterioplankton responses in both laboratory and solar incubations. These studies will lead to biological weighting functions and response models capable of predicting the impact of UV radiation on photosynthesis, bacterial incorporation, and DNA damage in the surface layer.

We will measure depth-dependent profiles of DNA damage, bacterial incorporation, photosynthesis, and fluorescence parameters over a 24-hour cycle. We have optimized measurements for typical springtime conditions in the Ross Sea, where stabilizing influences like solar heating and/or surface freshwater from melting ice mean that not enough turbulence is present to thoroughly mix the upper layer.

We will develop fine-scale vertical density profiles to directly estimate large eddy scales. Estimated turbulent diffusivities and eddy scales will be directly related to surface layer effects and used to generate models of UV radiation responses in the surface mixed layer.

This first in-depth study of UV radiation in the Ross Sea will enhance scientific understanding of vertical mixing processes, trophic interactions, and biogeochemical

cycling in the Ross Sea and will provide a valuable comparison with previous work in the Weddell–Scotia Confluence and Palmer Station regions. (B–200–N and B–203–N; NSF/OPP 01–27022 and NSF/OPP 01–27037)

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Ultraviolet-radiation-induced changes in the patterns of production and composition of biochemical compounds in antarctic marine phytoplankton.

Joaquim I. Goes, Bigelow Marine Laboratory.

There is enough evidence to show that present levels of incident ultraviolet (UV) radiation—280 to 400 nanometers (nm)—are impairing phytoplankton productivity in the Southern Ocean. Yet efforts aimed at extrapolating these findings to allow accurate and unambiguous predictions of the consequences of UV radiation on the antarctic marine food web and biogeochemical cycles in the sea have been confounded by uncertainty. Estimates of the effects of UV radiation on the antarctic marine ecosystem range from insignificant to catastrophic. This disparity has been attributed to lack of information in key areas of photobiology and photochemistry.

Generally, studies have been based on broadband UV radiation and do not take into account competing responses of phytoplankton at different wavelengths across the waveband. Such information is critical if we are to understand the consequences of UV radiation enhancement on carbon assimilation by marine phytoplankton and its consequences for the food web and biogeochemical cycles. This is especially true in regions like the Antarctic, where stratospheric ozone concentrations can decrease by about 50 percent each spring, thereby altering the proportion of UV–B (280 to 320 nm) and UV–A (320 to 400 nm) radiation that phytoplankton receive during their growth season.

We will systematically investigate changes in the production rates and composition of biochemical compounds within antarctic phytoplankton cells under spectrally defined conditions. We will examine both laboratory cultures and natural populations in order to understand:

- how the cellular biochemical processes of phytoplankton are affected by the interplay between the different UV wavelengths and visible light,
- how sensitivity to UV radiation varies across taxonomic groups of phytoplankton, and
- whether this difference in sensitivity is responsible for the dominance of one species over the other.

We will also study the effect of UV radiation on nutrient uptake by phytoplankton cells. The information we gain will help ascertain the role of UV radiation in the phytoplankton dynamics of the Southern Ocean. (Additional information can be found on our Web site: www.bigelow.org/arctic/goes/index.html.) (B–206–N; NSF/OPP 01–26150)

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Comparative and quantitative studies of protistan molecular ecology and physiology in coastal antarctic waters.

Rebecca J. Gast and Mark R. Dennett, Woods Hole Oceanographic Institution, and David A. Caron, University of Southern California.

Phototrophic and heterotrophic protists (single-cell organisms—e.g., protozoa) are ubiquitous in extreme cold-water environments, where they are central to the production and use of energy and the cycling of elements. The dominance of protists in antarctic food webs indicates major ecological and biogeochemical roles for these unicellular eukaryotes. Understanding the structure and diversity of these communities and the adaptations that allow them to flourish near the lower limit of temperature in the ocean

is of fundamental importance to a knowledge of biological oceanography, as well as the activities and evolution of life on our planet.

The diversity of protistan assemblages has traditionally been studied using microscopy and morphological characterization. Such an approach is inadequate for ecological studies of these communities due to its tedious nature and the inherent lack of taxonomic characters associated with most small protists. Molecular methods that use gene sequences to identify and quantify naturally occurring protists offer a better solution to this problem.

We will perform molecular and physiological studies on protistan assemblages in the sea water and ice habitats of the Ross Sea to address community structure, population abundance, and adaptation to life in extreme cold. We will focus primarily on species of phagotrophic protists (protozoa) that are ecologically important but for which no information exists. Our work is designed to contribute to the understanding of the biodiversity of the protistan assemblages of coastal Antarctica, to provide tools for ecological studies, and to produce benchmark data on the basic physiological processes of protistan species in this extreme cold-water environment. (B–207–N; NSF/OPP 01–25833 and NSF/OPP 01–25437)

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Southern Ocean GLOBEC (Global Ocean Ecosystem Dynamics) Mysticete whale acoustic census in the GLOBEC west antarctic project area.

John A. Hildebrand, Scripps Institution of Oceanography, University of California–San Diego, and Deborah Thiele, Deakin University.

Before large-scale commercial whaling during the early 20th century, the Southern Ocean held the world's most extensive population of baleen whales, as well as large numbers of blue, fin, sei, and humpback whales. Despite a nearly complete ban on whaling since the 1970s, antarctic populations of baleen whales remain low. Passive acoustic surveys, coupled with shipboard visual surveys, provide an efficient means of assessing the population, distribution, and seasonality of whales.

Our main interest is the blue whale (*Balaenoptera musculus*), followed by the fin (*B. physalus*), humpback (*Megaptera novaeangliae*), minke (*B. acutorostrata*), and sperm whale (*Physeter macrocephalus*, an odontocete). Because the vocalizations of these whales are unique and easily recognizable, it is possible to use passive acoustic techniques to distinguish particular species so we can understand why they return or do not return to the Southern Ocean.

We will examine the variability of whales in the Antarctic and how their presence relates to krill, ice, and other Southern Ocean Global Ocean Ecosystem Dynamics (SOGLOBEC) studies. Determining the patterns of whale abundance and distribution is central to understanding ecological interactions involving these top predators.

We are using continuous-recording sea floor packages and collecting data during biannual survey cruises. Instruments were deployed in 2001, and each records continuously at 500 samples per second for 15 months. During this season's cruises, we will refurbish and redeploy these seafloor recording packages and perform more passive acoustic studies. We will also conduct visual surveys and deploy sonobuoys, expendable underwater listening devices that can transmit acoustic data for up to 8 hours. Deployed around observed groups of whales, these recordings provide a means for correlating calls with numbers of whales present, and they can also be compared with the seafloor data.

The deployment of a large-aperture autonomous hydrophone array will promote incorporation of passive acoustics as a tool for whale detection and census and provide new insight into the role of these top predators in polar ecosystems. The recovery or potential loss of the antarctic blue whale population, which once numbered more than 200,000, is not only a question of species extinction, but it is also relevant to all Southern Ocean ecosystem studies. (B–239–N and B–280–N; NSF/OPP 01–36493)

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Physiological and molecular mechanisms of

stress tolerance in a polar insect.

Richard Lee, Miami University of Ohio, and David L. Denlinger, Ohio State University.

Polar terrestrial environments are often described as deserts. In addition, prolonged low winter temperatures threaten survival, and summer temperatures produce potentially rapid and difficult transitions from freezing to desiccation. Global warming has had a further impact, especially as a result of glacial retreat along the Antarctic Peninsula.

We will focus on thermal and hydric adaptations in the terrestrial midge, *Belgica antarctica*, the largest and most southerly holometabolous insect living in this challenging environment. Since free water is unavailable, overwintering midge larvae encased in the frozen substrate must endure desert-like conditions for more than 300 days. During the summer, larvae may be immersed in melt water or the outwash from penguin rookeries and seal wallows, in addition to saltwater splash. Alternatively, larvae may be subjected to extended periods of desiccation as their microhabitats dry out.

Our research will focus on three areas:

- **Microclimatic variability:** Our primary objective is to obtain a detailed characterization of microclimatic conditions experienced by *B. antarctica*, especially related to thermal and hydric diversity, both seasonally and among microhabitats near Palmer Station. These data will be critical for establishing the relevant ecological conditions to be used in laboratory experiments.

- **Physiological and molecular responses to extreme fluctuations in water availability:** We will assess the hypothesis that midge larvae use cryoprotective dehydration for winter survival. It is also anticipated that genes encoding heat shock proteins and other genes are up-regulated in larval responses to dehydration and rehydration.

- **Dietary transmission of cryoprotectants:** Our experiments are designed to test the hypothesis that midge larvae acquire increased resistance to desiccation and temperature stress by getting cryoprotectants from their host plants.

We will also provide outreach to elementary and secondary educators and their students. The field team will include a teacher and will use e-mail and digital pictures to communicate daily progress to elementary school teachers and students. These efforts will be supplemented by presentations at local schools and national teacher meetings and the publication of articles related to cryobiology and polar biology in education journals. Furthermore, our laboratories will continue to train undergraduate, graduate, and postdoctoral students. (B–256–P; NSF/OPP 03–37656)

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Soil biodiversity and response to climate change: A regional comparison of Cape Hallett and Taylor Valley, Antarctica.

W. Berry Lyons, Ohio State University; Diana H. Wall, Colorado State University; Ross A. Virginia and John E. Barrett, Dartmouth College; and Stephen C. Cary, University of Delaware.

Soil ecosystems along the Victoria Land coast from the McMurdo Dry Valleys in the south to Cape Hallett in the north occur across broad gradients of biodiversity, climate, and soil resource legacies from previous climates (organic matter, nutrients, and salts). The range of conditions can be used to test specific hypotheses derived from a soil biodiversity and habitat model developed from the McMurdo Dry Valleys Long-Term Ecological Research Program (LTER). This habitat suitability model describes the distribution, abundance, and diversity of soil biota based on a combination of legacy and contemporary soil and climate properties.

We will extend this model to the greater Victoria Land region at Cape Hallett. Insights into the relationship between biodiversity (microbes and invertebrates) and ecosystem functioning (soil respiration and nutrient cycling) may be especially important in Victoria Land since it encompasses a range of ecosystems, from those with near-minimum organic matter and no invertebrates to those with very high organic matter deposits and complex food webs. Our 2-year program of field and laboratory research will address

how soil food webs and ecosystem processes are affected by climate, legacy, and contemporary soil processes.

We will begin the regionalization of results and insights from the McMurdo LTER study and determine whether the changes in biodiversity along the range of soil habitats and landscape gradients in Taylor Valley occur similarly across gradients in a richer, more complex habitat (Cape Hallett). There is an immediate need to understand how soil biodiversity and ecosystem functioning are related and to determine the factors influencing the distribution of soil biodiversity across Antarctica.

The taxonomic complexity of soil food webs elsewhere limits our ability to draw inferences about the functional significance of biodiversity and the responses of soil communities to varying conditions and climate. The extension and testing of a conceptual model of soil biodiversity based on the simplest soil communities on Earth will contribute to the knowledge of complex temperate ecosystems. These linked studies of microbial and invertebrate diversity in relation to soil organic matter, moisture, and temperature change at Taylor Valley and Cape Hallett will provide one of the most complete quantitative assessments of soil diversity to date. (B–259–M; NSF/OPP 02–29836)

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Hydrologic controls over biogeochemistry and microbial community structure and function across terrestrial/aquatic interfaces in a polar desert.

Michael N. Gooseff, Utah State University; Cristina D. Takaes-Vesbach, University of New Mexico; and John E. Barrett, Dartmouth College.

Aquatic-terrestrial transition zones are crucial to understanding the biogeochemistry of landscapes. In temperate watersheds, these areas are generally dominated by riparian zones, which have been identified as biogeochemical hot-spots because of the increased microbial activity and because of their importance in facilitating and buffering hydrologic and biogeochemical exchanges between terrestrial and aquatic ecosystems.

In the antarctic Dry Valleys, terrestrial-aquatic transition zones are intriguing because of the vast importance of water in this polar desert and because the material and energy budgets of Dry Valley ecosystems are linked by hydrology. We will study hydrological margins in Dry Valley aquatic-terrestrial transition zones to answer two questions:

- What are the major controls over hydrologic and biogeochemical exchange across aquatic-terrestrial transition zones?
- To what extent do trends in nutrient cycling across these zones reflect differences in microbial communities or function versus differences in the physical and chemical environment?

The hydrologic gradients that define these interfaces provide the opportunity to assess the relative influence of physical conditions and microbial biodiversity and functioning on biogeochemical cycling. Our coordinated hydrologic, biogeochemical, and molecular microbial studies have the following research objectives:

- to determine the role of sediment characteristics, permafrost and active layer dynamics, and topography on subsurface water content and distribution in hydrologic margins;
- to determine the extent to which transformations of nitrogen in hydrological margins are influenced by physical conditions or by the presence of specific microbial communities; and
- to characterize the microbial community structure and function of saturated zones.

Our research will improve understanding of the interaction of liquid water, soils, microbial communities, and biogeochemistry within the Dry Valleys, whose streams and lakes are unique because higher vegetation does not influence the movement of water. They may therefore provide a model for understanding physical and hydrological influences on microbial ecology and biogeochemistry.

Our findings will contribute to antarctic science, as well as the broader study of riparian zones and hydrologic margins. We will involve graduate and undergraduate students in our research and will disseminate information through a project Web site. Outreach will include science education in local elementary, middle, and high schools. (B–268–M; NSF/OPP 03–38267, NSF/OPP 03–36970, and NSF/OPP 03–38174)

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Relevance of planktonic larval dispersal to endemism and biogeography of antarctic benthic invertebrates.

Kenneth M. Halanych, Auburn University, and Rudolf S. Scheltema, Woods Hole Oceanographic Institution.

Because of the extreme isolation of the antarctic continent since the Early Oligocene, a unique invertebrate benthic fauna with a high degree of endemism would be expected. Yet some invertebrate taxa that constitute important ecological components of sedimentary benthic communities include more than 40 percent nonendemic species (e.g., benthic polychaetes). To account for nonendemic species, intermittent genetic exchange between antarctic and other (South American) populations must occur. The most likely mechanism for such gene flow, at least for infaunal and mobile macrobenthos, is dispersal of planktonic larvae across the subantarctic and antarctic polar fronts.

To test for larval dispersal as a mechanism for maintaining genetic continuity across polar fronts, we will take plankton samples along transects across the Drake Passage during both the austral summer and winter seasons while concurrently collecting the appropriate hydrographic data (vertical and horizontal temperatures and horizontal current data). Such data will help elucidate the hydrographic mechanisms that allow dispersal across the Drake Passage.

Using a molecular phylogenetic approach, we will also compare seemingly identical adult forms from Antarctica and South America to identify genetic breaks and historical gene flow and control for the presence of cryptic species, and employ similar molecular tools to relate planktonic larvae to their adult forms. Through this procedure, we will link the larval forms to their respective antarctic or South American origins.

Our research is intended to build a synthetic understanding of historical gene flow and present-day dispersal mechanisms in the South America/Drake Passage/Antarctic Peninsula region. This work represents one of the first attempts to examine recent gene flow in antarctic benthic invertebrates. We will train graduate students and a postdoctoral fellow, and if possible, one of our team members will be a high school teacher in order to promote K–12 education. (B–281–L; NSF/OPP 03–38218 and NSF/OPP 03–38087)

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Genetic and photogrammetric investigations of three ecotypes of killer whales in the southern Ross Sea.

Robert L. Pitman, National Oceanic and Atmospheric Administration, and Richard LeDuc and Wayne L. Perryman, National Oceanic and Atmospheric Administration, National Marine Fisheries.

We will evaluate the hypothesis that three distinct ecotypes of killer whales (*Orcinus sp.*) are found in the Ross Sea during the austral summer. These forms have different prey and habitats, different school sizes and geographic distributions, and distinct morphologies. If true, this hypothesis will largely reshape our understanding of killer whales in Antarctica. Given their numbers (current estimates, 25,000 to 94,000) and status as top predators, killer whales are undoubtedly a major force in the antarctic ecosystem, but their role and conservation status depend on properly identifying their taxonomy, specifying their dietary needs, and assessing the impact of fisheries.

We will focus on two main activities:

- using a launch to collect projectile biopsy samples that will be sequenced and

analyzed to compare genetic divergence among the three forms. To date, we have collected 47 samples from antarctic killer whales; as a target sample size, we would like 50 of each form.

- using a helicopter-mounted camera system to obtain aerial photographs of individual whales. These photographs will be used to accurately determine length and body proportions for morphological comparisons.

Previously published data indicate that the form that is most common in the southern Ross Sea may be significantly smaller than the typical killer whale. The scarcity of exposed beaches on which whales might strand and the poor odds that they would be found if they did mean that collecting a holotype specimen seems unlikely. However, we have perfected a technique for accurately determining the body length and proportions of cetaceans photographed from the air to provide morphological evidence of phenotypic divergence.

The killer whale is one of the most recognizable and best-studied large animals on Earth. Yet basic questions about how many species there are and what their place is in the ecosystem remain unanswered. Our study will demonstrate the feasibility of using nonlethal techniques to conduct research on whales in the Southern Ocean Sanctuary: some 300 to 400 minke whales are killed each year in Antarctica to conduct similar research. Confirming new species would also highlight the fact that our knowledge of marine biodiversity is more rudimentary than is currently thought. (B–289–M; NSF/OPP 03–38428)

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Origin and evolution of antarctic and deep-sea macroinfauna: Systematics and reproductive patterns of polychaetes.

James A. Blake, University of Massachusetts.

We will address the origin of deep-sea benthic fauna in relation to the antarctic shelf and linkages to the deep-sea fauna of the Atlantic and Pacific Oceans, hypotheses to explain high biodiversity in the deep sea, benthic community structure in the Southern Ocean, and biological processes including reproduction and larval development of benthic invertebrates. We will focus on seven polychaete families: *Orbiniidae*, *Oweniidae*, *Paraonidae*, *Spionidae*, *Cirratulidae*, *Scalibregmatidae*, and *Opheliidae*. Other families will be included as appropriate.

Our research is divided into the following tasks:

- participate in the ANDEEP (antarctic benthic DEEP-sea biodiversity: colonisation history and recent community patterns) III survey, which will collect infauna samples from the deep basin between southern Africa and the Scotia Sea, the eastern Weddell Sea, and the deep Weddell Sea Basin; collect box core or multicore sediment samples (all fauna will be removed from the sediment, sorted, and preserved on the ship);
- study the systematics of the seven families;
- collect larval and postlarval polychaetes from surficial multicore sample sediments to develop data on transient postlarval stages;
- collect larvae from the near-bottom environment and from near the surface to understand the mode of larval dispersal of antarctic and deep-sea polychaetes;
- synthesize the results to develop a benthic community analysis comparable to that being developed from samples taken during ANDEEP II;
- synthesize the results of individual research and contribute to a larger interdisciplinary effort with other members of the ANDEEP team; and
- use surface photographs and sediment profile images to provide detailed supporting documentation of the physical and biological properties of the sediments.

There are very few studies that address the origins of polychaetes in the Southern Ocean and even fewer for the families we will study. We will use modern cladistic methods to

address the phylogenetic relationships and biogeographic origins of these polychaetes, as well as their systematics. Data on reproduction, development, and distribution will contribute to a benthic community database that will also permit comparisons with deep-sea fauna in other parts of the world. (B–292–E; NSF/OPP 00–86665)

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Biogeochemistry of dissolved organic material in Pony Lake, Ross Island.

Yu-Ping Chin, Ohio State University; Penney Miller, Rose-Hulman Institute of Technology; Diane M. McKnight, University of Colorado–Boulder; and Christine M. Forman, Montana State University.

Dissolved organic matter is a significant chemical component in aquatic systems because it acts as an important carbon source for microorganisms, absorbs harmful radiation, complexes metals, and participates in important biogeochemical redox reactions. We will study the biogeochemical cycling of dissolved organic matter in Pony Lake, a small coastal pond on Cape Royds, Ross Island. Because there are no higher plants, all of the organic matter in this lake is microbially derived from photoautotrophic (the ability to use light to synthesize food from inorganic materials), heterotrophic (dependent on complex organic compounds for nutrition), and mixotrophic organisms, making it an ideal study site.

We will:

- examine how natural photolytic processes in the lake and laboratory irradiations of water samples and reconstituted samples of dissolved organic matter alter its composition,
- determine changes in the redox state of this material in the water column and in sediment interstitial water with increased oxygen input,
- examine how the chemical properties of dissolved organic material change with microbial utilization,
- monitor the changes in microbial abundance that result from shifts in dissolved organic material during the transition from ice to open water,
- track the changes in the microbial community as the energy source changes,
- determine whether the extracellular enzyme profiles of the water column vary in relation to the altered material, and
- examine the relationship between microbial diversity and the biogeochemistry of the material.

During the first season, we will study the changes as the lake evolves from ice-covered to ice-free conditions. We will also fractionate samples into chemically unique classes, as well as monitor the composition and reactivity of the material. Finally, we plan to study the microbial community and monitor changes in abundance, diversity, and productivity that may occur during the transition from ice to open water and generate extracellular enzyme profiles, since enzymatic hydrolysis is believed to be the rate-limiting step in carbon remineralization.

In year 2, we will collect fulvic acid samples. The amount of water needed is significantly smaller than the amount lost to ablation, and all isolates will be thoroughly characterized. In year 3, we plan to perform solar-simulated photolysis and control experiments in the United States.

This project will greatly increase our understanding of the cycling of carbon and the relationship between microbial diversity and the biogeochemistry of dissolved organic matter. (B–300–M; NSF/OPP 03–38260, NSF/OPP 03–38121, NSF/OPP 03–38299, and NSF/OPP 03–38342)

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Salpa thompsoni in the Southern Ocean: Bioenergetics, population dynamics, and

biogeochemical impact.

Patricia Kremer, University of Connecticut, and Laurence P. Madin, Woods Hole Oceanographic Institution.

Salps are holoplanktonic grazers that are strikingly different from krill, copepods, or other crustacean zooplankton. Salps sometimes occur in very dense populations that cover large areas and have been shown to have a significant impact from both grazing and the production of fast-sinking fecal pellets. Although salps are commonly acknowledged as a major component of the Southern Ocean zooplankton community, often comparable to krill, they have received relatively little attention. Extensive sampling has documented the seasonal abundance of *S. thompsoni* in the Southern Ocean, but there still is a paucity of data.

In addition to various rate measurements, we will make quantitative surveys of the horizontal and vertical distribution of salps. Results will be used to construct a model of salp population dynamics. Both experimental and modeling results will be interpreted within the context of the physical and nutritional conditions to which the salps are exposed. This integrated approach will provide a good basis for understanding their growth dynamics.

Our tasks are as follows:

- survey the extent of *S. thompsoni* blooms to determine biomass and spatial distribution and to allow a regional assessment of their effects;
- measure the physical characteristics of the water column and the quantity and quality of particulate food;
- measure respiration and excretion rates for solitary and aggregate salps of all sizes;
- measure ingestion rates;
- determine somatic growth rates, fecundity (of solitaries), and fertilization success (for aggregates);
- synthesize rate measurements on salps into complete budgets for both carbon and nitrogen;
- formulate an individually based model of salp population dynamics that includes realistic behavior patterns as well as experimentally determined vital rates;
- identify salp hot spots and interpret distributions in an appropriate hydrographic context;
- use satellite imagery and information on sea-ice cover to test hypotheses about conditions that result in high densities of salps; and
- evaluate the relationship between specified hydrographic conditions, ice cover, and blooms.

Our work will also involve training graduate and undergraduate students, participating in teacher-researcher workshops, and collaborating with the New England Aquarium in an IMAX movie about research in Antarctica. (B–307–L; NSF/OPP 03–38290)

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What limits denitrification and bacterial growth in Lake Bonney, Taylor Valley, Antarctica?

Bess B. Ward, Princeton University; Mark L. Wells, University of Maine; and Charles G. Trick, University of Western Ontario, Canada.

Denitrification refers to the loss of fixed nitrogen from ecosystems, and thus its rate and regulation may directly affect primary short- and long-term production and carbon cycling. Our previous investigation of the role of bioactive metals in regulating denitrification in cultured bacteria and permanently ice-covered Lake Bonney in the Taylor Valley of East Antarctica produced three important findings:

- Growth experiments demonstrated that cultured denitrifying bacteria could be limited by copper or iron and that nitrogen oxides accumulated in the medium due to limitation at the nitrite and nitrous oxide reduction steps, respectively.

- Manipulations of metal availability using chelators, additions of substrates, and cultured bacteria all failed to elicit a response from the natural microbial communities in the lake. No denitrification or thymidine incorporation was detected in the subchemocline waters of the east lobe of Lake Bonney, while analogous experiments detected an active denitrifying community in the west lobe.

- Silver and iron were the only metals that showed dramatic distribution differences between the two lobes. Silver concentrations were up to 150-fold higher and iron concentrations were 200 times lower in the east lobe than in the west. Low iron concentrations may exacerbate the potential toxicity of other metals, so general metal toxicity could possibly inhibit denitrification. Since silver can specifically inhibit denitrification, high silver concentrations might prevent the functioning of nitrous oxide reductase in the same way that copper limitation does by causing a buildup of nitrous oxide and a nonfunctional nitrogen cycle.

Other factors are likely also at work. We will determine whether oxygen concentrations are low enough to trigger denitrification in the east lobe. We will also investigate silver toxicity, general metal toxicity, and oxygen concentration by using a suite of sentinel strains of denitrifying bacteria isolated from the lake, incubated in lake water, and subjected to various treatments to quantify their responses.

The relationships between metals and denitrification that we discover here are expected to shed light not only on Lake Bonney's unusual nitrogen cycle, but also, more generally, on the potential role of metals in regulating microbial nitrogen transformations. (B–310–M; NSF/OPP 02–30276 and NSF/OPP 02–30151)

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Prevention of environment-induced decrements in mood and cognitive performance.

Lawrence A. Palinkas, University of California–San Diego.

Cognitive performance degrades with residence in Antarctica, and mood alteration fits a seasonal pattern during extended residence. Although these changes suggest psychological responses to physiological adaptations to cold and dim light, the exact mechanisms are poorly understood.

Our first objective is to determine whether long-term exposure to cold temperatures and/or to dim light is associated with significant changes in cognitive performance and emotional well-being:

- Is physiological adaptation to cold or adaptation to dim light independently or synergistically associated with decrements in cognitive performance and emotional well-being?

- Do personnel at South Pole Station experience greater physiological adaptation and decrements than personnel at McMurdo Station do?

We also wish to determine whether these decrements can be prevented or minimized by pharmacologic interventions and/or phototherapy:

- What are the effects of combining liothyronine sodium with levothyroxine sodium versus supplementation with tyrosine (a precursor to both thyroid hormone and catecholamines) and daily phototherapy?

- Is phototherapy used in combination with a pharmacologic agent more effective than either intervention used alone?

In phase I, we established computer-testing protocols, developed an effective placebo capsule, packaged the necessary drugs, and tested the validity and reliability of computer-administered cognition and mood protocols with 30 hypothyroid outpatients on constant thyroid hormone replacement and 30 healthy, age- and sex-matched controls in New Zealand.

In phase II, 50 members of the 2002 winter crews, 35 at McMurdo Station and 15 at South Pole Station, were randomized in a double-blind crossover design into 1 of 2 treatment groups (20 subjects in each group) and 1 control group (10 subjects). Baseline measurements were conducted, and treatment groups were switched after a 1-month washout period. Mood and memory testing comprised 5 assessments over 12 months. Treatments consisted of 50 micrograms (mcg) of levothyroxine sodium plus 12.5 mcg of liothyronine per day, 150 milligrams per kilogram of tyrosine per day, and a placebo.

In phase III, a similar design will be used to evaluate the effectiveness of phototherapy, alone and in combination with the more effective of the two pharmacologic interventions.

Our research will lead to an improved understanding of the specific environmental conditions and physiological mechanisms that affect behavior and performance in the Antarctic, help develop countermeasures for circannual oscillations of mood and cognitive performance, and contribute to a reduction in accidental injuries at high latitudes. (B–321–M/S; NSF/OPP 00–90343)

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SPISE3 (Science Package for the Exploration of Extreme Environments 3): A noncontact instrument suite for rapid detection of chemical biosignatures.

Pamela G. Conrad, National Aeronautics and Space Administration.

Endolithic microbial communities inhabit harsh environments that may represent the closest analog to the Martian environment. As part of a study of the chemical signatures of endolithic microbes in hot and cold deserts, we will go to the McMurdo Dry Valleys with a unique set of portable nondestructive instruments that do not touch the rocks that host the organisms in order to detect subtle chemical biosignatures associated with life. The instrument suite, called SPISE3 (Science Package for the Exploration of Extreme Environments 3), is composed of a spectroradiometer, portable gas chromatograph, and an ultraviolet visible light wavelengths fluorescence spectrometer and imager. Our goal is to develop tools and strategies in preparation for life-detection missions to Mars and other planets. Our tasks are as follows:

- We will determine whether we can reliably and reproducibly detect chemical biosignatures that can be differentiated from chemical signatures associated with minerals.
- We will verify that biosignatures are observable over various spatial scales that in part define how far away one can be from a sample or how much sample is needed for chemical biosignatures to be observable.
- We will see whether the chemical fluxes associated with metabolism are distinct from abiological, geochemical ones.

Microbial endolithic communities living in cold deserts exhibit different chemical signatures than those adapted to life in hot deserts, and we will see whether these differences will be observable in terms of spatial and temporal scales and chemical concentrations.

Although the chemistry of the sandstone hosting endolithic communities in the antarctic Dry Valleys is relatively simple (mostly silicon and oxygen), there are a variety of endolithic communities in the Mojave Desert that inhabit more mineralogically and chemically complex rocks and sediment. What does the addition of more complex chemistry do to our instruments´ ability to differentiate between geological and biological contributions to the chemical environment?

Over a 10- to 14-day period during the austral summer, therefore, we will take measurements four times a day from the rocks at Battleship Promontory in the Dry Valleys. We will compare those measurements with the data we gathered from the endolithic communities in hot deserts, analyzing the data both in Antarctica and in our home laboratories. (B–330–M; NSF/NASA agreement, NASA award NASA ASTEP–02–0040–0014)

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Temporal variability in natural and anthropogenic disturbance of McMurdo Station, Antarctica.

Mahlon C. Kennicutt, Texas A&M University.

Antarctica represents one of the most carefully tended and strictly monitored habitats on Earth. Not only is it important to protect the flora, fauna, and atmosphere of a relatively pristine environment, but the extreme southern latitudes provide a virtual baseline barometer of global pollution. The Antarctic Treaty's Protocol on Environmental Protection, supplemented by the policies and practices of the nations that work there, have combined to focus scrutiny on any anthropogenic impacts that can be foreseen or detected.

We will therefore collect a series of observations that should enable scientists to be more aware of any such impacts on both marine and terrestrial habitats in and around McMurdo Station, locating them precisely and tracking them over time. An environmental monitoring program based on a 3-year pilot program of sampling and data analysis is continuing to collect samples. We will further evaluate the feasibility of this design and establish point-data sampling grids at various spatial scales measuring a series of attributes indicative of change.

Our objectives are to determine:

- the spatial and temporal scales of change and its origin,
- how efficiently this observational system documents relevant changes in important habitat characteristics, and
- the usefulness of various approaches to reference or control locations.

We will organize these diverse data sets into a coherent, coordinated framework. The results should provide additional fundamental scientific information for developing a long-term strategy to document and minimize the impact of future science (and support operations) on antarctic resources and values. (B–518–M; NSF/OPP 03–54573)

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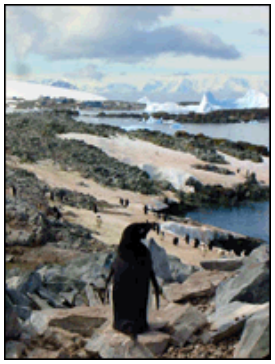
LONG-TERM ECOLOGICAL RESEARCH



An Adelie penguin rookery on Humble Island in the Antarctic Peninsula region. The buildings of Palmer Station can be seen in the background. Palmer Station sits on Anvers Island at 64° 46' S, 64° 03' W. (*NSF/USAP photo by Jeffrey Kietzmann, Raytheon Polar Service Corp.*)

On this page:

Overview

Ecology has taken its place among science's vital, strategic disciplines, thanks to an ever-greater awareness of how the web of life and the Earth's other dynamic processes constitute a closed and coherent system. As part of this evolution, the National Science Foundation's Long-Term Ecological Research (LTER) Program, begun in 1980, has grown into a network of 24 research sites, established to acquire long-term data sets from Alaska to Puerto Rico to Antarctica. Such a spread is necessary to collect information on a variety of ecosystem types, such as grassland, desert, forest, tundra, lake, stream, river, and agricultural and coastal systems.

To enhance understanding of ecological phenomena, the program focuses on the role of cyclical/episodic events (ranging from years to decades to centuries) in the structure and function of these distinctive ecosystems. To facilitate research on unique aspects of antarctic ecology, the Antarctic Biology and Medicine Program supports two of these LTER project sites: one near Palmer Station in the Antarctic Peninsula and the other in the McMurdo Dry Valleys.

The Palmer Station/Antarctic Peninsula LTER program is ideally sited to probe a fundamental issue: As the pack ice varies (seasonally and year by year), what happens to the antarctic marine community? That is, how do ecological processes influence organisms at different trophic levels? The Palmer Station LTER Program was initiated during the 1991-1992 season with the installation of an automatic meteorological station, annual research cruises in the austral summer, and a focused research program at the station facility. During the austral fall and spring seasons, process-study research cruises develop data that can be compared with data collected from other coastal systems in the Antarctic Peninsula.

Due to its unique site, the McMurdo Dry Valleys LTER project is more wide ranging and

focuses on the interdisciplinary study of aquatic and terrestrial ecosystems in a cold desert region of Antarctica. The area is one of the most fascinating and contrarian spots on Earth. In fact, it is almost unearthly. National Aeronautics and Space Administration scientists who wondered what conditions might be like on Mars came here, an island of rock in a sea of ice, the largest ice-free area in Antarctica, where winds howl, where what little water there is dessicates or evaporates, and where the only creatures that can survive are microorganisms, mosses, lichens, and relatively few groups of invertebrates. Higher forms of life are virtually nonexistent.

Thus, LTER projects based here take advantage of perhaps the coldest and driest ecosystem on Earth, where life approaches its environmental limits; as such, this may be seen as an "end-member" in the spectrum of environments included in the LTER network. Why is it necessary to conduct long-term ecological research in such a place? All ecosystems depend on liquid water and are shaped to varying degrees by climate and material transport; but nowhere is this more apparent than in the McMurdo Dry Valleys.

In very few of Earth's environments do minor changes in solar radiation and temperature so dramatically affect the capabilities of organisms to grow and reproduce as in the McMurdo Dry Valleys. Therefore, this site may well be an important natural, regional-scale laboratory for studying the biological effects of climate changes attributable to human activity. While the antarctic ice sheets respond to climate change on the order of thousands of years, the glaciers, streams, and ice-covered lakes in the McMurdo Dry Valleys often experience nearly immediate (and sometimes profound) change. As such, this area would be one of the first to show the effects of climate change in Antarctica.

The overall objectives of the McMurdo Dry Valleys LTER are to understand the influence of physical and biological constraints on the structure and function of Dry Valley ecosystems and to understand the modifying effects of material transport on these ecosystems. Though driven by the same basic processes found in all ecosystems (microbial use and remineralization of nutrients, for example), the Dry Valley ecosystems lack many of the confounding variables, such as diverse and fecund biota and many levels of plants and higher animals, inherent in other ecosystem research.

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Palmer Long-Term Ecological Research Project: Climate change, ecological migration, and teleconnections in an ice-dominated environment.

Hugh W. Ducklow, College of William and Mary.

The Palmer Long-Term Ecological Research Project (PAL LTER) seeks to understand the structure and function of the antarctic marine and terrestrial ecosystem in the context of physical forcing by seasonal to interannual variability in atmospheric and sea-ice dynamics, as well as long-term climate change. PAL LTER studies marine and terrestrial food webs consisting principally of diatom primary producers; the dominant herbivore the antarctic krill, *Euphausia superba;* the apex predator Adélie penguin, *Pygoscelis adeliae;* and an active microbial food web, consisting of planktonic bacteria and *Archaea,* bacterivorous protozoa, and dissolved organic matter. A biogeochemical component studies organic and inorganic carbon fluxes and the sedimentation of particulate matter into the deep sea.

This project monitors western Antarctic Peninsula ecosystems regionally over a grid of oceanographic stations and locally at Palmer Station. The extent and variability of sea ice affect changes at all trophic levels. In recent years, sea ice has diminished in response to general climate warming. A long-term population decline of ice-dependent Adélie penguins provides a clear example of the impact of this trend in the Palmer region. Adélie populations at the five major rookeries located near Palmer Station and studied for the past 30 years have all shown a gradual decrease in numbers. The western Antarctic Peninsula, the site of PAL LTER research, runs perpendicular to a strong climatic gradient between the cold, dry continental regime to the south and the warm, moist maritime regime to the north. More maritime conditions appear to be replacing the original polar ecosystem in the northern part of the Peninsula as the climatic gradient shifts southward. To date, this shift appears to be matched by an ecosystem shift along the Peninsula, as evidenced by declines in Adélie penguins, which require a longer snow-cover season, and changes in plankton distribution, as reflected in predator diets.

We hypothesize that ecosystem migration is most clearly manifested by changes in

upper-level predators (penguins) and certain polar fishes in predator-foraging environments because these longer lived species integrate recent climate trends and because individual species are more sensitive indicators than aggregated functional groups. We hypothesize that in the years ahead, analogous modifications will also become evident at lower trophic levels, although these changes are likely to be seen only through long-term studies of ecosystem boundaries along the peninsula.

By studying extant food webs in both the marine and terrestrial environments, we will continue to investigate ecosystem changes at lower trophic levels; changes in response to continued, dramatic warming; and shifts in the poleward climatic gradient along the western Antarctic Peninsula.

During the 2004–2005 field season, the following studies will be conducted as part of the PAL LTER project:

- **Seabird (penguins, giant petrels, and skuas) ecology.** (B–013–L/P; NSF/OPP 02–17282)
  William R. Fraser, Polar Oceans Research Group.
- **Primary production and phytoplankton ecology.** (B–016–L/P; NSF/OPP 02–17282)
  Maria Vernet, Scripps Institution of Oceanography, University of California–San Diego.
- **Physical oceanography and ocean–climate modeling.** (B–021–L; NSF/OPP 02–17282)
  Douglas G. Martinson, Columbia University
- **Zooplankton and nekton stocks, feeding, and growth.** (B–028–L/P; NSF/OPP 02–17282)
  Langdon B. Quetin and Robin M. Ross–Quetin, University of California–Santa Barbara.
- **Remote sensing and bio–optics.** (B–032–L/P; NSF/OPP 02–17282)
  Raymond C. Smith, University of California–Santa Barbara.
- **Microbial ecology and biogeochemistry.** (B–045–L/P; NSF/OPP 02–17282)
  Hugh W. Ducklow, College of William and Mary.

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The role of natural legacy on ecosystem structure and function in a polar desert: The McMurdo Dry Valley Long-Term Ecological Research Project.

W. Berry Lyons, Ohio State University.

The largest ice-free area in Antarctica is found in the McMurdo Dry Valleys, located on the western shore of McMurdo Sound. Among the most extreme deserts in the world, the McMurdo Dry Valleys are the coldest and driest of all the Long-Term Ecological Research (LTER) sites. Consequently, biological systems are limited to microbial populations, microinvertebrates, mosses, and lichens. Yet complex trophic interactions and biogeochemical nutrient cycles develop in the lakes, streams, and soils of the Dry Valleys. In the austral summer, solar energy produces glacial meltwater, providing vital water and nutrients that have a primary influence on the ecosystems. Such material transport and climatic influences shape all ecosystems, but nowhere is this more apparent than in the McMurdo Dry Valleys.

The McMurdo LTER project focuses on the aquatic and terrestrial ecosystems in the Dry Valley landscape as a context to studying biological processes and to exploring material transport and migration. During the second phase of this LTER project, we are extending our research by continuing to investigate the McMurdo Dry Valleys as an end-member system, hoping to better ascertain the role of past climatic legacies on ecosystem structure and function. We will test a series of eight hypotheses in three major focus-areas–hydrology, biological activity/diversity, and biogeochemical processes—by continuing our monitoring projects and long-term experiments.

Understanding the structure and function of the McMurdo Dry Valleys ecosystem requires deciphering the hydrological response to climate, both now and in the past. Current patterns of biological activity and diversity reflect past and present distributions of water,

nutrients, organic carbon, and biota. Biogeochemical processes responsible for the transport, immobilization, and mineralization of nutrients and other chemicals provide the linkages between the region's biota and the physical environment. The timing, duration, and location of biogeochemical processes in the past and present are controlled by the availability of water. We continue to focus on the integration of the biological processes within and among the lakes, streams, and terrestrial ecosystems that comprise the McMurdo Dry Valley landscape. Our interdisciplinary research team will continue to use modeling and other integrative studies to synthesize data and to examine the McMurdo Dry Valleys ecosystem.

During the 2004–2005 field season, the following studies will be conducted in the McMurdo Dry Valleys as part of the LTER project:

- **Chemistry of streams, lakes, and glaciers.** (B–420–M; NSF/OPP 98–10219)
  W. Berry Lyons, Ohio State University.
- **Flow, sediment transport, and productivity of streams; water quality of Lake Fryxell: Water loss from the streams to the atmosphere by sampling water–content changes.** (B–421–M; NSF/OPP 98–10219)
  Diane M. McKnight, University of Colorado–Boulder.
- **Lake pelagic and benthic productivity: Microbial food webs.** (B–422–M; NSF/OPP 98–10219)
  John C. Priscu, Montana State University–Bozeman.
- **The influence of environmental conditions on carbon and nitrogen cycling and on soil biota, the effects of environmental change and food supply availability on soil biota, and the effects of climate change on biota.** (B–423–M and B–424–M; NSF/OPP 98–10219)
  Ross A. Virginia, Dartmouth College, and Diana H. Wall, Colorado State University.
- **Glacier mass balance, melt, and energy balance: Climate monitoring in Taylor, Wright, Victoria, and Beacon Valleys.** (B–425–M; NSF/OPP 98–10219)
  Andrew Fountain, Portland State University.
- **Paleoclimatology, paleoecology, and meteorological data collection.** (B–426–M; NSF/OPP 98–10219)
  Peter T. Doran, University of Illinois–Chicago.

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U.S. Antarctic Program, 2004 – 2005

I. Aeronomy and Astrophysics

II. Biology and Medicine

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IV. Ocean and Climate Systems

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OCEAN AND CLIMATE SYSTEMS

The U.S. icebreaking research ship Laurence M. Gould is used by U.S. Antarctic Program scientists to support research including oceanography and marine biology. It is also used to transport personnel from Punta Arenas, Chile, to Palmer Station. (*NSF/USAP photo by Jeffrey Kietzmann, Raytheon Polar Service Corp.*)

On this page:

Overview

Though it borders the world's major oceans, the Southern Ocean system is like no other in the world, with 4 times more water than the Gulf Stream and 400 times more than the Mississippi River. It is a sea where average temperatures do not reach 2 °C in the summer, where even the water itself is so distinctive that it can be identified thousands of miles away in currents that originated here. These Antarctic Bottom Waters provide the major source of cooling for the world's oceans. In fact, if the Earth is a heat engine,

Antarctica should be viewed as its circulatory cooling component.

The climate in Antarctica is also unique, linked as it is to the extreme conditions of the land, ice, and sea below the troposphere (the inner region of the atmosphere, up to between 11 and 16 kilometers). This ocean/atmosphere environment defines and constrains the marine biosphere and in turn has a dynamic relationship with the global ocean and with weather all over the planet. Few major energy exchanges on Earth can be calculated without factoring in these essential antarctic phenomena. As such, they are both an indicator and a component of climate change.

A researcher attaches an instrument to a tethered balloon to measure the characteristics of water vapor in the lower two kilometers of the atmosphere at Amundsen–Scott South Pole Station, Antarctica. (*NSF/USAP photo by Jeff Ingles, Raytheon Polar Services Corp.*)

The Ocean and Climate System Program sponsors research that will improve understanding of the high-latitude ocean environment, including the global exchange of heat, salt, water, and trace elements; there is also an emphasis on sea-ice dynamics, as well as the dynamic behavior and atmospheric chemistry of the troposphere. Major program elements include the following:

- **Physical oceanography:** The dynamics and kinematics of the polar oceans; the interaction of such forces as wind, solar radiation, and heat exchange; water-mass production and modification processes; ocean dynamics at the pack-ice edge; and the effect of polynyas on ventilation.
- **Chemical oceanography:** The chemical composition of sea water and its global differentiation; reactions among chemical elements and compounds in the ocean; fluxes of material, within ocean basins and at their boundaries; and the use of chemical tracers to map oceanic processes across a range of temporal and spatial scales.
- **Sea-ice dynamics:** The material characteristics of sea ice, from the level of the individual crystal to the large-scale patterns of freezing, deformation, and melting.
- **Meteorology:** Atmospheric circulation systems and dynamics, including the energy budget; atmospheric chemistry; transport of atmospheric contaminants to the antarctic; and the role of large and mesoscale systems in the global exchange of heat, momentum, and trace constituents.

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Antarctic Troposphere Chemistry Investigation (ANTCI).

Fred Eisele, Douglas Davis, Yuhang Wang, David Tan, and L. Greg Huey, Georgia Institute of Technology; Richard Arimoto, New Mexico State University; Detlev Helmig, University of Colorado-Boulder; Manuel Hutterli and Roger Bales, University of Arizona; Jack Dibb, University of New Hampshire; Donald Blake, University of California-Irvine; and Richard Shetter and Roy Mauldin, National Center for Atmospheric Research.

We will study sulfur chemistry in the antarctic atmosphere to enhance our understanding of the processes that control tropospheric levels of reactive hydrogen radicals, reactive nitrogen, sulfur, and other trace species for the further purpose of improving the climatic interpretation of sulfur-based signals in antarctic ice-core records. Specifically, we will be making observations of reactive hydrogen radicals, sulfuric acid and its sulfur precursors, and the flux of ultraviolet radiation. The results we derive will lead to a far more comprehensive understanding of antarctic atmospheric chemistry, as well as the factors that influence the levels and distributions of climate proxy species in antarctic ice cores.

Our major science objectives include:

- evaluating the processes that control spring and summer levels of reactive radicals in the atmospheric surface layer at the South Pole,
- assessing how representative previously obtained South Pole and coastal

measurements are in the larger context of polar plateau processes, and

- investigating the relative importance of the oxidative processes involved in the coast-to-plateau transport of reduced sulfur and determining the principal chemical transition regions.

Secondary objectives include investigating snow/firn chemical species that undergo extensive exchange with the atmosphere and assessing the different chemical forms of the trace elements and their relationships to levels of ozone and other oxidants.

Atmospheric sulfur chemistry is important in climate change because both naturally and anthropogenically emitted sulfur compounds form minute particles in the atmosphere (so-called aerosols) that reflect solar radiation, produce atmospheric haze and acid rain, and affect ozone depletion. These sulfate particles may also act as condensation nuclei for water vapor and enhance global cloudiness. The primary natural sources of sulfur are volcanic emissions and dimethylsulfide production by oceanic phytoplankton.

On the millennial time scale, the variability and background level of atmospheric aerosols can be reconstructed from ice cores. It is, however, necessary to understand how the physical and chemical environment of the process affects the relative concentrations of the oxidation products that become buried in the ice. (O–176–M/S; NSF/OPP 02–30246, NSF/OPP 02–29633, NSF/OPP 02–29605, NSF/OPP 02–30046, NSF/OPP 02–30051, NSF/OPP 02–30117, and NSF/OPP 02–30178)

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Solar radiation processes on the east antarctic plateau.

Stephen G. Warren and Thomas C. Grenfell, University of Washington.

This project is an experimental study of solar radiation processes near the surface at Concordia Base at Dome C, the French-Italian station in East Antarctica. It will be carried out in cooperation with the Laboratoire de Glaciologie et Geophysique de l'Environment in Grenoble, France. The emphasis is on the reflection of sunlight by snow and the transmission of sunlight through clouds. The observations we gather will be relevant to climate, remote sensing, and the physics of ice and snow.

Observations of the angular pattern of solar radiation reflected from the snow surface will allow us to validate information from satellite-derived radiances. Using radiative transfer modeling through the atmosphere, we will reconcile measured surface-reflection functions with the empirical functions obtained from the Advanced Very-High-Resoution Radiometer on the polar orbiting satellites of the National Oceanic and Atmospheric Administration. (O–201–M; NSF/OPP 00–03826)

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Antarctic Meteorological Research Center (2002–2005).

Charles R. Stearns, University of Wisconsin-Madison.

The Antarctic Meteorological Research Center (AMRC) was created in 1992 to improve access to meteorological data from the Antarctic. The AMRC's mission is to conduct research in observational meteorology and the stewardship of meteorological data, along with providing data and expert assistance to the antarctic community to support research and operations. The AMRC fulfills its mission by

- continuing to maintain and expand, as appropriate, the long-term record of all meteorological data on Antarctica and the adjacent Southern Ocean and make these data available to the scientific community for multidisciplinary use (special attention will be given to obtaining data not normally or readily available by other means);

- continuing to generate satellite products, specifically, but not limited to, antarctic composite imagery, and expand and improve on them as much as possible;

- conducting research in observational meteorology, especially with regard to

climatological analyses and case studies; and

- continuing to conduct and expand, as appropriate, educational and public outreach activities associated with antarctic meteorology and related fields.

Using available meteorological interactive processing software and other standard computing tools, we will collect data from all available sources for processing, archiving, and distribution. The mission of the AMRC not only includes the opportunity to advance the knowledge of antarctic meteorology, but with the free availability of its data holdings, the AMRC gives others the opportunity to advance the frontiers of all antarctic science.

Continuing educational outreach activities on meteorology and the Antarctic, an important component of this work, have the potential to raise the science literacy of the general public, as well as the level of K–12 science education. (O–202–M/P/S; NSF/OPP 01–26262)

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Measurements of variations in atmospheric oxygen/nitrogen and argon/nitrogen ratios in carbon dioxide concentration in relation to the carbon cycle and climate.

Ralph F. Keeling, Scripps Institution of Oceanography, University of California–San Diego.

Oxygen, the most abundant element on Earth, comprises about a fifth of the atmosphere. But much of the Earth's oxygen resides in other chemical species (in water, rocks, and minerals) and, of course, in the flora and fauna that recycle it (both directly and as carbon dioxide) through photosynthesis and respiration. Thus, scientists are interested in measuring the concentration of molecular oxygen and carbon dioxide in air samples; our project includes a subset of sample collections being made at a series of baseline sites around the world.

These data should help improve estimates of the processes whereby oxygen is cycled throughout the global ecosystem, specifically through photosynthesis and atmospheric mixing rates, and also improve predictions of the net exchange rates of carbon dioxide with biota, on land and in the oceans. An important part of the measurement program entails developing absolute standards for oxygen-in-air to ensure stable long-term calibration. In addition, we are conducting surveys of the oxidative oxygen/carbon ratios of both terrestrial- and marine-based organic carbon, hoping to improve the quantitative basis for linking the geochemical cycles of oxygen and carbon dioxide.

These results should help enhance our understanding of the processes that regulate the buildup of carbon dioxide in the atmosphere and of the change processes, especially climate change, that regulate ecological functions on land and sea. (O–204–P; NSF/ATM 00–00923)

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Processes driving spatial and temporal variability of surface pCO_2 in the Drake Passage.

Taro Takahashi, Columbia University, and Jorge L Sarmiento, Princeton University.

The Southern Ocean is an important component of the global carbon budget. Low surface temperatures with consequently low vertical stability, ice formation, and high winds produce a very active environment for the exchange of gaseous carbon dioxide between the atmospheric and oceanic reservoirs. The Drake Passage is the narrowest point through which the Antarctic Circumpolar Current and its associated fronts must pass and is the most efficient location for the measurement of latitudinal gradients of gas exchange.

We will expand the measurement suite and lengthen the time series of dissolved carbon dioxide gas (pCO_2) along with occasional total carbon dioxide (TCO_2) in surface waters on transects of Drake Passage. This expanded suite will include the addition of an oxygen

probe to the pCO_2 system, as well as the addition of nutrient and carbon-13 measurements to the discrete TCO_2 samples now collected on regularly scheduled transects on the U.S. Antarctic Program research ship *Laurence M. Gould*.

Two short cruises (4 to 5 days) will also be dedicated to providing a baseline for surface measurements with water column profiles of TCO_2, pCO_2, nutrients, oxygen, and carbon-13. The continuation and expansion of the Drake Passage time series will contribute to achieving two main goals:

- quantifying the spatial and temporal variability and trends of surface pCO_2, TCO_2, oxygen, nutrients, and carbon-13 in four major regimes in the Drake Passage between March 2002 and June 2007 and
- understanding the dominant processes that contribute to variability in surface pCO_2 and the resulting air-sea flux of CO_2 in the Drake Passage.

We will test the hypothesis that the mean annual surface water pCO_2 in the Drake Passage is determined by the degree of winter mixing. This has special significance in light of two scenarios that may affect the ventilation of deep water in the Southern Ocean:

- a decrease in water-column stratification with observations of higher zonal winds or
- an increase in stratification due to higher precipitation and global warming.

If winter mixing determines the mean annual pCO_2 in the Drake Passage, the increase in atmospheric pCO_2 will have little effect on sea surface pCO_2. Because the Southern Ocean is a sink for anthropogenic carbon, further studies to understand the processes that determine this uptake and its response to climate change are needed. Our time series studies represent the highest concentration of pCO_2 measurements ever made both temporally and spatially in the Southern Ocean and so are an essential first step. Moreover, our study will make high-quality surface pCO_2 and discrete measurements of nutrients and carbon-13 available to help validate biogeochemical modeling efforts, as well as provide baseline data for studies throughout the Southern Ocean. (O–214–L/N; NSF/OPP 03–38248 and NSF/OPP 03–38155)

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AnSlope—Cross-slope exchanges at the Antarctic Slope Front.

Arnold L. Gordon, Stanley S. Jacobs, Martin Visbeck, William M. Smethie, and Peter Schlosser, Lamont-Doherty Earth Observatory, Columbia University; Alejandro H. Orsi and Thomas Whitworth, Texas A&M University; R. Dale Pillsbury, Oregon State University; and Laurence Padman, Earth and Space Research.

The importance of cold water masses originating in the Antarctic to the global ocean circulation and climate is now understood, but the processes by which these water masses enter the deep ocean circulation are not. Our program will address this issue.

Our primary goal is to identify the principal physical processes that govern the transfer of shelf-modified dense water into intermediate and deep layers of the adjacent deep ocean. At the same time, we seek to understand the compensatory poleward flow of waters from the oceanic regime. The upper continental slope is the critical gateway for the exchange of shelf and deep ocean waters. Here the topography, velocity, and density fields associated with the nearly ubiquitous Antarctic Slope Front (ASF) must strongly influence the advective and turbulent transfer of water properties between the shelf and oceanic regimes.

We will join the research icebreaker *Nathaniel B. Palmer* for three transects over a 12- to 14-month period beginning in austral summer 2003 and use an integrated observational and modeling program to achieve four objectives:

- determine the mean structure and principal scales of variability of the ASF and estimate its role on cross-slope exchanges and mixing of adjacent water masses;
- determine the influence of slope topography on frontal location and outflow of dense shelf water;

- establish the role of frontal instabilities, benthic boundary layer transports, tides, and other oscillatory processes on cross-slope advection and fluxes; and

- assess the effect of diapycnal (shear-driven and double-diffusive) mixing, lateral mixing, and nonlinearities on the rate of descent and fate of outflowing, near-freezing shelf water.

Our measurements will focus on the outer continental shelf and upper slope of the northwestern Ross Sea. We will also take benthic float measurements and develop the techniques for parameterizing cross-front exchanges in regional and global models. Ongoing studies by Italian and German researchers will complement our work and provide a test-bed for our parameterizations of cross-front exchange. Synergistic projects will sample for geochemical tracers, nutrients, and oxygen isotopes; make casts to measure ocean microstructure; investigate surface-water properties during transects to and from New Zealand; and survey the near-surface environment, including elements of its ecosystem and sea ice field.

AnSlope cruise III (NBP04-08), the final cruise of this project, is the "late winter" component. We plan to occupy as many CTD/LADCP (Conductivity Temperature Depth/Lowered Acoustic Doppler Current Profiler) stations as possible across and along the ASF in the Ross Sea. These include a transect near previously deployed bottom-moored arrays of current, temperature, conductivity, and pressure sensors. Synergistic projects will sample for geochemical tracers, nutrients, and oxygen isotopes; make casts to measure ocean microstructure; investigate surface water properties during transects to and from New Zealand; and survey the near-surface environment, including elements of its ecosystem and sea ice field. (O–215–N; NSF/OPP 01–25172, NSF/OPP 01–25521, NSF/OPP 01–25523, NSF/OPP 01–25084, NSF/OPP 01–25431, and NSF/OPP 01–25602)

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In situ measurements of halogen oxides in the troposphere.

Linnea M. Avallone, University of Colorado–Boulder.

The phenomenon of sudden and complete boundary-layer ozone loss has been observed at many northern high-latitude sites and more recently in Antarctica. Simultaneous observations of other species indicated that ozone loss was often tied to increases in pollutants, suggesting a relationship to the transport of polluted air from the northern continents into the more pristine arctic environment. However, subsequent studies showed that the ozone loss phenomena in the Arctic are tightly linked to catalytic gas-phase halogen chemistry similar to that responsible for Antarctica's ozone hole. Although the exact mechanism for the sudden boundary-layer ozone losses remains uncertain, it is clearly linked to active bromine. Modeling studies suggest that the ultimate source of bromine is sea salt, which undergoes transformation when it is airborne in particulate form or dissolved in surface snow.

Snow is both an important source and sink for reactive bromine. Widespread bromine activation in coastal regions seems to coincide with the average edge of the annual sea ice. Previous measurements of halogen oxides, ozone, and nitrogen oxides have revealed that McMurdo Station does indeed see some significant ozone loss events, many directly related to local pollution (perhaps power plant emissions). There were also a number of low ozone periods during and immediately after large southern storms. These bear further study.

We will attempt to answer three questions:

- How often is surface ozone at McMurdo Station affected by local pollution?

- What reactive bromine compounds are present and can we identify their source(s)?

- How much is the snow surface directly affecting ozone?

The relatively clean antarctic environment, far from most sources of anthropogenic sources of nitrogen oxides and hydrocarbons, will allow us to better constrain the natural role of snow- and ice-covered surfaces on the boundary-layer ozone budget. As sea-ice coverage changes in response to a changing climate, the frequency and duration of boundary-layer ozone loss related to the availability of bromine gases derived from sea

salt may change as well. A more thorough understanding of the nature and mechanism (s) for boundary-layer ozone losses will lead to better ways to predict the impact of future climate change on the chemical composition of the high-latitude troposphere. (O–251–M; NSF/OPP 04–11437)

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South Pole monitoring for climatic change—U.S. Department of Commerce NOAA Climate Monitoring and Diagnostic Laboratory.

David Hofmann, Climate Monitoring and Diagnostics Laboratory, National Oceanic and Atmospheric Administration.

For more than 30 years, the National Oceanic and Atmospheric Administration has been conducting studies to determine and assess the long-term buildup of trace atmospheric constituents that influence climate change and the ozone layer. Time-series analyses of long-term data provide insight into several phenomena of particular interest, including:

- seasonal and temporal variations in greenhouse gases,
- the depletion of stratospheric ozone,
- transantarctic transport and deposition,
- the interplay of trace gases and aerosols with solar and terrestrial radiation fluxes that occur on the polar plateau, and
- the development of polar stratospheric clouds over Antarctica.

Project scientists measure carbon dioxide, methane, carbon monoxide, stable isotopic ratios of carbon dioxide and methane, aerosols, halocarbons, and other trace constituents. Flask samples are collected and returned for analysis, while concurrent *in situ* measurements of carbon dioxide, nitrous oxide, selected halocarbons, aerosols, solar and terrestrial radiation, water vapor, surface and stratospheric ozone, wind, pressure, air and snow temperatures, and atmospheric moisture are made. Air samples are also collected at Palmer Station.

These measurements allow us to determine the rates at which concentrations of these atmospheric constituents change; they also point to likely sources, sinks, and budgets. We collaborate with climate modelers and diagnosticians to explore how the rates of change for these parameters affect climate. (O–257–S; NSF/NOAA agreement)

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The Drake Passage High-Density XBT/XCTD Program.

Janet Sprintall, Scripps Institution of Oceanography, University of California–San Diego.

We will study the seasonal to interannual variability and long-term change in upper-ocean temperature and geostrophic transport in the Drake Passage by means of high-density sections obtained on each crossing of the research ship *Laurence M. Gould*. Closely spaced temperature and salinity measurements are currently collected on six to eight crossings a year during which scientific shipboard personnel launch expendable bathythermographs (XBTs), supplemented by expendable conductivity-temperature-depth (XCTD) probes.

The information we gather from these studies will lead to the establishment of a high-quality database with which to study the magnitude and depth of penetration of seasonal signals, the connections to atmospheric forcing, and the effects of interannual variations such as those associated with the Antarctic Circumpolar Wave. These sections will supplement the approximately 20 sections obtained since September 1996. Continuing data analysis is carried out in cooperation with the Argentine Antarctic Institute in Buenos Aires. (O–260–L; NSF/OPP 00–03618)

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Collection of atmospheric air for the NOAA/CMDL worldwide flask-sampling network.

David Hofmann, Climate Monitoring and Diagnostics Laboratory, National Oceanic and Atmospheric Administration.

The National Oceanic and Atmospheric Administration has been conducting studies to determine and assess the long-term buildup of trace atmospheric constituents that influence climate change and the ozone layer. Time-series analyses of long-term data provide insight into several phenomena of particular interest, including:

- seasonal and temporal variations in greenhouse gases,
- the depletion of stratospheric ozone,
- transantarctic transport and deposition,
- the interplay of trace gases and aerosols with solar and terrestrial radiation fluxes that occur on the polar plateau, and
- the development of polar stratospheric clouds over Antarctica.

Personnel at Palmer Station collect air samples to be analyzed for carbon dioxide, methane, carbon monoxide, and stable isotopic ratios of carbon dioxide and methane. Flasks are also collected for analysis of halocarbons, nitrous oxide, and other trace constituents.

These measurements allow us to determine the rates at which concentrations of these atmospheric constituents change; they also point to likely sources, sinks, and budgets. We collaborate with climate modelers and diagnosticians to explore how the rates of change for these parameters affect climate. (O–264–P; NSF/NOAA agreement)

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Tracers of biological productivity and gas exchange.

Steven Emerson, University of Washington.

The export of carbon from the surface of the ocean is one of the processes controlling the atmospheric partial pressure of carbon dioxide (pCO_2), which greatly influences the Earth's climate. Changes in atmospheric pCO_2 over glacial time scales are often interpreted as a response to changes in the ocean's biological carbon pump. Models of the pump are limited by our understanding of the mechanisms that control it in different areas of the ocean. Satellite color images hold great promise for determining the biological pump globally, but only if the images can be validated by field measurements. To date, this calibration has been achieved in only four places in the ocean: the long-term time series locations and parts of the Equator.

Our goal, therefore, is to develop experimental methods of improving our knowledge of the ocean's biological carbon pump. We will use an upper-ocean oxygen mass balance method to determine the biologically produced flux of organic carbon from the euphotic zone of the ocean. In previous research, we approached the problem by measuring a suite of gases at a Hawaii site and by *in situ* measurements on a mooring.

We will build on these studies to improve methods for determining net biological oxygen production so that they can be used in different areas of the ocean. We will also build on our analytic ability to determine nitrogen, argon, and neon in sea water to characterize physical mechanisms like bubble processes that influence the flux and saturation state of oxygen in the upper ocean. Accurate measurements and a simple model can be used to determine the fraction of gas supersaturation caused by bubble processes in surface waters. We will measure this value as a function of wind speed on several short cruises in the Drake Passage.

By developing a correlation between bubble flux and wind speed, we will be able characterize the bubble process in locations where it is not possible to measure gases

and to improve estimates of the biologically produced oxygen flux from the ocean by using climatological surface ocean oxygen concentrations. Understanding the marine biological pump well enough to incorporate it into ocean-atmosphere models will greatly enhance the ability to predict climate. (O–271–L; OCE 02–42139)

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Operation of an aerosol sampling system at Palmer Station.

Colin G. Sanderson, U.S. Department of Energy, Environmental Measurements Laboratory.

Radionuclides, some of which occur naturally in the surface air, are atoms emitting radioactive energy. It is these, as well as nuclear fallout and any accidental releases of radioactivity, that the Environmental Measurements Laboratory's (EML's) Remote Atmospheric Measurements Program (RAMP) is designed to detect and monitor.

Since 1963, EML, which is part of the U.S. Department of Energy, has run the Global Sampling Network to monitor surface air. The RAMP system provides on-site analysis in 13 different locations around the world, including Palmer Station. Using a high-volume aerosol sampler installed in 1990, a gamma ray spectrometer, and a link to the National Oceanic and Atmospheric Administration's ARGOS satellite system, we will continue to sample the air at Palmer Station for anthropogenic radionuclides. Our data are analyzed and archived at EML and contribute significantly to its database on radionuclides. (O–275–P; NSF/DOE agreement)

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Antarctic automatic weather station program: 2004–2007.

Charles R. Stearns and George A. Weidner, University of Wisconsin–Madison.

A network of nearly 50 automatic weather stations (AWS) has been established on the antarctic continent and several surrounding islands. These facilities were built to measure surface wind, pressure, temperature, and humidity. Some of them also track other atmospheric variables, such as snow accumulation and incident solar radiation.

The data they collect are transmitted via satellite to a number of ground stations and put to several uses, including operational weather forecasting, accumulation of climatological records, general research, and specific support of the U.S. Antarctic Program, especially the Long-Term Ecological Research Program at McMurdo and Palmer Stations. The AWS network has grown from a small-scale program in 1980 into a significant, extremely reliable data retrieval system that has proven indispensable for both forecasting and research. This project maintains and augments the AWS as necessary. (O–283–M; NSF/OPP 03–38147)

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Solar/wind-powered instrumentation module development for polar environmental research.

Anthony D. Hansen, Magee Scientific Company.

We will develop and test a self-contained, transportable module that will provide a sheltered, temperature-controlled interior environment for standard, rack-mounted equipment. Electric power will be provided by solar panels and a wind generator, backed up by batteries with several days' capacity. The module will offer both alternating and direct current for internal and external use and will include data logging and communications capability for practical application in a polar environment.

At South Pole Station, McMurdo Station, and almost all other inhabited camps in Antarctica, aircraft, helicopters, ground vehicles, diesel generators, and other sources release exhaust, which can affect the environment. The collection of real-time pollution data at downwind locations can be used to assess the amount of pollution and the

effectiveness of efforts to improve air quality. At this time, optimal placement of measuring instruments is severely limited by the availability of power and shelter, a limitation that this module is intended to overcome.

Although designed to facilitate measurements at the South Pole, the module will be helpful in a variety of other situations where remotely located equipment is to be used for long-term monitoring of environmental phenomena. The module will have no emissions at all and therefore will not affect the environment that it is designed to study. Also, it can be placed anywhere it is needed. (O–314–M; NSF/DBI 01–19793)

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Southern Ocean current observations and acoustic Doppler current profiling from U.S. antarctic research vessels.

Eric Firing, University of Hawaii–Manoa, and Teresa K. Chereskin, University of California–San Diego.

We will build on a successful 5-year collaboration that developed the capability to routinely acquire, process, and archive ocean current measurements from hull-mounted shipboard acoustic Doppler current profilers (ADCPs) on board the research ships *Nathaniel B. Palmer* and *Laurence M. Gould*. We will enhance the technical capabilities of the program through new software developments and hardware acquisition. Also, we will continue the collection and dissemination of a quality-controlled data set of upper-ocean current velocities and acoustic backscatter in the sparsely sampled and remote Southern Ocean, an area that plays an important role in the global ocean circulation. In addition, we will perform scientific analyses of upper-ocean current structure in Drake Passage.

One of our short-term objectives is to develop the ongoing data collection program so it can be maintained with a minimum of personnel and resources and so the observations become publicly available in a timely manner.

Our long-term objectives are to:

- measure the seasonal and interannual variability of upper-ocean currents in the Drake Passage,
- combine this information with similar temperature observations to study the variability in the heat exchange, and
- characterize the velocity and acoustic backscatter structure in the Southern Ocean on a variety of time and space scales.

With new dual-frequency ADCP capability gained through the acquisition and installation of 38 kilohertz (kHz) phased-array Doppler sonars, in addition to the existing 150 kHz ADCP capability, the maximum profiling range will increase to about 1,000 meters (m) under good sea and scattering conditions while maintaining higher vertical resolution in the upper 300 m. New software developments will improve the ability to measure currents while the ships are in ice. The collection, quality control, real-time processing, and dissemination of this high-quality data set allow these observations to be used to support ongoing antarctic science programs and make the data easily accessible for conducting retrospective analyses, planning future observations, and validating numerical models.

Finally, after the ship leaves dry dock, we will replace the current logging computer with a newer one and upgrade the acquisition and processing software to accommodate the new system. (O–315–N and O–317–L; NSF/OPP 03–37375 and NSF/OPP 03–38103)

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Physics and mechanics of the breakup of warm Antarctic Sea ice: *In situ* experiments and modeling.

John Dempsey, Clarkson University, and David Cole, U.S. Army Cold Regions Research and Engineering Laboratory.

We will investigate the breakup of antarctic sea ice in McMurdo Sound in light of recent findings indicating that the fracture strength of first-year ice is strongly dependent on size, that the deformation and fracture on the scale of tens of meters is influenced by microstructural variation (or anisotropy), and that the characteristic flaws of sea ice (such as brine drainage features) give rise to length scales relevant to transitions in fracture behavior.

We will investigate the following topics:

- coupled deformation-diffusion influences on the fracture of sea ice (due to fluid transport within the ice matrix),
- the influence of loading rate versus specimen size on fracture behavior,
- fractal descriptions of the failure surfaces, and
- a new cyclic loading geometry that should benefit the constitutive measurements.

The direct tensile cyclic loading geometry we will use will allow constitutive testing to be conducted independent of fracture testing and at significantly higher stress levels than were previously attained. We will make combined acoustic emission (AE), pore fluid pressure, crack-opening-displacement, and fracture surface roughness measurements for each test, thereby enabling quantitative comparison between deformation and AE-deduced fracture energy and the fractal dimension. The ability of sea water and brine to be transported within the ice matrix will be examined both theoretically and experimentally to formulate a suitable poroelastic fracture mechanics model.

Our findings will give important insight into the underlying mechanisms of ice breakup and will significantly improve the reliability of models of this process. In addition, our work will improve the understanding of and ability to model the deformation and fracture of antarctic sea ice at scales applicable to the breakup of ice sheets.

We will involve two graduate students, and every effort will be made to recruit them from underrepresented groups. These students will participate in Clarkson University's K–12 Project-Based Learning Partnership Program. CDs will be produced, and a Web page will be maintained to broaden the dissemination of research and educational material. Moreover, a different K–12 teacher will be invited for each of the three trips planned. (O–316–M; NSF/OPP 03–38226)

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GEOLOGY AND GEOPHYSICS

A helicopter lifts off the ice at Beardmore Camp in the Transantarctic Mountains. Although ski-equipped C-130 air transports are used to move scientists and their equipment to remote sites, USAP often uses helicopters to support local fieldwork from large field camps like Beardmore Camp. (*NSF/USAP photo by Kristan Hutchinson, Raytheon Polar Services Corp.*)

On this page:

Overview

Near the Beardmore Glacier in the Transantarctic Mountains, paleontologists and geologists set up a camp to study the rock in the surrounding hills and peaks. The research in 2003 unearthed new

Antarctica is not only one of the world's seven continents, it also comprises most of one of a dozen major crustal plates, accounting for about 9 percent of the Earth's continental (lithospheric) crust. Very little of this land is visible, however, covered as it is by the vast East Antarctic Ice Sheet and the smaller West Antarctic Ice Sheet. These ice sheets average some 3 kilometers deep and form a virtual vault; 90 percent of the ice on Earth is here. And it is heavy, depressing the crust beneath it some 600 meters (m). These physical characteristics, while not static, are current. Yet Antarctica is also a time machine, thanks to the sciences of geology and geophysics, powered by

modern instruments and informed by the paradigm of plate tectonics/continental drift.

dinosaur bones, ancient plants and other clues to what Antarctica was like hundreds of millions of years ago. (*NSF/USAP photo by Kristan Hutchinson, Raytheon Polar Services Corp.*)

Geologists have found evidence that there was once a forested supercontinent, which they call Gondwanaland, in the Southern Hemisphere. Before the Earth's constantly shifting plate movement began to break the continent up 150 million years ago, Antarctica was a core piece of this assembly; the land adjoining it has since become Africa, Madagascar, India, Australia, and South America. Though the antarctic plate has drifted south only about a centimeter a year, geologic time eventually yields cataclysmic results. The journey moved the antarctic plate into ever-colder, high-latitude climates, at a rate of about 4°C for each million years; eventually conditions changed dramatically, and Antarctica arrived at a near-polar position. This astounding story—written in the language of rock and fossils—is locked in beneath the ice and the sea, and in the bedrock below both of them.

As the ice sheets developed, they assumed, through their interaction with oceanic and atmospheric circulation, what has become a key role in modulating global climate. As a bonus, the South Pole presents a strategic point to monitor the Earth's seismic activity. Antarctica is the highest continent on Earth (about 2,150 m above sea level), with its fair share of mountains and volcanoes; thus, many generic questions of interest to Earth scientists worldwide also apply to this region. Some specific issues of interest to the Antarctic Geology and Geophysics Program include the following:

- determining the tectonic evolution of Antarctica and its relationship to the evolution of the continents from Precambrian time (600 million years ago) to the present;
- determining Antarctica's crustal structure;
- determining how the dispersal of antarctic continental fragments may have affected the paleocirculation of the world's oceans, the evolution of life, and the global climate (from prehistoric times to the present);
- reconstructing a more detailed history of the ice sheets, identifying geologic controls to ice-sheet behavior, and defining geologic responses to the ice sheets on regional and global scales; and
- determining the evolution of sedimentary basins within the continent and along the continental margins.

These issues will all become clearer as scientists improve their models of where, when, and how crustal plate movement wrought Antarctica and its surrounding ocean basins. The Antarctic Geology and Geophysics Program funds investigations into the relationships between the geologic evolution of the antarctic plate and the life and processes that can be deduced to accompany it—the paleocirculation of the world's oceans, the paleoclimate of the Earth, and the evolution of high-latitude biota. A current emphasis is the West Antarctic Ice Sheet Program, focused on the smaller of the continent's two ice sheets and conducted jointly with the Glaciology Program. Several important research support activities are underway as well:

- **Meteorites:** In partnership with the National Aeronautics and Space Administration (www-curator.jsc.nasa.gov/curator/antmet/antmet.htm) and the Smithsonian Institution, the program supports meteorite collection through the antarctic search for meteorites (ANSMET) and chairs an interagency committee that is responsible for curating and distributing samples of antarctic meteorites.
- **Mapping and geodesy:** In partnership with the U.S. Geological Survey, the program supports mapping and geodetic activities as an investment in future research in earth sciences. The U.S. Antarctic Resources Center (USARC, http://usarc.usgs.gov/) constitutes the U.S. Antarctic Program's contribution to the Scientific Committee on Antarctic Research library system for earth sciences; housed here is the largest collection of antarctic aerial photographs in the world, as well as many maps, satellite images, and a storehouse of geodetic information.
- **Marine sediment and geological drill cores:** In partnership with the Antarctic Marine Geology Research Facility at Florida State University (www.arf.fsu.edu/), the program manages and disseminates marine sediment and geological drill cores mined in Antarctica. The collection includes an array of sediment cores as well as geologic drill cores from the Dry Valley Drilling Project, the Cenozoic Investigations of the Ross Sea Drilling Program, and the Cape Roberts Drilling Project. The facility fills requests for samples from researchers worldwide and also accommodates visiting researchers working onsite.

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Antarctic mapping, geodesy, geospatial data, satellite image mapping, and Antarctic Resource Center management.

Jerry L. Mullins, U.S. Geological Survey.

Antarctic mapping, geodesy, geospatial data, satellite image mapping, and the U.S. Antarctic Resource Center (USARC) constitute some of the activities necessary for the successful operation of a multifaceted scientific and exploratory effort in Antarctica. Year-round data acquisition, cataloging, and data dissemination will continue in the USARC in support of surveying and mapping. Field surveys are planned as part of a continuing program to collect the ground control data required to transform existing geodetic data into an Earth-centered system suitable for future satellite-mapping programs and to reinforce extant control of mapping programs to support future scientific programs. Landsat (Land Remote-Sensing Satellite) data will be collected as funding permits to support satellite image-mapping projects. These maps will provide a basis for displaying geologic and glaciologic data in a spatially accurate manner for analysis. They will also support future expeditions by providing a basis for planning scientific investigations and data collection. In addition, spatially referenced digital cartographic data will be produced from published maps.

Geodetic projects are planned as part of a continuing program aimed at building a continent-wide geodetic infrastructure (GIANT) that will support a wide range of U.S. and international scientific research objectives by:

- establishing and maintaining a framework of permanent geodetic observatories,
- extending and strengthening the existing network of stations linked to the International Terrestrial Reference Frame,
- establishing geodetic coordinates at identifiable points for georeferencing satellite image-mapping projects,
- maintaining and calibrating tide-gauge instrumentation,
- carrying out absolute gravity measurements,
- carrying out absolute gravity measurements,
- expanding the online geodetic database with new and historical data.

The geodetic field program is supported by a cooperative arrangement with Land Information New Zealand. (G–052–M/P/S; NSF/OPP 02–33246)

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Age, origin, and climatic significance of buried ice in the western Dry Valleys, Antarctica.

David R. Marchant, Boston University, and Joerg M. Schaefer, Lamont-Doherty Earth Observatory, Columbia University.

Buried ice deposits represent a potentially far-reaching archive of atmosphere and climate on Earth extending back many millions of years. These deposits are terrestrial analogs to widespread and young buried ice on the Martian surface as identified by recent data from Mars Odyssey. Just as earlier researchers asked whether a climate record was stored in the modern ice sheets of Antarctica and Greenland, we now ask whether ancient, debris-covered glaciers in the western Dry Valleys hold similar records of temperature and atmospheric change, but on time scales that are perhaps an order of magnitude greater than those for the deepest existing ice core.

The ice to be examined is over a million years old, making it by far the oldest ice yet known on Earth. An alternative view is that this buried ice is more recent segregation ice from the *in situ* freezing of groundwater. Distinguishing between these hypotheses is key to understanding Neogene climate change in Antarctica.

Our research is aimed at:

- better understanding the surface processes that permit ice preservation,
- testing the efficacy of cosmogenic and argon analyses in dating tills above buried ice,
- further assessing the use of cosmogenic-nuclide analyses and argon analyses of ashfall deposits to date buried ice, and
- using these data to help resolve the debate between the young and old ice scenarios noted earlier.

We will analyze a minimum of six cosmogenic-depth profiles to determine if and how cryoturbation reworks sublimation tills and assess the average rate of sublimation for three glaciers. We will use finite-element analyses to model at least three buried glaciers and compare the flow rates with those based on radiometric dating of surface deposits. We will also collect 10 ice cores.

Better understanding of surface processes above buried ice on Earth will permit researchers to gain access to a record of atmospheric and climate change that could well cover intervals that predate Quaternary time. Since the conditions in the Dry Valleys are analogous to those found on Mars, extending the results could bring valuable insight into the potential for life on Mars. (G–054–M; NSF/OPP 03–38291)

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Magmatism in the Dry Valleys: A workshop.

Bruce D. Marsh, Johns Hopkins University.

The most challenging aspect of understanding magmatism is that so little of the integrated nature of the full cycle can be directly examined in any realistic context. Planetary magmatism is a multifaceted process involving a spectrum of interleaved chemical and physical processes responsible for the chemical transformation of the initial primitive magma into the final product. Each essential component can be found well exposed somewhere on Earth, and each has been studied for nearly a century, but finding and studying any reasonable example of the entire process in a fully integrated context has proven singularly elusive.

The Ferrar dolerites of the McMurdo Dry Valleys exhibit in exquisite exposures the three-dimensional structural evolution of an extensive magmatic system that formed 180 million years ago. This system contains, on a manageable scale, all the essential features of major magmatic systems, which are seen only piecemeal elsewhere in the world. Because this unusual area is so inaccessible, we will hold a 2-week field workshop to introduce 20 to 25 researchers to the wonders of the McMurdo Dry Valleys, to stimulate cutting-edge research, and to delineate the unsolved problems posed by this magmatic system. This working conference will have discussions and laboratory work at McMurdo Station and fieldwork in the Dry Valleys.

Four magmatic processes will be considered:

- magma transport and differentiation in a mush column (East Bull Pass),
- crystal transport and sorting in ponding magma (East Dais),
- solidification front instability in sills (Pandora Spire/Solitary Rocks), and
- mechanics of sill emplacement (Victoria Valley and East Wright Valley).

To have the widest possible impact, participants will be researchers working on other parts of the Ferrar system, senior researchers studying layered intrusions and basaltic sills worldwide, young researchers studying magmatic processes, researchers studying ocean ridge magma chambers and melt sheets, and graduate students in igneous petrology. Undergraduates may also be involved. The workshop is intended to help enunciate a specific fundamental theme common to all magmatic processes, to understand the regional dynamics of the Ferrar-Transantarctic magmatic province, and to stimulate scientists to new horizons through exposure to a singular field area. (G–056–M; NSF/OPP 02–29306)

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The antarctic search for meteorites (ANSMET).

Ralph P. Harvey, Case Western Reserve University.

Since 1976, ANSMET (the antarctic search for meteorites program) has recovered more than 14,000 meteorite specimens from locations along the Transantarctic Mountains. Antarctica is the world's premier meteorite hunting ground for two reasons:

- First, although meteorites fall at random all over the globe, the likelihood of finding one is enhanced if the background material is plain and the accumulation rate of terrestrial sediment is low; this makes the East Antarctic Ice Sheet the perfect medium.
- Second, along the margins of the sheet, iceflow is sometimes blocked by mountains, nunataks, and other obstructions; this exposes slow-moving or stagnant ice to the fierce katabatic winds, which can deflate the ice surface and expose a lag deposit of meteorites (a representative portion of those that were sprinkled throughout the volume of ice lost to the wind). When such a process continues for millennia, a spectacular concentration of meteorites can be unveiled.

The continued recovery of antarctic meteorites is of great value because they are the only currently available source of new, nonmicroscopic extraterrestrial material. As such, they provide essential "ground truth" about the composition of asteroids, planets, and other bodies of our solar system. ANSMET recovers samples from the asteroids, the Moon, and Mars for a tiny fraction of the cost of returning samples directly from these bodies.

During the 2004–2005 field season, ANSMET's main field party (eight people) will work at the LaPaz icefields, approximately 250 miles from Amundsen–Scott South Pole Station. More than 1,000 meteorites were recovered from the site during visits in 1991, 2002, and 2003. This year's field team will continue systematic searches of the icefields in an effort to recover a representative sample of the extraterrestrial material falling to Earth.

A second team consisting of four people will conduct high-level reconnaissance at a number of icefields throughout the midrange of the Transantarctic Mountains. The team has three goals:

- to search for new meteorite stranding surfaces,
- to fully explore the potential of poorly known meteorite sites, and
- to wrap up collection efforts at sites where a full season by a large team is logistically not practical.

The team will visit poorly known or previously unvisited icefields, recovering meteorites and identifying their potential for more detailed searches during future seasons. In general, the team will move from south to north, starting near Zaneveld Glacier and ending near Buckley Island, with varying lengths of stay at key sites and constant re-evaluation of priorities depending on the density of meteorite finds, icefield conditions, and logistical needs.

The team will generally move between target sites and camps by plane. On a few occasions, the team will use a "flying traverse," where the plane ferries the gear while the team travels by snowmobile. This style of traverse works well for targets that are linked by a safe route and are relatively close together (> 30 kilometers). The field team will also be able to traverse such routes in emergencies. (G–058–M; NSF/OPP 99–80452)

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Evolution and biogeography of Late Cretaceous vertebrates from the James Ross Basin, Antarctic Peninsula.

Judd A. Case, Saint Mary's College of California, and James E. Martin, South Dakota School of Mines and Technology.

The Campanian through the Maastrichtian Ages (80 to 65 million years ago) are important in the history of vertebrate biogeography (dispersals and separations due to moving landmasses) and evolution between Antarctica and the rest of the Southern Hemisphere. Moreover, unresolved questions in paleontology relate to the dispersal of terrestrial vertebrates such as dinosaurs and marsupial mammals from North America to Antarctica and beyond to Australia via Patagonia and the Antarctic Peninsula, as well as the dispersal of modern birds from Antarctica northward. Dispersals include vertebrates in marine settings as well. Both widely distributed and localized marine reptile species have been identified in Antarctica, creating questions about their dispersal in conjunction with terrestrial animals.

The Weddellian Paleobiogeographic Province extends from Patagonia through the Antarctic Peninsula and western Antarctica to Australia and New Zealand. Within this province lie the dispersal routes for interchanges of vertebrates between South America and Madagascar and India, and also Australia. On the basis of our previous work, we theorize that an isthmus between more northern South America and the Antarctic craton brought typical North American dinosaurs, such as hadrosaurs (duck-billed dinosaurs), and presumably marsupials traveling overland and marine reptiles swimming along coastal waters to Antarctica in the late Cretaceous. This region also served as the cradle for the evolution, if not the origin, of groups of modern birds and the evolution of typical Southern Hemisphere plants.

To confirm and expand on these hypotheses, we will continue our investigations into late Cretaceous marine and terrestrial deposits in the James Ross Basin. We have previously recovered the following vertebrates from these sedimentary deposits: plesiosaur and mosasaur marine reptiles; plant-eating dinosaurs; a meat-eating dinosaur; and a variety of modern bird groups, including shorebirds, wading birds, and lagoonal birds. Moreover, we recently discovered the bones of what we believe to be an entirely new species of carnivorous dinosaur—one related to tyrannosaurs and velociraptors. These animals evidently survived in the Antarctic, which then had a climate similar to that of the Pacific Northwest, long after they had been succeeded by other predators elsewhere.

Our research will result in important insights into the evolution and geographic dispersal of several vertebrate species. We will collaborate with scientists from the Instituto Antártico Argentino and with vertebrate paleontologists from the Museo de La Plata, both in the field and at our respective institutions in Argentina and the United States. (G–061–E; NSF/OPP 00–03844 and NSF/OPP 00–87972)

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Collection of marine geophysical data on transits of the *Nathaniel B. Palmer*.

Joann M. Stock, California Institute of Technology, and Steven C. Cande, Scripps Institution of Oceanography, University of California–San Diego.

Well-constrained plate reconstructions of the antarctic region are critical for examining a number of problems of global geophysical importance. During this 3-year project, we will address questions about the motion history of the antarctic and other plates and improve plate reconstructions by surveying gravity, magnetics, and swath bathymetry on three selected transit cruises by the U.S. research icebreaker *Nathaniel B. Palmer*.

In July and August 2004 during a transit (cruise NBP 04–06) from Capetown, South Africa, to Auckland, New Zealand, we will survey in the Indian Ocean and the Tasman Sea several major features of the Africa and Australia plates that relate to their history of spreading away from the Antarctic Plate. These include fracture zones, part of the Broken Ridge and Diamantina fracture zones southeast of Australia, and Cenozoic magnetic anomalies formed by the spreading of the Capricorn and Australia plates away from Antarctica.

During January and February 2005 during the transit from McMurdo Station to Punta Arenas, Chile (cruise NBP 05–01), project team members will survey several major features of the Antarctic Plate, including fracture zones, the fossil spreading system in the Adare Basin, and Cenozoic magnetic anomalies formed by the spreading of the Australia Plate away from West Antarctica.

These data will be used in combination with GPS-navigated data from the Pitman fracture zone, at the southwestern end of the plate boundary, and magnetic anomalies from previous cruises near the Menard Fracture Zone to improve high-precision plate reconstructions and evaluate the limits of possible internal deformation of the Pacific and

antarctic plates in this sector.

Our results will contribute to knowledge of plate kinematics and dynamics, and lithospheric rheology. Moreover, we will integrate research and education by teaching 2 on-board marine geophysics classes to a total of 30 graduate and undergraduate students (some of them minorities). Classes will consist of daily lectures about the instruments and the data they record. In addition, each student will spend several hours a day standing watch and processing data and will also work on an individual independent research project. (G–071–N; NSF/OPP 03–38317 and NSF/OPP 03–38346)

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Stability of landscapes and ice sheets in the Dry Valleys, Antarctica: A systematic study of exposure ages of soils and surface deposits.

Jaakko Putkonen, University of Washington.

The near-perfect preservation of ancient, *in situ* volcanic ash and overlying sediments suggests that hyperarid cold conditions have prevailed in the McMurdo Dry Valleys for over 10 million years. The survival of these sediments also suggests that warm-based ice has not entered the valley system and that ice sheet expansion has been minimal. However, other evidence suggests that the Dry Valleys have experienced considerably more sediment erosion than is generally believed:

- The cosmogenic exposure ages of boulders and bedrock all show generally younger ages than volcanic ash deposits used to determine the minimum ages of moraines and drifts.
- There appears to be a discrepancy between the suggested extreme preservation of unconsolidated slope deposits (more than 10 million years) and adjacent bedrock that has eroded 2.6 to 6 meters during the same interval.

The fact that till and moraine exposure ages generally postdate the overlying volcanic ash deposits (a clear contradiction) could reflect expansion of the continental ice sheet into the Dry Valleys with cold-based ice, thus both preserving the landscape and shielding the surfaces from cosmic radiation. Another plausible explanation of the young cosmogenic exposure ages is erosion of the sediments and gradual exhumation of formerly buried boulders.

We will measure the accumulation of multiple cosmogenic isotopes in rock and sediment profiles to determine the minimum exposure ages, degree of soil stability or mixing, and shielding history of surfaces by cold-based ice to obtain unambiguous minimum ages for deposits. In addition, we should be able to identify areas disturbed by periglacial activity, constrain the timing of such activity, and account for the patchy preservation of important stratigraphic markers such as volcanic ash.

In a complex landscape such as the McMurdo Dry Valleys, individual exposure analyses will seldom give unambiguous ages for the surfaces. By contrast, our approach of looking at vertical profiles and multiple isotopes at a few sites will be considerably more informative. The result will be a better understanding of the stability of the East Antarctic Ice Sheet, which could fundamentally change how we view the dynamics of Southern Hemisphere climate on time scales of millions of years. (G–076–M; NSF/OPP 03–38224)

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Dry Valley Seismic Project.

Robert C. Kemerait, U.S. Air Force Technical Applications Center.

One recurrent issue in seismography is noise: that is, background phenomena that can interfere with clear and precise readings. The Dry Valley Seismic Project, a cooperative undertaking with the New Zealand Antarctic Program, was established to record broadband, high-dynamic-range, digital seismic data from the remote Wright Valley, a site removed from the environmental and anthropogenic noise that is ubiquitous on Ross Island.

The Wright Valley site provides one of the few locations on the continent with direct access to bedrock. The station there consists of a triaxial broadband borehole seismometer [100 meters (m) deep] and a vertical short-period instrument at 30 m. The seismological data are digitized at the remote location, telemetered by repeaters on Mount Newall and Crater Hill, and received eventually by the recording computer at the Hatherton Laboratory at Scott Base, where a backup archive is created.

From Hatherton, they pass along a point-to-point protocol link to the Internet at McMurdo Station and thence to the Albuquerque Seismological Laboratory for general distribution to the international seismological community. This data set has beautifully complemented the data from other seismic stations operated by the Albuquerque Seismological Laboratory at Amundsen–Scott South Pole Station, Palmer Station, and Casey, an Australian base. (G–078–M; NSF/OPP–DoD MOA)

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Transantarctic Mountains Deformation Network: Global positioning system (GPS) measurements of neotectonic motion in the antarctic interior.

Terry J. Wilson and Dorota Brzezinska, Ohio State University, and Larry D. Hothem, U.S. Geological Survey–Denver.

We will conduct global positioning system (GPS) measurements of bedrock crustal motions in an extension of the Transantarctic Mountains Deformation Network (TAMDEF) to document neotectonic displacements caused by tectonic deformation within the West Antarctic Rift or mass changes in the antarctic ice sheets. By monitoring the U.S. and Italian networks of bedrock GPS stations along the Transantarctic Mountains and on offshore islands in the Ross Sea, we will tightly constrain horizontal displacements related to active neotectonic rifting, strike-slip translations, and volcanism. We will use GPS-derived crustal motions, together with information from other programs on the ice sheets and from ongoing structural and seismic investigations in Victoria Land, to model glacio-isostatic adjustments due to deglaciation and to modern mass changes in the ice sheets. The integrative and iterative nature of this modeling will yield a holistic interpretation of neotectonics and ice sheet history that will help us discriminate tectonic crustal displacements from viscoelastic/elastic glacio-isostatic motions.

We will do repeat surveys of key sites southward about 250 kilometers along the Transantarctic Mountains. These measurements will cross gradients in predicted vertical motion due to viscoelastic rebound. The southward extension will also allow us to determine the southern limit of the active Terror Rift and provide a better baseline for constraints on any ongoing tectonic displacements across the West Antarctic Rift system as a whole. Further, we will investigate unique aspects of GPS geodesy in Antarctica to determine how the error spectrum compares with that found in mid-latitude regions and to identify optimum measurement and data processing methods. The geodetic research will improve position accuracies within our network and will also yield general recommendations for other deformation-monitoring networks in polar regions.

An education and outreach program targeted at Ohio State University undergraduates who are not science majors will illuminate the research process for nonscientists. This effort will educate students about science and inform them about Antarctica and how it relates to global science issues. (G–079–M; NSF/OPP 02–30285 and NSF/OPP 02–30356)

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Mount Erebus Volcano Observatory and Laboratory (MEVOL).

Philip R. Kyle and Richard C. Aster, New Mexico Institute of Mining and Technology.

Mount Erebus, Antarctica's most active volcano, is a rare example of a persistently active magmatic system. This volcano, which has a history of low-level eruptive activity associated with a highly accessible summit vent complex, also features one of Earth's few long-lived lava lakes. We are developing an interdisciplinary geophysics/geochemistry laboratory on Mount Erebus to pursue basic research on the eruption physics and associated magmatic recharge of active volcanoes. Erebus is especially appropriate because of its persistent open-conduit magmatic system, frequent

eruptions, ease of access (by antarctic standards), and established scientific and logistical infrastructure, including real-time data links and relative safety.

The key integrated data-gathering components we will rely on include video surveillance and seismic, infrasound, Doppler radar, infrared, volcanic gas, and geodetic studies. To collect the data, a combination of core Mount Erebus Volcano Observatory and Laboratory (MEVOL)-supported personnel and their students (with specialties in seismology, gas studies, and general volcanology) will collaborate with internationally recognized volcano researchers (with specialties in infrared, Doppler radar, gas studies, and infrasound).

We will then develop quantitative models of the magmatic system of an active volcano, including eruptive energy balance (gravity; explosive gas decompression; and thermal, seismic, acoustic, and kinetic components) and magma recharge (volcanic tremor, convection, residence time, gas emissions, and deformation). We expect this research to contribute substantially to basic knowledge of active volcanoes around the world.

Another part of our work involves a project to develop and deploy integrated low-power, low-cost, real-time-telemetered volcano monitoring stations at Erebus and other active volcanoes. (Many volcanoes, particularly in the developing world, have little or no modern instrumentation.) The goal is to contribute to the development of low-power, low-cost interdisciplinary geophysical observatories within the larger seismology, geodesy, and geophysical communities.

Our work also includes the education of graduate and undergraduate students in volcanology and geophysics, the dissemination of information to high school audiences, and the provision of year-round monitoring information to the National Science Foundation and to McMurdo Station. Finally, to convey the excitement and relevance of volcanology and other aspects of earth science to society, we expect to continue public outreach through lectures, media interaction, and inquiry response. (G–081–M; NSF/OPP 02–29305)

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SHALDRIL, a demonstration drilling cruise to the James Ross Basin.

John B. Anderson, Rice University; Patricia Manley, Middlebury College; and Sherwood W. Wise Jr., Florida State University.

For over three decades, U.S. scientists and their international colleagues exploring the shallow shelves and seas along the margins of Antarctica have been consistently frustrated by their inability to penetrate the overcompacted glacial diamictons encountered at shallow subbottom depths (within the upper 10 meters) over these terrains. This has been particularly frustrating because advanced high-resolution seismic reflection techniques clearly show the presence of older successions of Neogene and even Paleogene sequences lying just beneath this thin veneer of diamictons in many areas. Until the means to recover these sequences are developed, a detailed history of the antarctic ice sheets—an essential prerequisite to understanding Cenozoic paleoclimates and future climate change on a global scale—will remain an elusive and unobtainable goal.

A group of U.S. scientists called the SHALDRIL Committee has identified at least two diamond coring systems deemed suitable for use on existing U.S. Antarctic Research Program ships. We will use one of these systems on the research icebreaker *Nathaniel B. Palmer* to demonstrate the feasibility of both ship-based diamond coring and downhole logging. We will core along a high-resolution seismic reflection dip line off Seymour Island, Antarctic Peninsula, an area of high scientific interest in its own right. Here the well-defined geologic section is estimated to range from Eocene to Quaternary in age, effectively spanning the "greenhouse-icehouse" transition in the evolution of antarctic/global climate. A complete record of this transition has yet to be obtained from anywhere along the antarctic margin.

We will correlate the record we obtain with detailed fluctuations of the ice margin recently recorded at higher latitudes in the eastern Ross Sea. If successful, SHALDRIL will be able to further explore the gap in our technical capability to explore the antarctic shelves between the shoreline/fast-ice margin and the continental slope. This technological breakthrough will not only address major outstanding scientific issues of the past three decades, but will also favorably affect many other current antarctic or drilling-related initiatives. (G–083–N; NSF/OPP 01–25922, NSF/OPP 01–25480, and

NSF/OPP 01–25526)

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Global seismograph station at South Pole.

Rhett G. Butler, Incorporated Research Institutions for Seismology.

Seismology, perhaps as much as any other science, is a global enterprise. Seismic waves resulting from earthquakes and other events can be interpreted only through simultaneous measurements at strategic points all over the planet. The measurement and analysis of these seismic waves are not only fundamental for the study of earthquakes, but they also serve as the primary data source for the study of the Earth's interior. To help establish the facilities required for this crucial scientific mission, IRIS (the Incorporated Research Institutions for Seismology) was created in 1985.

IRIS is a consortium of universities with research and educational programs in seismology. Ninety-seven universities are currently members, including nearly all U.S. universities that have seismological research programs. Since 1986, IRIS, through a cooperative agreement with the National Science Foundation (NSF) and in cooperation with the U.S. Geological Survey (USGS), has developed and installed the Global Seismographic Network (GSN), which now has about 137 broadband, digital, high-dynamic-range seismographic stations around the world; most of these have real-time communications.

The GSN seismic equipment at Amundsen–Scott South Pole Station and at Palmer Station was installed jointly by IRIS and USGS, which continue to jointly operate and maintain them. The GSN sites in Antarctica are vital to seismic studies of Antarctica and the Southern Hemisphere, and they contribute to the international monitoring system of the Comprehensive Test Ban Treaty. The state-of-the-art seismic instrumentation is an intrinsic component of the NSF effort to advance seismology and earth science globally.

In 2003, with the completion of the South Pole Remote Earth Science and Seismological Observation (SPRESSO) in the Quiet Sector, the GSN seismic instrumentation was moved to the SPRESSO site, 8 kilometers from the Pole, and deployed into 300-meter deep boreholes in the ice below the firn. The new GSN site, QSPA, achieves the quietest conditions on Earth at frequencies above 1 hertz. (G–090–P/S; NSF/EAR 00–04370)

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High-resolution seismic tomography and earthquake monitoring at Deception Island volcano, Antarctica.

William Sam Douglas Wilcock, University of Washington.

Deception Island volcano, located in Bransfield Strait, is an active, back-arc stratovolcano with a flooded caldera. All historical eruptions have occurred near the ring fracture and extended around the caldera. The three most recent, in 1967–1970, are unusual in that each involved simultaneous eruptions from multiple vents.

Although the volcano has not erupted for 30 years, it is still very active, but the size, distribution, and interconnectivity of subsurface magma bodies and their relationship to resurgence, the eruptions, and the distribution and style of faulting are poorly constrained. On the one hand, chemical differences between lavas would be best explained if the eruptions were fed by isolated shallow intrusive pods, but their synchronicity and distribution suggest that they may have been driven by an extensive magma body underlying the caldera. On the other hand, a recent model suggests that the caldera was formed by progressive passive extension rather than catastrophic collapse and implies that magma may be less widely distributed underneath.

Many experiments have monitored seismicity at Deception Island, but they have all been small and lacked seafloor stations. We will therefore deploy a joint marine-land seismic network around Deception Island for an antarctic summer to monitor seismicity and to conduct a high-resolution active-source tomography experiment. Our goals are to understand:

- the distribution of magma and its relationship to recent volcanic activity,
- the resurgence in the northeastern portion of the caldera, and
- the distribution of faulting and the state of stress and its relationship to volcanic and tectonic processes.

We will collaborate with a Spanish group and join cruises on the Spanish research ships *Hespérides* and *Las Palmas*. We will contribute 14 short-period, 3-component ocean bottom seismometers (OBSs) for the 10-week deployment of an earthquake network comprising these OBSs and about 10 land stations; some of these will include both short-period and broadband seismometers. This will be followed by the active source experiment using the airgun array on the *Hespérides* to shoot to a very dense land network and to the OBS sites. The P-wave tomographic image of the volcano we obtain will clarify the relationship between the seismic structure, the distribution and nature of earthquakes, and volcanic processes at Deception Island volcano. (G–135–E; NSF/OPP 02–30094)

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University NAVSTAR Consortium (UNAVCO) global positioning system survey support.

Bjorn Johns, UNAVCO.

UNAVCO is a nonprofit, membership-governed consortium funded through the National Science Foundation and the National Aeronautics and Space Administration (NASA) to support and promote high-precision measurement techniques for the advancement of earth sciences. UNAVCO provides complete support for permanent stations, surveying, mapping, and other applications of the Global Positioning System (GPS) to U.S. Antarctic Program investigators and maintains a satellite facility with a full range of geodetic GPS equipment and support services at McMurdo Station during the austral summer research season.

A large pool of high-precision GPS receivers and associated equipment is provided for short-term surveys through multiyear data collection in Antarctica. Regular equipment upgrades ensure a steady influx of modern equipment, including:

- state-of-the-art dual-frequency GPS receivers,
- power and communication systems for remote locations,
- GPS monument and antenna mount options, and
- accessories for kinematic and real-time kinematic (RTK) surveys.

UNAVCO staff provides year-round support to help ensure the success of field projects and subsequent data management. The level of support is scalable and includes:

- survey planning,
- field survey and data processing training,
- custom engineering solutions,
- system integration,
- field assistance,
- GPS station maintenance, and
- data retrieval, flow monitoring, processing, and archiving.

UNAVCO also operates a community RTK GPS base station that covers McMurdo Station and provides maintenance support to the NASA GPS Global Network station MCM4 at Arrival Heights. (G–295–M; NSF/EAR 03–21760)

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GLACIOLOGY

Icebergs near the Antarctic Peninsula. (*NSF/USAP photo by Jeffrey Kietzmann, Raytheon Polar Service Corp.*)

On this page:

Overview

A science team loads equipment on to a ski-equipped C-130 air transport (LC-130). USAP's LC-130 airplanes, flown by the Air National Guard of Schenectady, New York, support remote field research throughout Antarctica and provide essential support to Amundsen-Scott South Pole Station. (*NSF/USAP photo.*)

Ice is indisputably the defining characteristic of Antarctica. The entire continent (with a few exceptions such as the McMurdo Dry Valleys and some lakes and mountains) is covered by ice sheets that have been laid down over eons, if the term "sheets" can be used to describe a dynamic mass that is several thousand meters (m) thick, that is larger than most countries, that rises over 2,000 m above sea level (and peaks in an ice dome nearly twice that high in the east), and that is heavy enough to depress the bedrock beneath it some 600 m. Actually, the continent has two distinctly different sheets: the much larger East Antarctic Ice Sheet, which covers the bedrock core of the continent, and the smaller, marine-based West Antarctic Ice Sheet, which is beyond the Transantarctic Mountains and overlays a group of islands and waters.

The Antarctic Glaciology Program is concerned with the history and dynamics of the

antarctic ice sheets; this includes research on near-surface snow and firn, floating glacier ice (ice shelves), glaciers, ice streams, and continental and marine ice sheets. These species of ice facilitate studies on ice dynamics, paleoenvironments (deduced from ice cores), numerical modeling, glacial geology, and remote sensing. Current program objectives include the following:

- correlating antarctic climatic fluctuations (from ice-core analysis) with data from arctic and lower-latitude ice cores;
- integrating the ice record with terrestrial and marine records;
- investigating the physics of fast glacier flow with emphasis on processes at glacier beds;
- investigating ice-shelf stability; and
- identifying and quantifying the relationship between ice dynamics and climate change.

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Mechanics of dry-land calving of ice cliffs.

Bernard Hallet and Erin Pettit, University of Washington, and Andrew G. Fountain, Portland State University.

We will perform a comprehensive study of land-based polar ice cliffs. Through field measurements and modeling, we will identify the physics underlying the formation of ice cliffs at the margin of Taylor Glacier in the McMurdo Dry Valleys.

Preliminary modeling suggests that horizontal velocity peaks one-third the distance up the cliff face and that the highest shear strain rates are at the base. We hypothesize that the displacement field of the glacier is more important than the local ablation pattern in maintaining ice cliffs and that the timing of calving is controlled by rapid temperature fluctuations that cause transient stress fields to develop in the thermal skin of the cliffs.

We will use a combination of strain gauges, tilt sensors, thermistors, and a global positioning system surface strain network to measure ice deformation and temperature near the cliff face at three sites. An ablation stake network will augment existing energy balance data, and a small seismic network will monitor local ice quakes associated with cracking and calving. Ultimately, the field data will be used to validate a model that will enable us to explore the sensitivity of ice cliff evolution to basal sliding rate, ice temperature, and angle of incident solar radiation. Finally, we will determine the slope, aspect, and height of ice cliffs using a model derived from a laser altimetry survey conducted by the National Aeronautics and Space Administration.

Our work will provide insight into calving and glacier terminus evolution and will shed light not only on other land- and water-based glacier termini on Earth, but also possibly on the Martian ice caps. Moreover, a better grasp of ice cliff processes will improve predictions of glaciers' response to climate change. A better understanding of moraine formation at polar ice cliffs will contribute to more precise interpretation of paleoglacier margins in the McMurdo Dry Valleys and their correlation with paleoclimatic events derived from the Taylor Dome ice core.

This research will have student involvement and will be incorporated into the curriculum of a wilderness science education program for high school girls, as well as several classroom science workshops for middle and high school girls in the Seattle area. (I–139–M; NSF/OPP 02–30338 and NSF/OPP 02–33823)

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Airborne geophysical survey of the Amundsen Sea embayment, Antarctica (AGASEA).

John W. Holt, David L. Morse, and Donald D. Blankenship, Institute for Geophysics, University of Texas-Austin.

The West Antarctic Ice Sheet, the only marine ice sheet remaining from the last glacial period, has been the subject of intensive study since it was recognized to be a potential

source for a rise in sea level of up to 5 meters, possibly on a short time scale. The West Antarctic Ice Sheet has three primary drainages; the Ross Sea and Weddell Sea embayments have been the primary focus of attention, while the Amundsen Sea embayment has been studied comparatively little, primarily because it is so remote. However, satellite remote-sensing studies, combined with limited data on ice thickness, indicate that the Amundsen Sea embayment discharges the largest ice flux in West Antarctica; furthermore, of all the major antarctic drainage basins, it is the only one to exhibit significant change in elevation over the period of recent satellite observations.

At present, we lack the knowledge of the ice thickness and subglacial boundary conditions needed to understand the evolution of this embayment or its sensitivity to climatic change. We therefore intend to perform comprehensive aerogeophysical surveys of the two major drainage basins within the Amundsen Sea embaymen t: the Thwaites Glacier Basin and the Pine Island Basin. We will analyze the data we gather and generate maps of laser surface elevation, radar surface elevation and ice thickness, ice accumulation rate from shallow radar layer interpolation, internal layer preservation depth, crevasse classification, gravity and magnetic anomalies, detailed basal morphology and roughness statistics, and coherent radar echo strength and scattering characterization.

Our surveys and analyses will be achieved through collaboration with the British Antarctic Survey and will include graduate students in all phases of the project. Undergraduates and high school apprentices will also be fully integrated into data analysis. Given the substantial public and scientific interest that recent reports of change in West Antarctica have generated, we expect fundamental research in the Amundsen Sea embayment to have a widespread impact. (I–141–M; NSF/OPP 02–30197)

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Late Quaternary history of Reedy Glacier.

John O. Stone and Howard B. Conway, University of Washington, and Brenda L. Hall, University of Maine.

The stability of the marine West Antarctic Ice Sheet remains an important, unresolved issue for predicting future changes in sea level. Studies indicate that the mass balance of the ice sheet today could be negative or positive. The apparent difference could stem in part from short-term fluctuations in flow. By comparison, geologic observations provide evidence of behavior over much longer time scales. Recent work suggests that deglaciation of both the Ross embayment and coastal Marie Byrd Land continued into the late Holocene (about the past 2,000 years) and leaves open the possibility of ongoing deglaciation and grounding-line retreat. However, previous work in the Ross embayment was based on data from just three locations that are all far north of the present grounding line. Additional data from farther south are needed to determine whether the recession has ended or whether the rate and pattern of deglaciation inferred from our previous study still apply.

We will therefore reconstruct the evolution of Reedy Glacier, in the southern Transantarctic Mountains, since the last glacial maximum. Because the glacier emerges from the mountains above the grounding line, its surface slope and elevation should record changes in the thickness of grounded ice in the Ross Sea up to the present. The deglaciation chronology of Reedy Glacier can thus indicate whether the Holocene retreat of the West Antarctic Ice Sheet ended thousands of years ago or is still continuing.

We will map, date, and correlate moraines at sites along the length of the glacier over two field seasons and make radar and global positioning system measurements to supplement existing ice thickness and velocity data. We will also construct a model of glacier dynamics and use it to relate geologic measurements to the grounding-line position downstream. Ultimately, we will integrate the mapping, dating, and ice-modeling components of the study into a reconstruction that defines changes in ice thickness in the southern Ross Sea since the last glacial maximum and relates these changes to the history of grounding-line retreat.

Our work directly addresses the key goals of the West Antarctic Ice Sheet Initiative, which are to understand the dynamics, recent history, and possible future behavior of the West Antarctic Ice Sheet. (I–175–M; NSF/OPP 02–29314 and NSF/OPP 02–29034)

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West Antarctic Ice Sheet stability: The glacial

geologic record from the Ohio Range of the Horlick Mountains in the Bottleneck.

Harold W. Borns, University of Maine, and Sujoy Mukhopadhyay, Harvard University.

We will study the West Antarctic Ice Sheet at the Ohio Range near the head of Mercer Ice Stream; this is located in the Bottleneck, a unique, relatively narrow passage in the Transantarctic Mountains connecting the West and East Antarctic Ice Sheets.

We will map glacial deposits and erosion features and combine these with cosmogenic surface-exposure dating on Ohio Range nunataks to determine the chronology of past ice sheet levels and glacier fluctuations. Exposure ages of fresh glacial erratics, up to 60 meters above the present level, will be used to constrain the timing of the last high stand and draw-down of the ice sheet in this sector, while exposure ages of debris bands on the surface will constrain the duration of continuous ice cover near the present elevation. A complementary local proxy climate record will also be obtained from a chronology of local glacier moraines.

These glaciers are sensitive to changes in snow accumulation and predominant wind direction. When compared with the record of the fluctuations of the adjacent ice sheet, the timing of alpine glacier advance will yield information that can be used to test climate reconstructions based on antarctic ice core records. Our data will contribute to the development of time-dependent, nonequilibrium models since the last glacial maximum 20,000 years ago. Moreover, such data are critical to testing and calibrating the models necessary to predict the behavior of the ice sheet in response to climate changes.

The behavior of this ice sheet is significant because of its link to sea levels. Melting would raise sea levels, negatively affecting the large portion of the population living near the coasts. Because the West Antarctic Ice Sheet is largely grounded below sea level, it is subject to gravitational collapse that could be ongoing or triggered by global warming.

In addition, the glacial record in the Bottleneck will reflect the history of the interaction of the West Antarctic and East Antarctic Ice Sheets, which could be used to test hypotheses on the collapse of the former during the Pleistocene (10,000 to 1.8 million years ago). (I–187–M; NSF/OPP 03–38189)

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Earth's largest icebergs.

Douglas R. MacAyeal, University of Chicago; Emile A. Okal, Northwestern University; and Charles R. Stearns, University of Wisconsin-Madison.

Icebergs released by the antarctic ice sheet represent the largest movements of fresh water within the natural environment. Several of these icebergs, B–15, C–19, and others calved since 2000, represent over 6,000 cubic kilometers of fresh water—an amount roughly equivalent to 100 years of the flow of the Nile River.

We will study the drift and breakup of the Earth's largest icebergs, which were recently released into the Ross Sea as a result of calving from the Ross Ice Shelf. We will attempt to ascertain the physics of iceberg motion within the dynamic context of ocean currents, winds, and sea ice, which determine the forces that drive iceberg motion, and the relationship between the iceberg and the geographically and topographically determined pinning points on which it can ground. In addition, we will study the processes by which icebergs influence the local environment (sea ice near Antarctica, access to penguin rookeries, air-sea heat exchange and upwelling at iceberg margins, nutrient fluxes), as well as the processes by which icebergs generate globally far-reaching ocean acoustic signals that are detected by seismic-sensing networks.

In addition, we will attempt to deploy automatic weather stations, seismometer arrays, and global positioning system tracking stations on several of the largest icebergs presently adrift, or about to be adrift, in the Ross Sea. Data generated and relayed via satellite to our home institutions will lead to theoretical analysis and computer simulation and will be archived on a Web site (http://amrc.ssec.wisc.edu/iceberg.html) that scientists and the general public can access.

A better understanding of the impact of iceberg drift on the environment, and particularly the impact on ocean stratification and mixing, is essential to understanding the abrupt

global climate changes witnessed by proxy during the Ice Age and future greenhouse warming. More specifically, the study will generate a knowledge base useful for the better management of antarctic logistical resources that can occasionally be influenced by the adverse effects icebergs have on sea ice (the shipping lanes to McMurdo Station, for example). (I–190–M; NSF/OPP 02–29546, NSF/OPP 02–29492, and NSF/OPP 02–30028)

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Dry Valleys Late Holocene climate variability.

Karl J. Kreutz and Paul A. Mayewski, University of Maine.

We will collect and develop high-resolution ice-core records from the Dry Valleys in southern Victoria Land and provide interpretations of interannual to decadal climate variability during the past 2,000 years (late Holocene). We will test hypotheses related to ocean/atmosphere teleconnections (e.g., El Niño Southern Oscillation, Antarctic Oscillation) that may be responsible for major late Holocene climate events such as the Little Ice Age in the Southern Hemisphere.

Conceptual and quantitative models of these processes in the Dry Valleys during the late Holocene are critical for understanding recent climate changes. We plan to collect intermediate-length ice cores (100 to 200 meters) at four sites along transects in Taylor and Wright Valleys and analyze each core at high resolution for stable isotopes, major ions, and trace elements. A suite of statistical techniques will be applied to the multivariate glaciochemical data set to identify chemical associations and to calibrate the time-series records with available instrument data.

Broader impacts of the project include:

- contributions to several ongoing interdisciplinary antarctic research programs;
- graduate and undergraduate student involvement in field, laboratory, and data interpretation activities;
- use of project data and ideas in several University of Maine courses and outreach activities; and
- data dissemination through peer-reviewed publications, University of Maine and other paleoclimate data archive Web sites, and presentations at national and international meetings. (I–191–M; NSF/OPP 02–28052)

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Tidal modulation of ice stream flow.

Sridhar Anandakrishnan, Richard B. Alley, and Donald Voigt, Pennsylvania State University; Robert Bindschadler, Goddard Space Flight Center, National Aeronautics and Space Administration; and Ian Joughlin, Jet Propulsion Laboratory, National Aeronautics and Space Administration.

We will investigate the newfound, startling sensitivity of major west antarctic ice streams to tidal oscillations to learn the extent and character of the effect and its ramifications. Ice streams D, C, and Whillans (B) all show strong but distinct tidal signals. The ice plain of Whillans is usually stopped outright, forward motion being limited to two brief periods a day, at high tide and on the falling tide. Motion propagates across the ice plain at seismic wave velocities. Near the mouth of D, tides cause a diurnal variation of about 50 percent in ice-stream speed that propagates upglacier more slowly than on Whillans, and seismic data show that C experiences even slower upglacier signal propagation. Tidal influences are observed more than 100 kilometers (km) upglacier on C and more than 40 km upglacier on D and may be responsible for fluctuations in basal water pressure reported 400 km upstream on Whillans.

During the first year, five coordinated seismic and global positioning system (GPS) instrument packages placed 100 km apart on each stream measured Whillans and ice stream D. These packages were deployed at sites selected by satellite imagery and operated autonomously for two lunar cycles to study the sensitivity of the streams to spring and neap tides. Also, we examined existing data sets for clues to the mechanisms involved and developed preliminary models.

During the second and third seasons, we will examine in greater detail the tidal behavior of Whillans and D. We will focus especially on at least one source area for Whillans, assuming that areas inferred from preliminary data remain active. Vertical motions have not yet been detected, but differential GPS will increase sensitivity. Seismic instrumentation will greatly increase temporal resolution and the ability to measure the propagation speed and any spatial heterogeneity.

Improved knowledge of ice-stream behavior will contribute to assessing the potential for rapid ice-sheet change affecting global sea levels. Results will be disseminated through scientific publications and talks at professional meetings, as well as contacts with the press, university classes, visits to schools and community groups, and other activities. (I–205–M; NSF/OPP 02–29629 and NSF/OPP 02–29659)

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Monitoring an active rift system at the front of Amery Ice Shelf, East Antarctica.

Helen A. Fricker and Jean-Bernard Minster, Scripps Institution of Oceanography, University of California–San Diego.

Antarctic ice sheets lose mass primarily by iceberg calving from the front of the fringing ice shelves. This mass contributes to the freshwater flux of the Southern Ocean, but does not cause a change in sea level, since the ice was already floating. However, ice shelves can influence the discharge of inland ice via the streams that feed them; in particular, a reduction in ice shelf could increase the discharge rate. Furthermore, any changes in the mass lost by calving could be an indicator of regional effects of climate change and could modify freshwater mass production rates, which might have global consequences. Therefore, it is important not only to monitor the frequency of calving, but also to understand the mechanisms behind it.

Icebergs calve when rifts—crevasses that penetrate from the ice shelf surface to its base—propagate far enough that a part of the shelf becomes detached. Because this process is not well understood, we will combine *in situ* and remote-sensing data with numerical modeling to study rift growth on the Amery Ice Shelf, an active rift system combining two longitudinal-to-flow rifts that originated at the ice shelf front in the suture zones between merging flowbands and two transverse-to-flow rifts that formed at the tip of the western longitudinal rift about 7 years ago. The propagation of the two transverse rifts is not independent, and the longest of them is growing at around 8 meters a day.

When this rift meets the eastern longitudinal rift, which we expect to occur in mid-2006, a huge iceberg will calve. Once it does, we will examine the effects on the dynamics of the ice shelf and on previously inactive rifts.

Iceberg calving has a history of sparking a great deal of media and public interest, especially since the recent large calving from the Ross and Ronne Ice Shelves and the break-up of the Larsen Ice Shelf. We intend to report our results widely at conferences and in the scientific literature, and we will display our results to local faculty and researchers, undergraduate and graduate students, and school children and their teachers. (I–277–E; NSF/OPP 03–37838)

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Is Kamb Ice Stream Restarting? Glaciological investigations of the Bulge-Trunk transition on Kamb Ice Stream, West Antarctica.

Slawek M. Tulaczyk, University of California–Santa Cruz; Ian Joughlin, Jet Propulsion Laboratory, National Aeronautics and Space Administration; and Robert W. Jacobel, St. Olaf College.

The West Antarctic Ice Sheet contains enough ice to raise the global sea level by several meters, and concerns have been raised about its possible retreat or collapse. However, measurements have shown that the Ross Sea sector of this ice sheet is in a positive mass balance. This is surprising, because geologic and glaciologic data indicate that the ice sheet has been retreating for about 10,000 years. It is possible that the observed positive mass balance is a result of a short-term (decadal- or century-scale) oscillation in ice discharge, rather than an indication of a long-term shift in ice-sheet behavior. In

particular, the Ross Sea sector of the West Antarctic Ice Sheet could return to neutral or negative mass balance if the Kamb Ice Stream (formerly called "Ice Stream C"), which has stopped, restarts and begins flowing at ice-stream -like velocities. Because the tributaries of this stream are still active, a massive ice bulge is building up where they run into the locked-up trunk of the Kamb Ice Stream, near the site of the former Upstream C Camp. On mountain glaciers, buildup of ice bulges is associated with a sharp increase in ice velocity in a relatively short time.

We will test to see whether the Kamb Ice Stream may already be in the process of restarting. If so, we will establish what the rate of reactivation is and what mechanisms are controlling it. If not, we will determine what physical controls are preventing surging and what the alternative scenarios for the evolution of the stream are. One scenario is an increase in ice diversion toward neighboring Whillans Ice Stream; this could prevent a complete stoppage of the stream, which has been slowing down for almost the past 25 years.

Our work will have two components:

- field observations of bed properties, geometry of internal radar reflectors, surface strain rates, and velocity/topography changes using ice-penetrating radar and differential global positioning systems and
- numerical modeling of the evolution of the Kamb Ice Stream over the next 100 to 1,000 years.

This project is a collaboration of scientists from three different types of U.S. institutions—a liberal arts college (St. Olaf College), a public research university (University of California–Santa Cruz), and a National Aeronautics and Space Administration research laboratory (the Jet Propulsion Laboratory). We will make project results available to the public and educators through downloadable graphics and animations posted on the research Web site. Field data resulting from the project will be shared with other investigators through the Antarctic Glaciological Data Center. (I–345–M; NSF/OPP 03–38295 and NSF/OPP 03–37567)

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Investigating atmospheric chemistry through oxygen and sulfur isotopes in volcanic sulfate from South Pole ice cores.

Jihong Cole-Dai, South Dakota State University, and Mark H. Thiemens, University of California–San Diego.

It is well known that large, sulfur-rich volcanic eruptions can influence the radiative budget of the atmosphere and the global climate. Less understood is the direct impact on atmospheric chemical processes, especially the impact of massive eruptions that alter the composition of the entire atmosphere.

We will use mass-independent isotope chemistry, which has been shown to be an effective tool in understanding a variety of gas-phase atmospheric processes. Preliminary results of oxygen and sulfur isotope measurements in samples from several eruptions indicate that the isotopic composition of volcanic sulfate in antarctic snow and ice contains valuable information on atmospheric chemical and dynamic processes that have not been previously investigated. For example, mass-independently fractionated sulfur isotopes demonstrate that atmospheric photolysis (chemical decomposition induced by light) of sulfur compounds occurs at longer ultraviolet (UV) wavelengths than those in the Archean atmosphere (Precambrian era), possibly reflecting atmospheric ozone or oxygen concentration (or both). This suggests that the isotopic composition of atmospheric sulfate may be used to track the evolution (oxygenation) of the atmosphere and the origin of life on Earth.

Using tested methodology, we will:

- locate and isolate known volcanic events in six shallow South Pole ice cores,
- extract volcanic sulfate from at least five major eruptions (Pinatubo, Tambora, Unknown 1809, Kuwae, Unknown 1259) from these samples,
- use established isotope analytical procedures to determine oxygen and sulfur

isotopes, and

- interpret the data we gather.

These steps will help us address a number of important questions:

- What impact do massive volcanic eruptions have on the oxidative capacity of the atmosphere?
- What oxidants and mechanisms are involved in the oxidation or conversion of volcanic sulfur dioxide to sulfate in the stratosphere?
- What isotopic criteria could be used to differentiate ice core signals of stratospheric eruptions from those of tropospheric eruptions?
- What is the role of UV radiation in sulfur dioxide conversion in the atmosphere?
- Does the photo-oxidation mechanism of volcanic sulfur dioxide depend on and reflect ozone/oxygen levels in past atmospheres? (I–355–S; NSF/OPP 03–37933)

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ARTISTS AND WRITERS PROGRAM

Underwater photographer Norbert Wu, a participant in NSF's Antarctic Artists and Writers program, documents McMurdo Sound's unique ecosystem in photographs and text on his web site and in the HDTV film Under Antarctic Ice, aired on PBS television in 2003 (http://www.norbertwu.com/). (*Photo courtesy of Nobert Wu.*)

On this page:

Overview

The National Science Foundation's (NSF's) Antarctic Artists and Writers Program makes it possible for the humanities (painting, photography, writing, and history) to be part of the U.S. Antarctic Program. Artists and writers work at U.S. stations and camps, often with science groups but sometimes on their own, to create works that portray the region or the activities that take place there.

The Antarctic Artists and Writers Program contributes to NSF's goal of advancing discovery while disseminating results broadly to enhance scientific and technological understanding. The program helps record the Nation's antarctic heritage, responding to White House direction that the U.S. Antarctic Program support the range of U.S. interests in the region. Application procedures are available on the NSF web site at www.nsf.gov/pubsys/ods/getpub.cfm, and a list of past participants can be found at www.nsf.gov/od/opp/aawr.htm.

The selection process for the Artists and Writers Program is comparable to the one for science projects in that a peer-review panel meets at NSF annually to evaluate the applications; this panel's advice heavily influences the selections. The applicants who are chosen receive field support (including air travel from the United States), but no direct NSF funding. The program, while intended mainly for U.S. citizens, considers requests from artists and writers who live in other Antarctic Treaty nations but whose applications demonstrate that their works will reach a significant U.S. audience. The application deadline for participation in the 2006–2007 austral summer season will be 1 June 2005.

Mission Antarctica.

Yann Arthus-Bertrand.

Mr. Arthus-Bertrand plans to take aerial photos that will be used in several ways: first, they will be part of the Earth from Above project, which includes an exhibit that will tour the United States (with stops in Chicago, Los Angeles, Miami, and New York, among other cities). Second, they will be incorporated into the Altitude Photographic Library, one of the world's largest collections of aerial photographs. Third, they will be part of a book. Finally, European magazines such as *Stern*, *Paris Match*, and *El Pais* are interested in using them to accompany reports on the region. The photos would be accompanied with texts written by environmental scientists. (W–217–M)

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Antarctic anthology.

Susan Fox Rogers.

Ms. Rogers will assemble an anthology of writings on life in Antarctica as experienced by researchers, explorers, artists, and others who have spent a significant amount of time on the ice. To make this anthology a well-rounded representation of the people and experiences in the U.S. Antarctic Program, she will travel extensively (to South Pole and McMurdo Stations, to several field camps, and possibly to one of the research vessels) to meet and interview possible contributors.

She also intends to visit those sites that will be described in this collection (or comparable ones): the McMurdo Dry Valleys, a remote camp (which can then serve as a representative of other remote camps), and the South Pole. Such experiences will help her shape the collection and provide the background to edit the personal essays that will be included. She will record, transcribe, and edit the stories of those who cannot write down their experiences. The final product, a book-length collection of personal essays, will offer an intimate portrait of life on the continent. (W–218–M)

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End as beginning: An American antarctic imaginary.

Elena Glasberg.

Ms. Glasberg will gather material for a manuscript on U.S. antarctic fiction, history, and material culture. Her focus is the interplay of ice and human culture both historically and today, so she will interview people on their previous knowledge of Antarctica and ask them how they discovered it in their own lives and in their professional lives. Was it through popular culture, in school, or elsewhere? What archives, images, and presuppositions do people have, and how do they affect people? How do they shape people's encounter with the place and thus the place itself?

She will visit South Pole Station and deep field sites, Black Island, and Palmer Station. She will engage in as many activities as possible to experience the range of historical, iconic polar activities in the company of the people who live and work there. (W–219–M)

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Time, place, and imagination: Images and poems from Antarctica.

Judith E Nutter.

Ms. Nutter plans to study what happens in, and to, the mind when a person finds himself or herself in a extreme landscape: That is, what narratives and images does the mind produce out of its experience and understanding of such landscapes, whether they are physical or emotional?

She will produce a series of poems and visual images that will be published and exhibited together. She will explore the myths and realities of Antarctica through words and visual images in an attempt to arrive at a deeper understanding of its abiding hold on the human imagination. This work will be created in response to the antarctic landscape as well as to the history of Antarctica and the internal landscapes of the people who are

drawn to work there. She writes both lyric (meditative, personal) and narrative poems, and her previous visual work has been done primarily in pastels. However, she intends to capture the starkness and grandeur of the landscape in watercolors, a more ethereal medium.

She plans to travel with grantees in their fieldwork whenever possible and sail on the research ship *Laurence M. Gould*, especially if it goes to Palmer Station via the Gerlache and Bransfield Straits. She also plans to stay overnight in a tent at Old Palmer Station and possibly at Janus or DeLaca Island, or at another location. (W–220–P)

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Vast Active Living Intelligence System: Photographing the South Pole.

Connie Samaras.

Ms. Samaras will photograph the new Amundsen-Scott Station under construction at the South Pole from a number of vantage points, both inside and outside, to underscore the space between life support architecture and extreme climate. She plans to juxtapose seemingly disparate views within the same frame (reflections, indoor and outdoor lighting, interior spaces against landscape) to underscore the sometimes contradictory intersections of technology, culture, nature, and time unique to the Antarctic. The title of the series—*Vast Active Living Intelligence System*—is borrowed from science fiction writer Philip K. Dick.

Another objective is to depict the intersection of the real and virtual worlds, that is, the impact of the influx of communications and new technologies on scientific investigation and community life at the station.

With their permission, she will photograph a range of subjects—scientists, construction workers, support personnel, and so on—and, whenever possible, will accompany them to nearby sites. She also hopes to take aerial shots from the cockpit of the plane at arrival and departure and aerial views of the South Pole itself.

Before she leaving for Antarctica, she will talk with engineers and construction personnel to refine her ideas and contact the Ferraro Choi architectural firm to familiarize herself with the concepts that went into formulating their design.

Her work—most recently urbanscapes of Los Angeles, Las Vegas, and New York—has been extensively exhibited both nationally and internationally. Her antarctic project will also be widely exhibited, as well as published in various catalogs and journals. Moreover, because this project is essentially a documentary mapping the significant architectural and historical changes at the South Pole, she plans to donate some of the images and negatives to the archives of the National Science Foundation (and/or the Smithsonian photographic archives). (W–221–S)

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Antarctica—The Biography of a Continent.

Gabrielle Walker.

Ms. Walker will be doing research for a science book titled *Antarctica—The Biography of a Continent*. This narrative, nonfiction book will be written for a lay audience and will weave together descriptions of science, places, and people in Antarctica. The idea is to get at the personality of the continent through the eyes of researchers, through vivid descriptions of the different environments in which they work, and through what antarctic science tells us about the continent and its place in the world.

The book will be divided into four parts: past, present, future, and afterlife. It aims to give readers a good sense of the variety of the landscape and the many different kinds of science that are being done. To that end, she hopes to visit a range of different field environments and join scientists involved in different kinds of research. Later in the season, she also hopes to join a scientific cruise and visit some sites run by European programs, notably the British Antarctic Survey's Rothera Station. (W–223–M)

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