USAP Introduction
Final Draft
11/21/03

U.S. ANTARCTIC PROGRAM, 2003–2004

As part of the U.S. Antarctic Program, nearly 700 researchers and special participants will conduct 156 projects during the 2003–2004 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*.

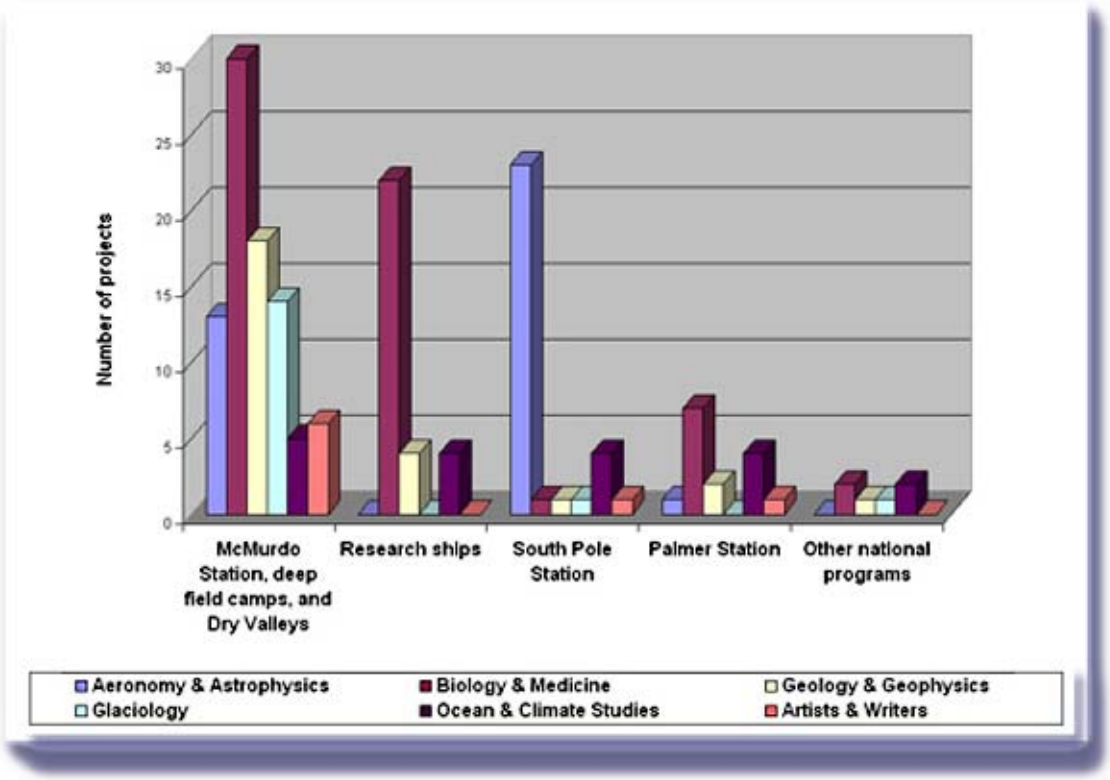
Dr. Ian Hawes begins to drop into the dive hole in Lake Hoare in the McMurdo Dry Valleys to collect algae samples from the lake floor. He is a New Zealand scientist with the National Institute of Water and Atmospheric Research, working with U.S. scientists participating in the McMurdo Dry Valleys Long Term Ecological Research (LTER).

NSF/U.S. Antarctic Program photo by Kristan Hutchison, Antarctic Sun, RPSC.

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) supports Teachers Experiencing Antarctica and the Arctic (TEA), which strives to create a polar learning community of teachers, students, school districts, and researchers. During this austral summer, as part of their professional development, six competitively selected teachers will work with six research teams headed by U.S. Antarctic Program investigators who have volunteered to include TEA participants in their field parties. Another OPP program—the Antarctic Artists and Writers Program—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 03–551; http://www.nsf.gov/pubsys/ods/getpub.cfm?nsf03551). Operational resources in Antarctica are also used to support scientists from other Federal agencies. U.S. antarctic policies, facts about Antarctica and the U.S. research program, and details and statistics about 2003-2004 U.S. operations in Antarctica are described at http://www.nsf.gov/od/opp/antarct/treaty/opp4001/nsf04013.htm.

USAP science projects by discipline and research site



During the 2003–2004 austral summer, 86 projects will be based at McMurdo Station or at remote field sites, 30 will be supported on research ships, 31 will work at Amundsen-Scott South Pole Station, 15 will work in and around Palmer Station, and 6 will be supported by other nations.

Science highlights

The following projects are among those supported in Antarctica during this austral summer and winter. Where applicable, 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 http://www.fastlane.nsf.gov/a6/A6AwardSearch.htm. 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.

Aeronomy and astrophysics

- **Ten-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 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)

- **IceCube.** During this austral summer, a consortium led by the University of Wisconsin–Madison will begin building 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 be used during the austral summers over 6 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)

Artists and writers program

- **Antarctic Artists and Writers Program.** NSF's Antarctic Artists and Writers Program (NSF 03-030; http://www.nsf.gov/od/opp/aawr.htm), 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 have six projects. Among them, Edward J. Larson, Russell Professor of History at the University of Georgia–Athens, will conduct field research leading to a book-length history of antarctic science. Professor Larson's articles have appeared in *Nature, Scientific American,* the *Wall Street Journal,* and elsewhere. His recent books include *Evolution's Workshop: God and Science in the Galapagos Islands* (2001) and *Summer for the Gods: The Scopes Trial and America's Continuing Debate Over Science and Religion* (1997), which won the Pulitzer Prize. (W–221–M)

- **Teachers Experiencing Antarctica and the Arctic.** Six K–12 teachers will spend a month each with NSF-funded antarctic research projects to improve classroom science by integrating research and education. The teachers, from schools around the Nation, competed for these opportunities in a program, *Teachers Experiencing Antarctica and the Arctic*, supported by OPP and NSF's Division of Elementary, Secondary, and Informal Education. (http://tea.rice.edu/tea_meetteachers.html)

TEA participants and associated science projects				
Teacher	**School**	**Event Number**	**Principal Investigator**	**Project**
Michael Lampert	West Salem High School Salem, Oregon	A-131-M	Terry Deshler	Measurements addressing quantitative ozone loss, polar stratospheric Cloud Nucleation, and large polar stratospheric particles during austral winter and spring
Andres Sajor	Peru Central School Peru, New York	G-298-M	William Hammer	Vertebrate Paleontology of the Triassic to Jurassic Sequence in the Beardmore Glacier Area of Antarctica
Coleen Brogenski	St. John's School Houston, Texas	G-081-M	Philip Kyle	Mount Erebus Volcano Observatory and Laboratory (MEVOL)
Robin Ellwood	Rye Junior High School Rye, New Hampshire	B-426-M	Peter Doran	McMurdo Dry Valleys LTER: The role of natural legacy on ecosystem structure and function in a polar desert
Amy Stoyles	Harlee Middle School Bradenton, Florida	B-019-M	Laurie Connell	Yeasts in the Antarctic Dry Valleys: Biological Role, Distribution, and Evolution
Susy Ellison	Yampah Mountain High School Glenwood Springs, Colorado	B-009-M	Bob Garrott	Patterns and Processes: Dynamics of the Erebus Bay Weddell Seal Population

- Scouting in Antarctica. Eagle Scout Brad Range is working in the U.S. Antarctic Program for 8 months to learn more about career choices in the sciences and engineering and to communicate his experiences to his fellow Boy Scouts (and others) in a Web site. A nationwide Boy Scouts of America competition led to his selection, which will involve a year's absence from his studies at the Georgia Institute of Technology. Girl Scouts of the USA and NSF partner in a similar program. (**http://www.scouting.org/nav/enter.jsp?c=xds&terms=antarctic&x=29&y=5**)

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 24 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/)

- **Response of terrestrial ecosystems along the Antarctic Peninsula to a changing climate.** Striking increases in air temperatures and ultraviolet-B radiation (UV–B) documented along the west coast of the Antarctic Peninsula over the past 50 years represent a profound climatic change.

In addition, annual precipitation and the depth of the winter snow pack appear to be increasing. These rapid changes in climate provide a unique opportunity to examine the effects of climate change on terrestrial ecosystems. Building on past work focused on the impact of warming and UV–B on terrestrial vascular plants on the Peninsula, a research team will examine how climate change alters nutrient pools and cycling among plants, litter, and soils in vascular-plant-dominated communities, with the goal of predicting long-term effects on plant productivity. (NSF/OPP 02–30579)

- **Culture and health in Antarctica.** In many ways, the emergence of a long-term population in space will parallel the emergence of a sustained population in Antarctica. Such organizational and cultural merging in restricted environments undoubtedly creates new cultural landscapes that could influence health and health behavior. The study of cultural emergence in Antarctica as an analog to space could help planners develop models of health and health behavior in an isolated confined environment and structure such environments to reduce health risks and identify factors that predispose people to those risks. (NSF/OPP 01–25893)

- **Interactive effects of ultraviolet radiation and vertical mixing on phytoplankton and bacterioplankton in the Ross Sea.** UV radiation influences plankton in the near-surface waters of most ecosystems. Southern Ocean ecosystems are particularly vulnerable 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 antarctic marine bacteria and phytoplankton, important issues remain. Little is known, for example, about how the dominant phytoplankton in the southern Ross Sea (*Phaeocystis antarctica)* responds. Open water at a far southerly location within the ozone hole in the spring, together with continuous daylight with implications for DNA repair, makes the Ross Sea of intense interest. Several studies suggest that vertical mixing significantly modifies the impact of UV radiation, but the few measurements that have been done on turbulence intensity in the surface layer have not been integrated with parallel studies of the effects of UV radiation on phytoplankton and bacterioplankton. To address these issues, three research teams will focus on vertical mixing and UV radiation in the Ross Sea and characterize phytoplankton and bacterioplankton responses in both laboratory and solar incubations. (NSF/OPP 01–27022, NSF/OPP 01–27037, and NSF/OPP 01–25818; http://www,serc.si.edu/uvb/Ross_Sea_index.htm; http://uwf.edu/wjeffrey/rosssea.html)

Geology and Geophysics

- **Beardmore Glacier and Moody Nunataks regions investigations.** Earth science research in the central and southern Transantarctic Mountains during the past four decades has provided a wealth of new information on the geologic evolution of the Ross Sea sector of the continent. Many of these advances, such as vertebrate faunas, anatomically well preserved plant fossils, and young fossiliferous glacial deposits indicating radically different climatic conditions, have been significant to the global geosciences community. During this austral summer, eight field teams will work from camps in the Beardmore Glacier region and in the Moody Nunatak area. Their research will focus on Late Paleozoic–Mesozoic fauna, environment, and climate; Permian and Triassic floras; geophysical mapping of the East Antarctic shield; the evolution of Triassic vegetation; the terrestrial paleoecology and sedimentary environment of the Beardmore Glacier region; Triassic to Jurassic vertebrate paleontology; and Permian-Triassic mass extinction. (NSF/OPP 01–26146, NSF/OPP 01–26230, NSF/OPP 02–30280, NSF/OPP 02–29877, NSF/OPP 02–30696, NSF/OPP 02–29757, NSF/OPP 02–29698, and NSF/OPP 02–30086)

- **West Antarctica GPS Network (WAGN).** This season, researchers will deploy a series of GPS transceivers across the interior of the West Antarctic Ice Sheet—an area approximately the size of the contiguous United States from the Rocky Mountains to the Pacific coast. The ability to measure the motion of the Earth's crust in the bedrock surrounding and underlying the West Antarctic Ice

Sheet is critical to understanding the past, present, and future dynamics of the sheet and its potential role in future global change scenarios, as well as improving our understanding of Antarctica's role in global plate motions. WAGN will complement existing GPS projects by filling a major gap in coverage among several discrete crustal blocks that make up West Antarctica—a critical area of potential bedrock movements. (NSF/OPP 00–03619; http://www.ig.utexas.edu/wagn/index.htm)

- **Transantarctic Mountains Deformation Network: GPS measurements of neotectonic motion in the antarctic interior.** Using the GPS, a research team will measure 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. These measurements—along with those from other U.S. and Italian GPS networks, from other programs on the ice sheets, and from ongoing structural and seismic investigations in Victoria Land—will provide data for modeling glacio-isostatic adjustments due to deglaciation and to modern changes in the mass of 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 discriminate tectonic crustal displacements from viscoelastic/elastic glacio-isostatic motions. (NSF/OPP 02–30285 and NSF/OPP-02–30356; http://www.geology.ohio-state.edu/TAMDEF)

- **TAMSEIS: A broadband seismic experiment to investigate deep continental structure across the east-west antarctic boundary.** How were the Transantarctic Mountains formed? Many theories, ranging from delayed phase changes to transform-flank uplift, have been proposed. All of these make various assumptions about the structure of the upper mantle beneath and next to the rift-side of the mountain front. East Antarctica has a bedrock continent-like foundation, while the ice sheet over West Antarctica covers a series of islands. West Antarctica shares a geologic history with the South American Andes Mountains, the result of plates colliding and subducting. East Antarctica is more like a large coherent chunk that broke free of the supercontinent Gondwanaland and drifted to a new position at the bottom of the world. At the boundary between these two regions, called the east-west antarctic boundary, the crust and upper mantle reveal many important distinctions that tell the basic story of the tectonic development of Antarctica. Collecting seismic data over three austral summers, one research team will evaluate geodynamic models for the tectonic development of Antarctica and develop new maps of the variation in crustal thickness, upper mantle structure, anisotropy, and mantle discontinuity topography across the boundary of East and West Antarctica. (NSF/OPP 99–09603; http://levee.wustl.edu/seismology/TAMSEIS)

Glaciology

- **Snow megadunes.** Megadunes of the East Antarctic Ice Sheet are subtle features 2 to 4 meters (6.5 to 13 feet) high, 2 to 5 kilometers (1 to 3 miles) apart, and as much as 100 kilometers (62 miles) long. Extending over 500,000 square kilometers, the dunefields may have been even more extensive in the past and may affect the interpretation of climate in deep ice cores. Investigators are conducting ground-penetrating radar and global positioning surveys, collecting firn cores, sampling snow in pits, installing automatic weather stations, and studying snow permeability to determine the physical and chemical characteristics of the dunes and understand their significance, including their effect on ice cores. Megadunes, a manifestation of an extreme terrestrial climate, may provide insights into past terrestrial climate or processes active on other planets. (NSF/OPP 01–25570, NSF/OPP 01–25276, NSF/OPP 02–25992, and NSF/OPP 01–25960; http://nsidc.org/antarctica/megadunes/)

  A second project will focus on a region of megadunes near Vostok Station (80º 78' S, 124º 50' E) in central East Antarctica to explore the chemical composition of air in the snow layer (firn) and test the hypothesis that a deep convective zone of vigorous, wind-driven mixing can prevent gas

fractionation in the upper one-third of the polar firn layer. In the megadunes, ultra-low snow accumulation rates lead to structural changes that make firn much more permeable to air movement. The unknown thickness of the convective zone has hampered the interpretation of ice-core nitrogen- and argon-isotope ratios that indicate past firn thickness—a key constraint on the climatically important variables of temperature, accumulation rate, and gas age–ice age difference. Studying this extreme end-member example will better define the role of the convective zone in gas reconstructions. (NSF/OPP 02–30452; http://icebubbles.ucsd.edu)

- **Tidal modulation of ice stream flow.** Ice from the West Antarctic Ice Sheet flows to the sea through a series of ice streams. Recent observations give a glimpse of the surprising sensitivity of these streams to tidal oscillations. Measuring ice stream response to the rise and fall of the tide is an excellent natural experiment that can improve scientific understanding of controls on the streams and improve models of the West Antarctic Ice Sheet. The goal for this field season is to deploy 20 global positioning system (GPS) receivers in arrays on ice streams E, D, C and the Whillans Ice Stream (B) and at fixed base stations to record vertical and horizontal ice stream motion and to correlate this motion to ocean tides in the Ross Sea. Passive seismic sensors will be deployed with the GPS units. Data will be collected at rates that allow the velocity variations of the ice streams to be measured over two tidal cycles. Improved knowledge of ice-stream behavior will help assess the potential for rapid ice-sheet change affecting global sea levels. (NSF/OPP 02–29629; http://www.geosc.psu.edu/~sak/Tides)

- **Refining a 500,000-year climate record from the Mount Moulton blue ice field in West Antarctica.** The summit crater of Mount Moulton contains a 600-meter-thick, horizontally exposed section of ice with tephra layers from nearby Mount Berlin inserted. Argon-isotopic dating of the thick, near-source tephra indicates that the age of the ice section ranges between 15,000 and 492,000 years. Thus, the Mount Moulton site offers an unparalleled repository of ancient West Antarctic snow and trapped air that can be used to investigate climate over much of the past 500,000 years. Data collected earlier suggest that there is a usable record of past climate extending back beyond 140,000 years. Research during this austral summer includes evaluating more thoroughly the integrity of the climatic record; improving the radioisotopic dating of specific tephra layers; obtaining baseline information about modern snowfall deposition, mean annual temperature, and wind pumping around the summit of Mount Moulton; and studying how firn densification differs when surface accumulation changes from net accumulation to net ablation. (NSF/OPP 02–30021, NSF/OPP 02–30348, and NSF/OPP 02–30316; http://www.geosc.psu.edu/~sowers/index.html)

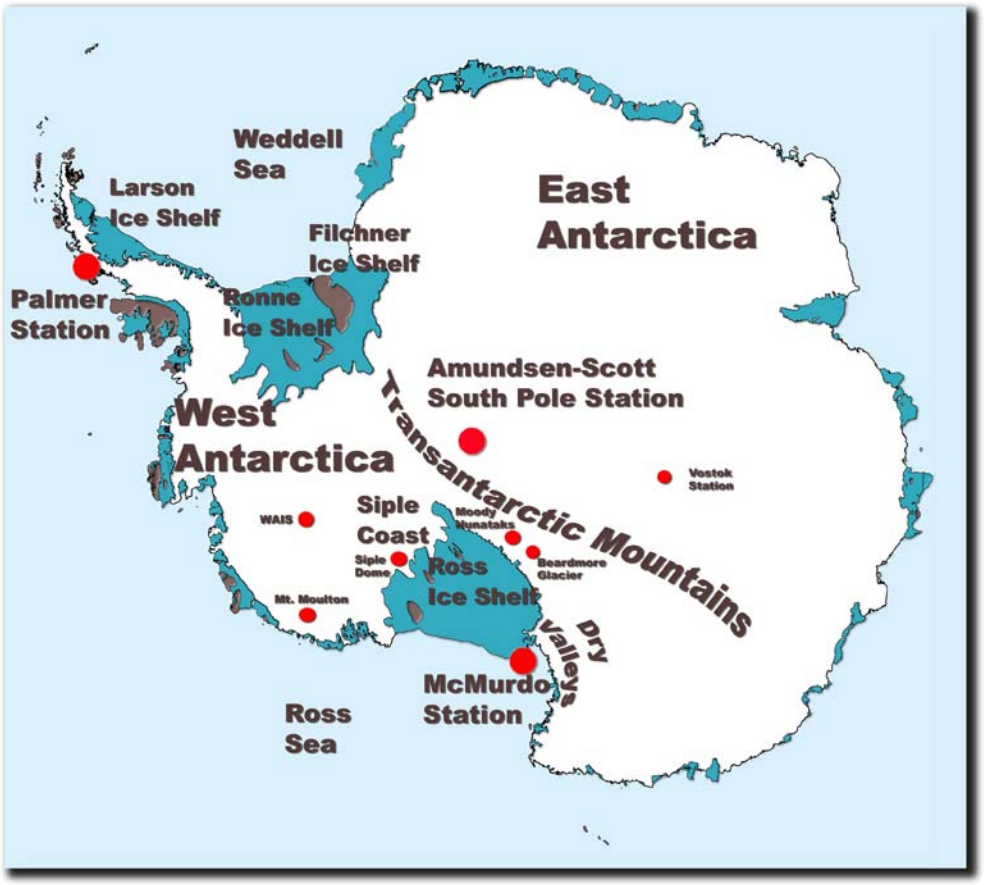
Ocean and climate studies

- **Antarctic Troposphere Chemistry Investigation (ANTCI).** Working at Amundsen-Scott South Pole Station, seven research teams will study sulfur chemistry in the atmosphere to enhance our understanding of the processes controlling tropospheric levels of reactive hydrogen radicals, reactive nitrogen, sulfur, and other trace species and to improve the climatic interpretation of sulfur-based signals in antarctic ice-core records. The results from observing reactive hydrogen radicals, sulfuric acid and its sulfur precursors, and the flux of ultraviolet radiation will lead to a more comprehensive understanding of antarctic atmospheric chemistry, as well as the factors that influence the levels and distribution of climate proxy species in ice cores. (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; http://acd.ucar.edu/~mauldin/ANTCI_Web/ANTCI_Home.htm)

- **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

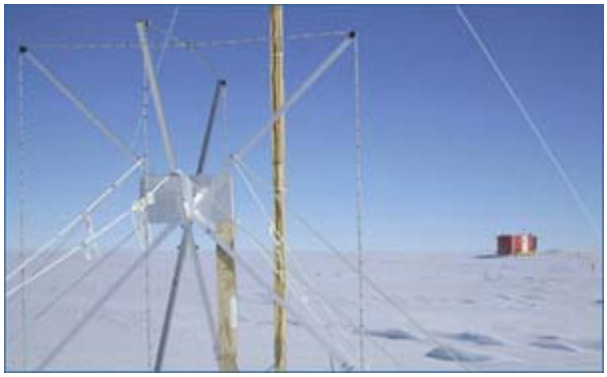
experiment, focuses on these cross-slope exchanges between the Antarctic Shelf and the deep ocean. Although scientists understand the role that cold-water masses originating in the Antarctic play in global ocean circulation and climate, the processes by which these water masses enter deep ocean circulation 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; http://www.ldeo.columbia.edu/res/fac/physocean/anslope/)

U.S. Antarctic Program, 2003–2004
Sites of Major Activities



AERONOMY AND ASTROPHYSICS

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.



A low-frequency receiver listens for electromagnetic activity at a remote Automatic Geophysical Observatory (AGO) site.

NSF photo by Kristan Hutchison

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 Systems Program), is nowhere better exemplified than in Antarctica.

Background imaging of Cosmic Extragalactic Polarization (BICEP): An experimental probe of inflation.
Andrew Lange, James Bock, and Brian Keating, California Institute of Technology; and William Holzapfel, University of California–Berkeley.

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 is being constructed and will be available for deployment in 2003. BICEP will operate 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-cm 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)

Conjugate studies of ultra-long-frequency (ULF) waves and magnetospheric dynamics using ground-based induction magnetometers at four high-latitude manned sites.
Mark Engebretson, Augsburg College, and Marc R. Lessard, Dartmouth College.

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 manmade 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 manmade systems, it will also involve space weather prediction. (A–102–M/S; NSF/OPP 02–33169)

A search for extrasolar planets from the South Pole.
Douglas Caldwell, SETI Institute.

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 to detect 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, thus allowing 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 lower mass planets that have not previously been detectable. Combining the transit results (which give the size of the planet) with Doppler velocity measurements (which give the planetary 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)

Dayside auroral imaging at South Pole.

Stephen 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 there is a body of literature about the auroral footprints of the dayside reconnection region 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)

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

Umran 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)

South Pole Air Shower Experiment–2.
Thomas Gaisser, Todor Stanev, and Timothy Miller, University of Delaware; and Albrecht Karle, University of Wisconsin–Madison.

Cosmic rays consist of protons and other atomic nuclei, accelerated (scientists believe) to high energy levels in such distant astrophysical sources as the remnants of supernovas. As cosmic rays arrive at Earth from space, they interact in the upper atmosphere. The South Pole Air Shower Experiment–2 (SPASE–2) is a sparsely filled array of 120 scintillation detectors spread over 15,000 square meters at the South Pole. This array detects the charged particles (primarily electrons) that are produced by interactions of these very-high-energy cosmic rays.

A nine-station subarray called VULCAN has been constructed to detect the Cherenkov radiation produced high above the ground in the same showers. (Cherenkov radiation is the light emitted by a charged particle moving through a medium at a speed faster than the speed of light within that material, analogous to the shock wave produced by objects moving faster than the speed of sound.) The SPASE–2 array is located less than half a kilometer from the top of AMANDA (the antarctic muon and neutrino detector array) and is designed to complement its neutrino-detecting capacity (see project A–130–S). SPASE–2 has two goals:

First, it is intended to investigate high-energy primary (galactic in origin) cosmic radiation by determining the relative contribution of different groups of nuclei at energies greater than about 100 teraelectronvolts. This can be done by analyzing coincident events between SPASE–2 and AMANDA. Such events are produced by high-energy cosmic ray showers with trajectories that pass through SPASE–2 (on the surface) and AMANDA (buried 1.5 to 2 kilometers beneath it). AMANDA detects the high-energy muons penetrating the Earth in those same showers for which SPASE–2 detects the low-energy electrons arriving at the surface. The ratio of muons to electrons depends on the mass of the original primary cosmic ray nucleus. The VULCAN detector further permits the calculation of two other ratios that also depend on primary mass in readings from the showers it detects.

Second, it is intended to use the coincident events as a tagged beam to investigate and calibrate certain aspects of the AMANDA response. This project is performed in cooperation with the University of Leeds in the United Kingdom. (A–109-S; NSF/OPP 99–80801)

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 an interesting and 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 motions and thermospheric persistent vertical winds near Arrival Heights simultaneously with those at South Pole Station. In both locations, observations are made 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 maintenance and make system upgrades. (A–110–M/S; NSF/OPP 02–29251)

Riometry in Antarctica and conjugate regions.
Theodore Rosenberg, University of Maryland, and Allan Weatherwax, Siena College.

We will continue studying the polar ionosphere and magnetosphere from Antarctica and nominally conjugate regions in the Arctic. High-frequency cosmic noise absorption measurements (riometry) and auroral luminosity measurements (photometry) will form the basis of our investigations, which will involve extensive collaboration with other researchers using complementary data sets.

We will continue to maintain imaging and broadbeam riometers and two wavelength zenith photometers at South Pole and McMurdo Stations. In addition, we will continue to provide the data acquisition systems at both stations for the common recording of other geophysical data and their dissemination to collaborating investigators. To enhance the usefulness and timeliness of these data, we will maintain a homepage from which the general scientific community can access these antarctic data sets on a daily basis and, by special arrangement, in near real time. Imaging riometer measurements will also be continued at Iqaluit, Northwest Territories, Canada, which is the nominal magnetic conjugate point of South Pole Station.

Our activities will enable us to participate in, and contribute to, several major science initiatives, including the GEM, CEDAR, ISTP/GGS, and National Space Weather programs. A primary focus of our analysis will be

coordinated ground- and satellite-based studies of Sun-Earth connection events. The overall objective is to understand the relevant physical processes that produce the observed phenomena and how they relate to internal and external driving forces (magnetospheric/ionospheric instabilities and solar wind/interplanetary magnetic field variations, respectively). From this may emerge an enhanced capability to predict the possible occurrence of events that might have negative technological or societal impacts sufficiently in advance to lessen their effects. (A–111–M/S; NSF/OPP 00–03881)

Polar experiment network for geophysical upper-atmospheric investigations.

Theodore Rosenberg, University of Maryland.

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 electrodynamics of the polar cap region and the key role this region plays in coupling the solar wind with the Earth's magnetosphere, ionosphere, and thermosphere. Measurements that are central to understanding include the electric field convection pattern across the polar cap and knowledge of the response of the atmosphere to the many forms of high-latitude wave and particle energy inputs during both geomagnetically quiet and disturbed situations.

The U.S. automatic geophysical observatory (AGO) network, which consists of a suite of nearly identical instruments (optical and radio wave auroral imagers, magnetometers, and narrow- and wide-band radio receivers) at locations on the polar plateau, actively studies the coupling of the solar wind to ionospheric and magnetospheric processes, emphasizing polar cap dynamics, substorm phenomena, and space weather. Among these projects are

- an investigation that uses extreme-low-frequency and very-low-frequency waves as a tool to understand the electrodynamic coupling between upper-atmospheric regions and the interaction of the magnetosphere and ionosphere;
- an investigation that employs autonomous, compact, and low-power atmospheric lidar (light detection and ranging) instruments to detect polar stratospheric clouds and profile the overlying atmosphere; and
- an investigation that uses magnetometers at conjugate sites in Antarctica and the Northern Hemisphere to measure variations in hydromagnetic waves with the optical emissions caused by charged particles that precipitate from the trapped radiation of the Earth into the upper atmosphere.

When combined with measurements made at certain staffed stations, AGO network data facilitate both large- and small-scale studies of the energetics and dynamics of the high-latitude magnetosphere. The research will be carried out with in situ observations of the geospace environment by spacecraft, in close cooperation with other nations working in Antarctica and in conjunction with studies performed in the Northern Hemisphere. (A–112–M; NSF/OPP 03–34467)

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 season. As a point on the Earth's rotational axis, the pole provides a unique vantage to observe the airglow and to 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)

Spaceship Earth: Probing the solar wind with cosmic rays.

John 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 continues a series of year-round observations at McMurdo and Amundsen-Scott South Pole Stations recording cosmic rays with energies in excess of 1 billion electronvolts. 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/OPP 00-00315)

Tracer-Lite II Project: Transition Radiation Array for Cosmic Energetic Radiation.

Dietrich Müller, University of Chicago.

The origin of high-energy cosmic rays remains a mystery. To solve this mystery, it is important to determine the energy spectrum of cosmic rays at the source, which is known to be different from the observed energy spectrum, at least over a narrow range of energies. Examining the chemical composition of cosmic rays at high energies provides the only means of determining the cosmic ray spectrum at the source. The steeply falling energy spectrum of cosmic rays requires long observation times with large detectors. The Transition Radiation Array for Cosmic Energetic Radiation (TRACER) was constructed for long-duration balloon flights around the polar circle. It will study the abundance of elements from oxygen to iron in the cosmic ray spectrum up to approximately 10 tera electron volts/nucleon. Such information can be used to constrain models of cosmic ray propagation and acceleration.

The instrument requires careful handling and storage. During its trip from Port Hueneme to Williams Field, its temperature must remain between 0°C and +40°C. Project members will arrive in Antarctica at intervals as the mission unfolds: one will arrive early to help unload, transport, and store the instrument. Then, others will arrive to unpack it and prepare it for flight. Once that stage is complete, different personnel will be responsible for monitoring the flight. After the flight, still other personnel will take part in the recovery phase, dismantle the instrument, and pack it for return shipment to Port Hueneme. (A–125–M; NASA award)

A versatile electromagnetic waveform receiver for South Pole Station.

James LaBelle, Dartmouth College, and Allan 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)

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 Sivjee, 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 99–09339)

Antarctic muon and neutrino detector array (AMANDA).

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

The AMANDA project takes advantage of unique polar conditions to discover and probe the sources, both inside our galaxy and beyond, of the shower of very-high-energy neutrinos descending on (and usually passing through) the Earth. Neutrinos are elementary particles believed to have very little or no mass and no electrical charge. Coursing through the Universe, they can take any of three forms and interact only rarely with other particles. Thus they arrive on Earth with potentially unique information about where they may have originated. They could be diffuse (made up of contributions from many active galactic nuclei) and may even be an indicator of the decomposition of the mysterious dark matter now believed to dominate the Universe. Or they could be single sources, such as supernova remnants, rapidly rotating pulsars, the gas around black holes, neutron stars, or individual blazars.

AMANDA is the largest detector of neutrinos in the world. During the past 5 seasons, the installation of over 600 photomultiplier tubes [embedded between 1 and 2 kilometers (km) into the ice and oriented downward] has established a natural detector of Cherenkov radiation in the ice. (Cherenkov radiation is the light emitted by a charged particle moving through a medium at a speed faster than the speed of light within that material, analogous to the shock wave produced by objects moving faster than the speed of sound.) High-energy neutrinos with enough energy to pass through the Earth's mass may collide with an atomic nucleus in the ice or rock near the tubes. Such collisions produce a distinctive eerie blue glow, which the basketball-sized glass tubes can detect for up to several hundred meters through the clear ice.

Neutrino astronomy has previously 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 (SN–1987a). In recent years, new sources of high-energy gamma rays have been discovered, among them Mrk–421, which was seen by the National Aeronautics and Space Administration's Compton Gamma Ray Observatory and the Mount Hopkins Observatory. AMANDA is designed to study just such objects, which are believed to emit copious numbers of high-energy neutrinos. Now that first-generation detectors such as AMANDA have been enhanced (the array may one day number 5,000 tubes strung on some 80 cables within 1 cubic km of ice), neutrino astronomy would appear to be on the verge of detecting high-energy particles that carry information from the outer edges of the universe. (A–130–S; NSF/OPP 99–80474)

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 Alberto Adriani, 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 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. An international experiment to address some of these details is planned for June through October 2003.

This experiment will compare balloon-borne ozone observations from nine antarctic stations (South Pole, General Belgrano II, Dumont d'Urville, Vicecomodoro Marambio, Georg von Neumayer, Rothera, Syowa, Davis, and McMurdo) with several three-dimensional chemical transport models. Balloon releases will be coordinated to sample air parcels previously sampled at another location. Comparing the changes within these air parcels will provide an excellent test of our understanding of stratospheric chemistry as represented in the models.

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

Measurements of vertical ozone 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 http://www.ndsc.ws). This project represents a collaboration between Italian researchers and the University of Wyoming. (A–107–M and A–131–M; NSF/OPP 02–30424 and U.S./Italian agreement)

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

Marc R. Lessard and James LaBelle, Dartmouth College.

We aim to detect and record magnetic field fluctuations in the extremely-low-frequency (ELF) range at South Pole Station, specifically auroral ion cyclotron waves, which have been well correlated with flickering aurora. 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. Perhaps 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)

Development and test flight of a small, automated balloon payload for observations of terrestrial x-rays.

David Smith, University of California–Berkeley.

We plan to develop and test a balloon payload designed to detect mega electron volt (MeV) electron precipitation into the atmosphere from the Earth's radiation belts. Relativistic electron precipitation has been found to occur at high latitudes, but it is not known how common such events are, nor is much known about the conditions that lead to these events. These particles endanger astronauts and unmanned satellites, but neither the cause of their energization nor the cause of their loss (precipitation) is well understood. The precipitation of the highest energy electrons occurs in rare, rapid events that we will study with a balloon payload.

The instrument we will develop will be very small and lightweight, and it will include real-time data communications via the Iridium satellite system. This new technology will allow a payload that can be launched on small balloons as well as on long-duration balloons. (A–144–M; NSF/ATM 02–33370)

Long-duration balloon program.

William Stepp, National Aeronautics and Space Administration/National Scientific Balloon Facility.

As a means of high-altitude exploration, free-flying balloons have many advantages over satellites. Balloons remain in a specific location much longer, cost little to launch, and are designed to return their instruments safely to Earth. Balloons have been flying for two centuries, but until recently were limited by how long they

could stay aloft. The latest scientific balloons, deployed from the National Scientific Balloon Facility (NSBF) in Palestine, Texas, are able to fly missions of 100 days or longer.

The current NSBF effort in Antarctica, known as the long-duration balloon (or LDB) program, launches high-altitude balloons carrying scientific payloads into the stratosphere. Many important scientific observations in fields such as hard x-ray/gamma ray and infrared astronomy, cosmic rays, and atmospheric studies have been made from balloons. (A–145-M; NSF/NASA agreement)

Trans-Iron Galactic Element Recorder/ANITA-lite (TIGER–ANITA-lite).

Walter Binns, Washington University.

Our primary objectives for the Trans-Iron Galactic Element Recorder (TIGER) experiment are to measure ultra-heavy galactic cosmic rays in order to determine the source of the material that is accelerated as galactic cosmic rays and the mechanism for injecting that material into the cosmic ray accelerator. Specifically, TIGER will build on our previous work and will collect additional data in order to measure the abundance of the elements in the charge range of interest. Our primary objectives for the Antarctic Impulsive Transient Antenna (ANITA)–lite experiment, which will fly on the same balloon with TIGER, are to measure the ambient very-high-frequency and ultra-high-frequency (VHF/UHF) impulsive noise levels at float altitudes over the antarctic ice sheet. The ANITA-lite experiment is a pathfinding mission for the ANITA experiment, which is a neutrino telescope that will be designed to detect neutrinos converting in the polar ice sheet.

We will place these experiments on an long-duration balloon that will fly two revolutions around Antarctica to obtain a long data acquisition time for galactic cosmic rays (TIGER) and VHF/UHF impulsive noise levels (ANITA-lite). We will collaborate with the National Scientific Balloon Facility (NSBF), which will ship our experiment and associated equipment to McMurdo Station, provide laboratory space for integration and testing, launch the TIGER/ANITA-lite payload from Williams Field, and conduct flight operations. We will monitor the experiment with electronic ground support equipment at Williams Field for line-of-sight data. Following the flight, NSBF and project personnel will recover the instrument and ship it back to the United States. (A–149–M; NASA award)

Infrared measurements of atmospheric composition over Antarctica.

Frank Murcray, Ronald 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 would also provide validation for new satellite sensors. 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 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)

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

Susan K. Avery, James Avery, and Scott Paolo, University of Colorado–Boulder, and Denise Thorsen, University of Alaska.

This is a propitious time to study a number of atmospheric phenomena, because the 11-year solar cycle has peaked and because of the National Aeronautics and Space Administration's (NASA's) TIMED (thermosphere-ionosphere-mesosphere-energetics and dynamics) satellite mission (see project A–129–S). In addition to measurements derived from TIMED instruments, we have installed a meteor radar at

Amundsen-Scott South Pole Station. Concentrating on the dynamics of the mesosphere and lower thermosphere, we are looking at

- the space-time decomposition of wave motions,
- the delineation of the spatial climatology over Antarctica with emphasis on the structure of the polar vortex, and
- the dynamic response to energetic events and interannual variability.

The meteor radar is a very-high-frequency system capable of measuring the spatial structure and temporal evolution of the horizontal wind field over the South Pole. Spatial climatology data will also come from existing ground-based radar at Davis Station, Syowa Station, Rothera Station, and the Amundsen-Scott base.

As NASA's TIMED satellite orbits over the South Pole, wind and temperature data will provide counterpoint and corroborative information. Thus, experiments based both in space and on the ground can be mounted, and data that previously relied on a single source can be better validated. (A–284–S; NSF/ATM 00–00957)

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

Umran 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; they are 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)

IceCube.

Francis Halzen, University of Wisconsin–Madison.

We will begin 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 6 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.

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 super massive 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 super symmetric particles, and search for compactified dimensions.

This season we will plan the schedule and begin assembling and testing the components and drilling systems we will use to construct the observatory. 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 02–36449)

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

Antony Stark, Smithsonian Institution Astrophysical Observatory.

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 for 9 years 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 the 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,
- examined the gradient of heavy elements in the galaxy, and
- recently produced extensive, high-sensitivity maps of several atomic and molecular transitions toward the Galactic Center.

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.

We will devote equal effort to three initiatives: large-scale maps of emissions in the Galactic Center and the Magellanic Clouds (these will be made freely available), support of proposals from the scientific community, and installation and use of the detector systems under development. (A–371–S; NSF/OPP 01–26090)

DASI (degree angular scale interferometer).

John Carlstrom, University of Chicago.

We plan to continue cosmological observations with DASI (degree angular scale interferometer), which was first deployed at the Amundsen-Scott South Pole Station during the 1999–2000 austral summer. DASI is providing continuous high-quality measurements of the cosmic microwave background (CMB) radiation anisotropy over the critical range of angular scales spanning the first three acoustic peaks in the CMB power spectrum. The data are transferred daily to the University of Chicago, where analysis is keeping pace with the data. We published the resulting power spectrum in *Nature* in December 2002 and intend to publish again in 2003.

We will also use DASI to measure the currently undetected polarization of the CMB anisotropy. The measurements will provide a critical test of the standard theory of the early Universe. The observations will also be done using full Stokes parameters, allowing a measurement of the cross-correlation of total intensity and polarization anisotropy. We will construct new receiver components to reconfigure DASI from 30 gigahertz (GHz) to 100 GHz for intensity and polarization measurements of the fine-scale CMB anisotropy power spectrum. These new capabilities will allow detailed observations of the Sunyaev-Zel'dovich Effect (SZE) in nearby galaxy clusters and allow SZE surveys from massive clusters.

These efforts complement other ongoing and planned CMB experiments with instruments in Chile and at the South Pole. These three instruments can view the same region of the sky and will provide detailed power spectra over this angular range, thereby gathering crucial data for understanding foreground contamination. These three instruments, working together, will allow this essentially unexplored but theoretically important portion of the CMB anisotropy power spectrum to be fully determined.

We will disseminate and implement outreach and education related to the project through established structures and mechanisms. These programs, which reach out to local and distant K–12 schoolteachers and students, will use the excitement of exploring our Universe to help attract women and minorities to science. Also, we will integrate graduate and undergraduate education and research into the construction of the instrumentation, as well as into the data analysis. (A–373–S; NSF/OPP 00–94541)

Mapping galactic magnetic fields with the submillimeter polarimeter for antarctic remote observations (SPARO).

Giles Novak, Northwestern University.

The submillimeter polarimeter for antarctic observations (SPARO) maps interstellar magnetic fields by measuring the linear polarization of submillimeter thermal emission from magnetically aligned interstellar dust grains. Interstellar magnetic fields are generally difficult to observe, especially in the dense regions to which SPARO is most sensitive. It is important to study these fields because their energy density is comparable to that of the other physical ingredients that are found in interstellar regions, so they can play important roles in the physical processes that occur there. This program is designed to contribute to our understanding of two general problems in which interstellar gas (and probably magnetic fields as well) has an important role: the study of the Galactic Center region and star formation.

The study of the super-massive black holes that are found at the centers of many galaxies is motivated in part by our desire to understand the behavior of nature in such extreme environments and in part by the likely influence of these active galactic nuclei on the evolution of galaxies and perhaps of the Universe. Also, magnetic fields in star-forming regions may help support star-forming clouds against gravity, or they may help clouds collapse via angular momentum transfer. The SPARO instrument is operated on the Viper 2-meter telescope at the South Pole. Observations are carried out by personnel who remain there for the 8-month winter when South Pole Station is inaccessible. These observations are complementary to submillimeter polarimetry that is being carried out by larger telescopes at Mauna Kea, but SPARO is much more sensitive to submillimeter emissions because of the exceptionally good atmospheric transmission and the stability of the winter skies over the antarctic plateau.

Therefore, our observations are specifically aimed at

- confirming SPARO's discovery of a large-scale toroidal magnetic field at the Galactic Center;
- testing a magnetic outflow model for the Galactic Center Lobe, a radio structure possibly tracing gas that has been ejected from the galactic nucleus; and
- mapping large-scale magnetic fields in a sample of star-forming clouds to study the relationship between the elongated shapes of these clouds and their magnetic fields. (A–376–S; NSF/OPP 01–30389)

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

Gordon Stacey, Cornell University.

SPIFI (the South Pole Imaging Fabry-Perot Interferometer) is the first direct detection imaging spectrometer for use in the submillimeter band and 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 SPIFI 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)

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

William 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-mm 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 in 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 Sunyeav-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)

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

John Carlstrom, University of Chicago; Antony Stark, Smithsonian Institution Astrophysical Observatory; John Ruhl, Case Western Reserve University; Joseph Mohr, University of Illinois–Urbana-Champaign; and William 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. This survey 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)

BIOLOGY AND MEDICINE

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.)

Brett Pickering, a member of Dr. Bill Fraser's research team, counts Adélie penguins on Torgersen Island, near Palmer Station. Dr. Fraser, from the Polar Oceans Research Group, has been traveling to Palmer Station since 1975. His research is examining the impact of tourism on Adélie penguins.

NSF photo by Laura Hamilton

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 (in this field, 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 object 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 manmade 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.

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

Ronald Kiene, University of South Alabama, and David Kieber, State University of New York–Syracuse.

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 in teaching undergraduate and graduate courses and will enrich students' experience. (B–002–N and B–266N; NSF/OPP 02–30497 and NSP/OPP 02–30499)

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

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

The striking increases in air temperatures and ultraviolet-B radiation (UV-B) 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 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.

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)

Antifreeze proteins in antarctic fishes: Integrated studies of freezing environments and organismal freezing avoidance, protein structure-function and mechanism, genes, and evolution.

Arthur 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 AFP 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)

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

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

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 35 years, a total of 15,636 animals have been tagged, with 144,927 resighting records logged in the database. This study is a valuable resource for understanding population dynamics not

only of Weddell seals, but also of other species of both terrestrial and marine mammals. We intend to proceed with 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 the 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 will involve an intensive study of mass dynamics of both pups and adult females to assess annual variation in marine resources and their 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. (Regional 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 knowledge of pinniped population dynamics, as well as 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 impacts of human activities such as global warming and the commercial exploitation of antarctic marine resources. (B–009–M; NSF/OPP 02–25110)

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

Stacy 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.

In October and November 2002, we collected data to describe the habitat and community while the outfall was still in operation. This will be added to the data we collected from 1988 to 1998 to provide a baseline. We initiated experiments with organic content, burial, and disturbance size as variables. During the next two seasons, we will track the recovery of the benthic community, compare the rates 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. (B–010–M; NSF/OPP 01–26319)

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

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

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 since 1993. 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. The transient nature of these ponds 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 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)

Drinking and sodium/potassium–ATPase alpha-subunit isoform expression and antarctic fish.

David Petzel, Frank Dowd, Margaret Scofield, and Philip Brauer, Creighton University.

Notothenioid fishes inhabiting the near-freezing (–2ºC) waters of McMurdo Sound have some of the highest serum and cellular sodium concentrations and the lowest gill sodium/potassium-ATPase (Na/K-ATPase, the sodium/potassium pump) activities of any marine teleost. The enzyme Na/K-ATPase regulates the sodium concentration in the cells of many organisms. Maintaining a high salt content in the cells of these fish lowers the freezing point to allow them to inhabit cold antarctic waters and reduces the salt gradient between them and the sea water.

On the basis of previous studies of temperature effects, we hypothesize that compared with New Zealand notothenioids that inhabit warmer waters, antarctic notothenioids have lower drinking rates, lower salt excretion rates, and a higher proportion of the low intracellular sodium affinity for a specific subunit of the Na/K-ATPase (a3-isoform). These unique osmoregulatory properties explain the high serum and cellular sodium concentrations found in notothenioids south of the antarctic Polar Front. We will compare and contrast the unique osmoregulatory mechanisms of antarctic and New Zealand notothenioids with respect to

- sea water drinking rates and the serum and cellular chemical composition of the fish,
- enzymatic properties and the expression pattern of mRNA and protein, and
- temporal and spatial localization of the Na/K-ATPase a3-isoform subunit in the gills.

To accomplish these objectives, we will study four species of notothenioids, representing ecologically diverse habits above and below the Polar Front.

The information we gain will increase our knowledge about the role of Na/K-ATPase in the cellular function in many organisms, strengthen our understanding of the biochemical and physiological adaptations that allow antarctic notothenioids to survive and thrive in the ice-laden waters south of the antarctic Polar Front, provide field and laboratory research experience for graduate and undergraduate students, and contribute to significant outreach activities in science education for elementary and high school students and teachers. (B–012–M; NSF/OPP 02–29462)

Remotely operable microenvironmental observatory for antarctic marine biology research.

Samuel 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 mm) 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, transmitting 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)

Yeasts in the antarctic dry valleys: Biological role, distribution, and evolution.

Laurie B. Connell, University of Maine.

The soil community of the antarctic polar desert comprises few endemic species of bacteria, fungi, and invertebrates. Both filamentous and single-cell fungi have been isolated from a diversity of antarctic soil types, but only yeasts appear to be endemic to the polar desert soils. Although their ecological role in antarctic soils is undefined, yeasts may be the principal taxa synthesizing the sterols required by soil invertebrates. In addition, yeasts may be involved in accumulating and mobilizing growth-limiting nutrients such as phosphorus into the polar desert food web. Although yeasts have been well described in agricultural and industrial systems, little is known about their ecological role.

This multidisciplinary, collaborative research will characterize the role soil yeasts have in the McMurdo Dry Valley ecosystem in order to better understand polar deserts and other extreme environments, as well as provide a foundation for incorporating yeasts into biogeochemical models of temperate environments. Soil microbiota mediate most processes such as decomposition, soil respiration, uptake and fixation of micro- and macronutrients, and detoxification of heavy metals and serve as major global carbon sinks. The complexity of soil communities in temperate regions poses difficulties in studying the relationships between biotic and abiotic parameters, and the factors controlling populations of soil microbiota remain poorly understood. The extreme climate and relatively simple community structure of the continental antarctic desert lend themselves to such studies.

We will first correlate the abundance and distribution of yeasts in polar desert soils with physical and chemical soil properties. Several physiological parameters will be explored in vitro to develop a basis for understanding the functional role these organisms might have. Sterols synthesized by McMurdo Dry Valley soil yeasts, as well as their ability to survive multiple freeze-thaw cycles, will be characterized. The capacity of indigenous antarctic yeasts to use, compete for, and store phosphorus will be ascertained. The evolution of Dry Valley yeasts will be addressed by determining intra- and intervalley relatedness patterns based on DNA sequence.

Both soil samples and extracted DNA will be shared with other interested laboratories. Moreover, students from middle school (Biolab Inc.) through college (University of Maine) will be given the opportunity to collaborate on this project, as well as to develop their own projects. (B–019–M; NSF/OPP 01–25611)

The chemical ecology of shallow-water marine macroalgae and invertebrates on the Antarctic Peninsula.

Charles D. Amsler and James B. McClintock, University of Alabama–Birmingham, and Bill J. Baker, University of South Florida.

Many organisms are not mobile and so cannot escape from predators. One way they can keep from being eaten is to make themselves unappetizing by producing defensive chemicals known as secondary metabolites. However, the energy and other resources that go into making these compounds could instead have gone into growth or reproduction. We are studying the evolution of these tradeoffs and hope to understand ways that organisms maximize the usefulness of their investments in defensive chemistry.

For marine plants, the physical environment of Antarctica is very different from most other places in the world's oceans because nutrients are plentiful but light is often limited. So the currency that is used to pay for defense, growth, and reproduction is different than it is for plants in most other marine communities. This allows us to test theories about the costs and benefits of defense in ways not possible elsewhere in the world.

For marine animals, Antarctica is unique in that predation by sea stars is much more important than in other marine communities. Sea stars feed by extending their stomachs through their mouths and digesting prey outside their bodies. We predict that this should lead to a much higher investment in defensive metabolites in the outer layers of the prey. We intend to test the hypothesis that sponges (an important component of these communities) will maximize their investment in chemical defense by having the highest levels of defensive secondary metabolites in their outermost layers.

This research should also advance our general understanding of the evolution of chemical defenses. We hope to elucidate the nature and role of bioactive agents in the specific ecology of the antarctic marine

benthos (that is, organisms living at the bottom of marine environments). (B–022-L/P; NSF/OPP 01–25181 and NSF/OPP 01–25152)

Dynamics of predator-prey behavior in the Southern Ocean.

Richard Veit, City University of New York–College of Staten Island.

We plan to bring two groups of undergraduate students to the Antarctic, where they will learn a broad range of skills in physical and biological oceanography by participating in collecting data on seabird abundance and behavior. We will combine research on the dynamics of seabirds that feed on antarctic krill with the teaching of mathematical modeling of foraging behavior and spatial statistics. Our goal is to learn how foraging antarctic seabirds respond to changes in the abundance and distribution of their prey, primarily antarctic krill.

Our approach will be to study bird behavior near krill swarms and to contrast this behavior with that observed in areas lacking krill. From these comparisons, we will build foraging models that will make predictions about the dispersion of birds under differing levels of krill abundance. Our long-term goal is to be able to make predictions about the impact of future changes in krill stocks on seabirds. We will conduct our work in the vicinity of Elephant Island over two seasons. Each season, we will survey the insular shelf north of Elephant Island and record the abundance, distribution, and behavior of seabirds.

We will attempt to quantify the linkage between prey abundance and bird behavior in order to use this behavioral information to index long-term changes in the prey base. Our teaching goal is twofold: first, we will introduce inner-city college students to a spectacular and economically important ecosystem. Through their work on an oceanographic research vessel, students will be exposed to a broad range of research topics and methods, from behavioral ecology to physical oceanography. Second, once back at home, students will participate in the development of a mathematical biology initiative at the College of Staten Island. Here, they will be encouraged to apply basic mathematical reasoning and computer modeling to a real problem—determining how foraging choices made by seabirds can ultimately impact their reproductive success. (B–023–L; NSF/OPP 99–83751)

Culture and health in Antarctica.

Timothy 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 face residents, 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)

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

Adam 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 –1.8ºC. We will quantify temperature effects on gene expression and protein turnover networks during early development by using a Bayesian network 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)

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, Southern Illinois University–Carbondale.

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 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.

None of the colonies 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, large colonies affect the foraging patterns of smaller ones 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. Yet to be determined is the demographic mechanism of colony growth (or decline). Reproductive success does not appear to be important, however.

We will use seven 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 been often noted. Understanding the demographic mechanisms behind this sensitivity will contribute greatly to knowledge of the effects of climate change on antarctic marine organisms. (B–031–M; NSF/OPP 01–25608)

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

Steven 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: more 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 these sites 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)

The development of olfactory foraging strategies in antarctic procellariiform seabirds.

Gabrielle Nevitt, University of California–Davis.

Procellariiform seabirds (petrels, albatrosses, and shearwaters) are distinguished by their acute sense of smell. These birds have pelagic lifestyles and forage over thousands of miles of ocean to find patchily distributed resources. We will study the development of olfactory sensitivity in burrow-nesting procellariiform seabirds within the Kerguelen Archipelago and will explore the hypothesis that during development, chicks become tuned to odors associated with feeding in a manner analogous to olfactory imprinting.

We have three primary objectives:

- First, we will use videotape documentation to characterize the behavioral responses of chicks to two prey-related odors (dimethylsulfide and cod-liver oil), one novel odor (phenyl ethyl alcohol or rose scent), and burrow-related odors (burrow and colony dirt).

- Second, we will determine whether chicks can learn odor cues by exposing them to a non-prey-related odor during the egg stage and then testing for increased sensitivity to that odor after they hatch.

- Third, we will quantify key behavioral responses induced when a chick is exposed to an odor plume within a portable wind flume.

Only a handful of studies have addressed the olfactory abilities of procellariiform seabirds or indeed any bird. Results from our research will be among the first to address the development of olfaction in an ecologically important context. Overall, these results will greatly extend our knowledge of the foraging ecology of these fascinating birds. Such knowledge is not only useful to basic science, but it may also help bolster efforts to ensure the conservation of procellariiforms, given the threatened or endangered status of many species.

Our work will include research experience for a graduate student and an active international collaboration with the French Institute for Polar Research and Technology. Furthermore, our results may be transferable to other potentially important organisms, such as salmon and insects, where understanding the developmental stages of olfaction has commercial importance. (B–035–E; NSF/OPP 02–29775)

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 specific wood-destroying fungus. 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–M; NSF/OPP 02–29570)

International collaborative expedition to collect and study fish indigenous to subantarctic habitats.

H. William Detrich, Northeastern University.

Notothenioids are a major group of fish in the Southern Ocean. The ancestral notothenioid fish stock of Antarctica probably arose as a sluggish, bottom-dwelling perciform species that evolved some 40 to 60 million years ago in the then temperate shelf waters of the antarctic continent. The grounding of the ice sheet on the continental shelf and changing trophic conditions may have eliminated taxonomically diverse late Eocene fauna and initiated the original diversification of notothenioids. On the high antarctic shelf today, notothenioids dominate the ichthyofauna in terms of species diversity, abundance, and biomass, the latter two at levels of 90 percent to 95 percent. Since the International Geophysical Year of 1957–1958, fish biologists from the Antarctic Treaty nations have made impressive progress in understanding the notothenioid ichthyofauna of the cold antarctic marine ecosystem. However, integration of this work into the broader marine context has been limited, largely because of lack of access to, and analysis of, specimens of subantarctic notothenioid fish.

The fish of this suborder are critical for a complete understanding of the evolution, population dynamics, ecophysiology, and ecobiochemistry of their antarctic relatives. Our project will support an international, collaborative research cruise to collect and study fish indigenous to subantarctic habitats. Research topics include systematics and evolutionary studies; life history strategies and population dynamics; physiological, biochemical, and molecular biological investigations of major organ and tissue systems; genomic resources for the subantarctic notothenioids; and ecological studies of transitional benthic invertebrates.

In a world that is experiencing changes in global climate, the loss of biological diversity, and the depletion of marine fisheries, the antarctic and subantarctic regions and their biota offer compelling natural laboratories for understanding the evolutionary impact of these processes. Our work will contribute to developing a baseline understanding of these sensitive ecosystems, one against which future changes in species distribution and survival can be evaluated judiciously. (B–039–N; NSF/OPP 01–32032)

Foraging behavior and demography of *Pygoscelis* penguins.

Wayne 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 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 to 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)

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

Walker 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 distributions and reproductive success of birds and marine mammals.

Even though it is so central to the food web, surprisingly little is known about how phytoplankton production 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)

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 with 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–E; NSF/OPP 02–30069)

Microbial diversity and function in the permanently ice-covered lakes of the McMurdo Dry Valleys, Antarctica.1

John Priscu, Montana State University–Bozeman; Michael Madigan, Southern Illinois University–Carbondale; Brian Lanoil, University of California–Riverside; and Steven 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)

Diving physiology and behavior of emperor penguins.

Paul 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)

Monitoring the human impact and environmental variability on 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 scales 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)

Interactive effects of ultraviolet radiation and vertical mixing on phytoplankton and bacterioplankton in the Ross Sea.

Wade Jeffrey, University of West Florida; Patrick Neale, Smithsonian Institution; and Ann Gargett, Old Dominion University.

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 in the spring, well within the ozone hole, and 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 use 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, B–203–N, and B–208–N; NSF/OPP 01–27022, NSF/OPP 01–27037, and NSF/OPP 01–25818)

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

Joaquim 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. (B–206–N; NSF/OPP 01–26150)

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

Rebecca Gast and Mark Dennett, Woods Hole Oceanographic Institution, and David 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 biological oceanography and to understanding 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 in order 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)

Plankton community structure and iron distribution in the southern Drake Passage.
B. Greg Mitchell, University of California–San Diego; Christopher Measures, University of Hawaii–Manoa; Meng Zhou, University of Massachusetts; and Osmund Holm-Hansen, Farooq Azam, Sarah T. Gille, and Katherine Barbeau, Scripps Institution of Oceanography, University of California–San Diego.

The Shackleton Fracture Zone (SFZ) in the Drake Passage marks a boundary between low- and high-phytoplankton waters. West of the passage, waters have very low concentrations of surface chlorophyll, and east of the SFZ, mesoscale eddy kinetic energy and chlorophyll are higher than they are west of it. Data from a 10-year survey confirm the existence of a strong hydrographic and chlorophyll gradient in the region. We hypothesize that bathymetry, including the 2,000-meter-deep SFZ, influences mesoscale circulation and transport of iron, leading to the differences in phytoplankton patterns.

To test this hypothesis, we will examine phytoplankton and bacterial physiological states (including responses to iron enrichment) and the structure of plankton communities from virus to zooplankton; the concentration and distribution of iron, manganese, and aluminum; and mesoscale flow patterns near the SFZ. We will examine relationships between iron concentrations and phytoplankton in the context of the mesoscale transport of trace nutrients to determine how much of the variability in biomass can be attributed to iron supply, as well as the most important sources of iron east of the Drake Passage. Our goal is to better understand how plankton productivity and community structure in the Southern Ocean are affected by bathymetry, mesoscale circulation, and nutrient distributions.

We will perform rapid surface surveys of chemical, plankton, and hydrographic properties, complemented by a mesoscale station grid for vertical profiles, water sampling, and bottle incubation enrichment experiments. Manganese and aluminum distributions will help distinguish aeolian, continental shelf, and upwelling sources of iron. We will monitor the physiological state of the phytoplankton by active fluorescence methods sensitive to iron limitation. Concentrations of pigment, carbon, and nitrogen will be obtained by analysis of filtered samples, cell size distributions by flow cytometry, and species identification by microscopy. We will measure primary production and photosynthesis parameters (absorption, quantum yields, variable fluorescence) with depth profiles, surface surveys, and bulk samples from enrichment experiments. We will also determine the abundance of viruses and bacteria and ascertain whether bacterial production is limited by iron or organic carbon sources.

We aim to improve scientific understanding of processes controlling iron distribution and the response of plankton communities in the Southern Ocean. Moreover, we will have an undergraduate and teacher outreach component and plan to create a Web site and K–12 curricular modules. (B–228–L and B–248–L; NSF/OPP 02–30443, NSF/OPP 02–30445, and NSF/OPP 02–29966)

Southern Ocean Global Ocean Ecosystems Dynamics (GLOBEC): Mysticete whale acoustic census in the GLOBEC west antarctic project area.
John Hildebrand, Mark McDonald, and Sue Moore, Scripps Institution of Oceanography, University of California–San Diego.

The U.S. Southern Ocean Global Ocean Ecosystems Dynamics (GLOBEC) program focused on the distribution of antarctic krill (Euphausia superba) in the Marguerite Bay/West Antarctic Peninsula region, as well as on environmental and ecosystem factors that are important for krill distribution. Our primary goal was to study the distribution and abundance of mysticete whales by using both visual and acoustic techniques. These data allowed us to model the rates of krill predation by whales in the study area.

In continuing our research, we hope to better understand the relationship between the physical and biological factors that affect the behavior of whales and their krill predation. To estimate the population of mysticete whales, we used passive acoustic recording of vocalizing marine mammals and assessed their abundance and distribution by a combination of bottom-mounted acoustic recorders and sonobuoys. During the 2001–2002 austral summer, eight bottom-mounted acoustic recorders were recovered and redeployed at sites in the west Antarctic Peninsula. This austral summer, we intend to recover these acoustic recorders and begin analyzing our findings. (B–239–L; NSF/OPP 99–10007)

Soil biodiversity and response to climate change: A regional comparison of Cape Hallett and Taylor Valley, Antarctica.
W. Berry Lyons, Ohio State University; Diana Wall, Colorado State University; Ross A. Virginia and John Barrett, Dartmouth College; and S. Craig 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 a 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)

Iron and light effects on Phaeocystis antarctica isolates from the Ross Sea.

Giacomo DiTullio, University of Charleston, and Peter Sedwick, Bermuda Biological Station Research.

The colonial prymnesiophyte *Phaeocystis antarctica* is a major bloom-forming alga in antarctic shelf waters, where, together with diatoms, it is considered a key species in regional biogeochemical cycling and ecosystem structure. Iron levels in these waters fall sharply during the mid- to late summer to concentrations that are likely to limit the growth of phytoplankton, including *P. antarctica.* However, in contrast to diatoms, very little work has been done to examine the effects of iron, or the combined effects of iron and irradiance, on the growth, physiology, and biochemical composition of *P. antarctica.* We will collect samples of *P. antarctica* from the southern Ross Sea and samples grown in semicontinuous batch cultures to investigate the effects of iron availability and irradiance on growth rate, cellular iron quota, buoyancy, biogenic sulfur production, pigment content, redox-protein expression, and photosynthetic efficiency.

Over time scales ranging from seasonal to interannual, *P. antarctica* is known to have a significant effect on regional biogeochemical cycles of carbon, nutrient elements, and sulfur in the Ross Sea. This species may also have played a central role in the inferred basin-scale changes in biogeochemical cycles linked to glacial-interglacial climatic change. Thus, it is important to develop a mechanistic understanding of the factors that control the growth, physiology, and biochemical composition of *P. antarctica* in order to better understand the biogeochemical ecology of the Ross Sea and the wider Southern Ocean and possible linkages with regional and global climate. The data we gather from these laboratory experiments, together with the results of recent and ongoing field and modeling studies, will substantially improve our ability to predict how the antarctic region will be affected by and modulate future climate change. (B–272–M; NSF/OPP 02–30513 and NSF/OPP 02–30559)

Dynamic similarity or size proportionality? Adaptations of a polar copepod.

Jeannette Yen, Marc Weissberg, and Donald Webster, Georgia Institute of Technology.

We will explore the feasibility of using fluid physical analyses to evaluate the importance of viscous forces over compensatory temperature adaptations in a polar copepod. The water of the Southern Ocean is 20ºC colder and nearly twice as viscous as subtropical seas, and the increased viscosity has significant implications for swimming zooplankton. In each of these warm and cold aquatic environments have evolved abundant carnivorous copepods in the family Euchaetidae.

In this exploratory study, we will compare two species from the extremes of the natural temperature range (0º and 23ºC) to test two alternate hypotheses on how plankton adapt to the low temperature–high viscosity realm of the Antarctic and to evaluate the importance of viscous forces in the evolution of plankton. How do stronger viscous forces and lower temperature affect the behavior of the antarctic species? If the antarctic congener is dynamically similar to its tropical relative, it will operate at the same Reynolds number (Re). Alternatively, if the adaptations of the antarctic congener are proportional to size, they should occupy a higher Re regime, which suggests that the allometry of various processes is not constrained by having to occupy a transitional fluid regime.

We designed our experiments with clearly defined outcomes on a number of copepod characteristics, such as swimming speed, propulsive force, and size of the sensory field. These characteristics determine not only how copepods relate to the physical world, but also how their biological interactions are structured. The

results we derive will provide insights into major evolutionary forces affecting plankton and provide a means of evaluating the importance of fluid physical conditions relative to compensatory measures for temperature.

Fluid physical, biomechanical, and neurophysiological techniques have not been previously applied to these polar plankton. However, if productive and feasible, these approaches will provide ways to explore the sensory ecology of polar plankton and the role of small-scale biological-physical-chemical interactions in a polar environment. Experimental evidence validating the importance of viscous effects will also justify further research using latitudinal comparisons of other congeners along a temperature gradient in the world's oceans. (B–285–L; NSF/OPP 03–24539)

Victoria Land latitudinal gradient project: Benthic marine habitat characterization.

Rikk Kvitek, California State University–Monterey Bay.

Our work is part of a multinational, multidisciplinary program called the Victoria Land Latitudinal Gradient Project (VLLGP), which includes scientists from both the Italian Antarctic Research Program (PNRA) and the Antarctica New Zealand Research Program. The overall goal of the VLLGP is to take a latitudinal gradient approach to ecosystem studies in Victoria Land.

Personnel from the Seafloor Mapping Lab (SFML) at California State University–Monterey Bay will participate in a 20-day PNRA cruise on the research ship *Italica* during January 2004. The specific goals of this Italian/U.S. collaboration are to

- identify the environmental gradients linked to latitude and to relate community transitions along the Victoria Land coast to climatic, geomorphologic, and oceanographic features;
- identify biochemical, physiological, and other adaptive responses of representative organisms;
- quantify biodiversity patterns and test the hypothesis of progressive emergence of marine assemblages with latitude; and
- use biotic changes associated with steep environmental gradients to predict possible effects of climate change.

We will use high-resolution acoustic remote-sensing (multibeam and sidescan sonar) and spatial data-modeling tools to identify and characterize benthic habitats and species/habitat associations along the gradient from a depth of 0 to 200 meters. Accurate mapping and classification of habitat types within each study area will be critical to selecting comparable sampling sites so valid community comparisons can be made along the latitudinal gradient. Since the Ross Sea coast extends across one of the longest latitudinal gradients in the Antarctic (15 degrees), this study offers a unique opportunity for predicting and establishing a baseline to detect environmental and community responses to global change and anthropogenic disturbance.

This work will not only foster research, logistical, and data management collaboration among scientists from different disciplines and national programs, but it will also provide undergraduate students with the opportunity to participate in the research. (B–320–E; NSF/OPP 02–29991)

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 and/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 will comprise 5 assessments over 12 months. Treatments consist 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)

Complex pelagic interactions in the Southern Ocean: Deciphering the antarctic paradox.

Thomas Frazer, University of Florida.

Our primary goal is to quantify, examine, model, and validate the complex interactions involving the direct, indirect, and feedback effects that regulate the planktonic food web in the coastal waters of the Southern Ocean in order to find the causes of low phytoplankton biomass and production there despite the plentiful availability of nutrients. In particular, we will evaluate the feedback mechanisms induced through the role of ammonium, which is largely released by aggregations of herbivorous zooplankton (krill specifically) present in the Southern Ocean, on the resistance to ultraviolet stress by the phytoplanktonic community and, in particular, the effects on nitrogen incorporation rates, both ammonium and nitrate, and the subsequent development of phytoplankton blooms.

We will not only address the problem experimentally, but will also consider the context of the heterogeneous landscape, dominated by small parcels of water, where these complex interactions occur. This project will be conducted through a shore-based (at the Spanish station Juan Carlos I) operation in 2004 and a subsequent cruise (on the R/V *Hesperides*) in 2005. (NSF/OPP 03–36469)

Food web structure across a large-scale ocean productivity gradient: Top predator assemblages in the southern Indian Ocean

George Hunt, University of California–Irvine.

A pervasive goal of biological oceanography is to understand the processes that structure pelagic communities. Research suggests that the distribution of oceanic species is influenced by physical and biological variability on a number of spatial-temporal scales. Our objective is to test the hypothesis that the dispersion and community of top predators vary in accordance with large-scale variability in physical structure and ocean productivity in pelagic ecosystems. We will therefore conduct a survey of bird and mammal use of distinct oceanographic domains in the southern Indian Ocean.

Two U.S. scientists will join French scientists on board a French research vessel near Reunion Island. The French scientists will sample the physical environment and estimate oceanic productivity, while the U.S. scientists will survey top predator distributions in physical and biological properties across a 35-degree latitudinal gradient from subtropical to subantarctic waters.

We hypothesize that top predator assemblages are structured by spatial gradients in hydrographic properties and ocean productivity patterns known to influence the distribution and patchiness of their prey (zooplankton, fish, and squid) and that the overall abundance of marine top predators within a specific oceanic domain is largely determined by ocean productivity. Also, we hypothesize that the energetic costs of foraging determine which types of top predators inhabit specific domains. Species with high foraging costs must exploit dense prey aggregations within highly productive areas. Conversely, taxa with low foraging costs can inhabit low-productivity areas with more dispersed prey.

We will quantify the association of specific water masses with top predator assemblages, as well as their aggregative response at hydrographic and bathymetric domains. Because top predators respond to oceanographic variability at multiple scales of time and space, we will use a variety of analytical methods to assess their responses in the context of large- and coarse-scale (thousands and tens of kilometers, respectively) hydrographic and ocean productivity patterns in the subtropical and subantarctic Indian Ocean. This interdisciplinary perspective will enhance our understanding of the way physical and biological

processes structure pelagic communities in the southern Indian Ocean and will provide a model that has broader implications for the oceans as a whole. (NSF/OPP 02–34570)

LONG-TERM ECOLOGICAL RESEARCH

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 geographical 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.

Joe Mastroianni stops to take a photo of Lake Hoare on a hike from Lake Bonney in the Dry Valleys near the Transantarctic Mountains. Mastroianna is a member of Dr. Anthony Hansen's science team, measuring the particles of "black carbon" found in the Dry Valleys. This is part of the Long Term Ecological Research (LTER) being conducted in Antarctica. LTER focuses on the role of cyclical/episodic events (ranging from years to decades to centuries) in the structure and function of distinctive ecosystems. The Antarctic Biology and Medicine Program supports two of these LTER project sites to facilitate research on unique aspects of antarctic ecology: one near Palmer Station in the Antarctic Peninsula and the other in the McMurdo Dry Valleys.

NSF photo by Kristan Hutchison

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. The Antarctic Biology and Medicine Program supports two of these LTER project sites to facilitate research on unique aspects of antarctic ecology: 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 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.

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. The PAL LTER grid is designed to study marine and terrestrial food webs consisting principally of diatom primary producers, the dominant herbivore antarctic krill, *Euphausia superba*, and the apex predator Adélie penguin, *Pygoscelis adeliae*. An attenuated microbial food web, consisting of planktonic bacteria and Archaea and bacterivorous protozoa, is also a focus of study.

This project monitors western Antarctic Peninsula ecosystems annually over a grid of oceanographic stations and seasonally 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 a general regional 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, characteristic of the interior, 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 longer snow-cover seasons.

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 2003–2004 field season, the following studies will be conducted as part of the LTER project:

Palmer Long-Term Ecological Research Project: Climate change, ecological migration, and teleconnections in an ice-dominated environment. (B–013–L/P; NSF/OPP 02–17282)
William R. Fraser, Polar Oceans Research Group.

Palmer Long-Term Ecological Research Project: Climate change, ecological migration, and teleconnections in an ice-dominated environment. (B–016–L/P; NSF/OPP 02–17282)
Maria Vernet, Scripps Institution of Oceanography, University of California–San Diego.

Palmer Long-Term Ecological Research Project: Climate change, ecological migration, and teleconnections in an ice-dominated environment (modeling component). (B–021–L; NSF/OPP 02–17282)
Douglas G. Martinson, Columbia University.

Palmer Long-Term Ecological Research Project: Climate change, ecological migration, and teleconnections in an ice-dominated environment (prey component). (B–028–L/P; NSF/OPP 02–17282)
Langdon B. Quetin and Robin M. Ross, University of California–Santa Barbara.

Palmer Long-Term Ecological Research Project: Climate change, ecological migration, and teleconnections in an ice-dominated environment. (B–032–L/P; NSF/OPP 02–17282)
Raymond C. Smith, University of California–Santa Barbara.

Palmer Long-Term Ecological Research Project: Climate change, ecological migration, and teleconnections in an ice-dominated environment. (B–045–L/P; NSF/OPP 02–17282)
Hugh Ducklow, Virginia Institute of Marine Sciences.

Transport and fate of persistent organic pollutants in antarctic coastal seas. (B–045–L/P; NSF/OPP 00–87872
Hugh Ducklow, College of William and Mary.

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 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 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 2003–2004 field season, the following studies will be conducted in the McMurdo Dry Valleys as part of the LTER project:

- **Paleoclimatology, paleoecology, and meteorological data collection.** (B–426–M; NSF/OPP 98-10219)
  Peter T. Doran, University of Illinois-Chicago.

- **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.

- **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 McKnight, University of Colorado.

- **Lake pelagic and benthic productivity: Microbial food webs.** (B–422–M; NSF/OPP 98-10219)
  John 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 Wall, Colorado State University.

Study of consequences of a January 2003 hydrocarbon spill on the ice cover of Lake Fryxell, McMurdo Dry Valleys.

Taylor Valley in the McMurdo Dry Valleys of East Antarctica is the site of a Long-Term Ecological Research (LTER) project. The pristine Taylor Valley has three major closed-basin, perennially ice-covered lakes (Hoare, Fryxell and Bonney). On 17 January 2003, a Bell 212 helicopter crashed on the 5-meter-thick ice cover of Lake Fryxell, spilling about 730 liters of diesel fuel, as well as small amounts of synthetic lubricants and hydraulic fluids. Although cleanup efforts by personnel based at McMurdo Station began within 4 days of the crash, at least half of the spilled fluids could not be recovered because of the condition of the ice and the unavoidable close of the field season in early February, which precluded further access to the site. These fluids will remain trapped in the ice until the spring melt season starts in December 2003. The site will become accessible in November 2003, when ice cores and water samples can be collected for detailed analyses.

This coordinated research effort is aimed at documenting the fate and transport of hydrocarbons within the ice and water of the lake. Our goals are to understand the physical, chemical, and biological changes that have occurred since the spill and what, if any, its longer-term impact will be. The results of our research will also provide important information to help improve accident response policies in the Dry Valleys.

Study of natural attenuation of contaminants derived from a January 2003 helicopter fluids spill at Lake Fryxell (McMurdo Dry Valleys), a Long-Term Ecological Research site.

Fabien Kenig and Peter Doran, University of Illinois–Chicago.

In this component of the project, we will document the natural attenuation of helicopter fluids in the lake ice. We have two major objectives:

- to assess the level of disturbance in the lake ecosystem by evaluating the changes in the lipid constituents of Lake Fryxell ice caused by this crash. Over a 2-year period, we will compare lipids analyzed in preaccident lake water and surface sediments with the contaminant (jet fuel, lubrication oil, and transmission fluids), as well as postaccident ice-cover samples, lake water samples, and surface sediments.

- to quantify and evaluate the level of natural attenuation (evaporation and biodegradation) of the composition of spilled fluids in the ice cover of the frozen lake. Graduate students will participate in this research. (NSF/OPP 03–46316)

Physical and biological consequences of a hydrocarbon spill on the ice cover of Lake Fryxell, Antarctica.

John Priscu and Edward Adams, Montana State University–Bozeman.

In this component of the project, we will conduct a variety of physical and biological experiments to determine the fate of hydrocarbons within the ice and their influence on biological activity and diversity. Undergraduate, graduate, and postdoctoral students will participate in this research. (NSF/OPP 03–46272)

Field sampling coordination and mathematical modeling of a hydrocarbon spill on the ice cover of Lake Fryxell, Antarctica.

W. Berry Lyons and Anne Carey, Ohio State University.

In this component of the project, we will coordinate the field sampling in the 2003–2004 season, integrate the data, and develop a mathematical model to better predict hydrocarbon movement within the ice cover of the lake. (B–429–M; NSF/OPP 03–47219)

OCEAN AND CLIMATE STUDIES

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 Racer Rock weather station is located on a small outcrop of land approximately 150 miles from Palmer Station near the northern tip of Two Hummock Island on the Antarctic Peninsula. It is one of five remote weather stations on the peninsula that monitor wind, temperature, pressure, humidity and sea temperature. The data is sent to U.S. researchers via satellite. Due to the station's isolated location, it is not often that conditions are conducive to landings by zodiac boat. Sea ice can block a route into the station making it difficult to maintain. In late September 2002, a new solar panel, batteries and a field repair to the antenna brought the station on line and weather data was again being sent to the U.S. for analysis.

NSF photo by Jeff Kietzmann

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.

The Ocean and Climate Systems 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.

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)

Solar radiation processes on the east antarctic plateau.
Stephen G. Warren and Thomas Grenfell, University of Washington.

This project is an experimental study of solar radiation processes near the surface 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)

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 and NSF/OPP 01–26263)

A study of atmospheric oxygen variability in relation to annual-to-decadal variations in terrestrial and marine ecosystems.

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 in the sea. (O–204-P; NSF/ATM 00–00923)

Validation of the Atmospheric Infrared Sounder (AIRS) over the Antarctic Plateau.

Von P. Walden, University of Idaho.

The Antarctic Plateau is ideal for calibrating and validating infrared satellite instruments. The large continental ice sheet is one of the most homogeneous surfaces on Earth in terms of surface temperature and emissivity. Ground-based measurements of upwelling infrared radiation from the surface between 8 and 12 micrometers are very nearly equal to those measured by satellite instruments because of minimal atmospheric emission and absorption. Therefore, accurate measurements of spectral infrared radiance can provide valuable validation data for the National Aeronautics and Space Administration’s Atmospheric Infrared Sounder (AIRS).

We will measure upwelling and downwelling spectral infrared radiance with the Polar Atmospheric Emitted Radiance Inferometer. Its viewing angle will be adjustable in both nadir and azimuth to match the AIRS viewing angle of the surface and atmosphere. Also, we will use the AIRS Mobile Observing System to map changes in surface radiation at spatial scales similar to the AIRS field of view. Then, in conjunction with the University of Nice and the University of New South Wales, we will use a Vaisala atmospheric sounding system to obtain temperature and humidity profiles. Finally, using a ground-based global positioning system unit, we will attempt to measure the extremely low values of total precipitable water (about 1 millimeter in the summer).

The data we gather will be extremely helpful in validating the measurements obtained from AIRS. (O–213–M; NASA award)

Measurements and improved parameterizations of the thermal conductivity and heat flow through first-year sea ice.
Hajo Eicken, University of Alaska–Fairbanks, and Martin Jeffries, University of Alaska Geophysical Institute.

The sea-ice cover in the polar oceans strongly modifies ocean-atmosphere heat transfer. Most important, the ice cover thermally insulates the ocean, with sea-ice thermal conductivity determining the magnitude of the heat flow for a given ice temperature gradient. Despite the importance of sea ice (second only to ice albedo), our knowledge of sea-ice thermal conductivity is limited to highly idealized models developed several decades ago. General circulation models (GCMs) and large-scale sea-ice models include overly simplistic parameterizations of ice thermal conductivity that are likely to contribute significantly to errors in estimating ice production rates.

We will carry out a set of field measurements from which the thermal conductivity of first-year sea ice will be derived as a function of ice microstructure, temperature, salinity, and other parameters. Measurements will be carried out by letting thermistor arrays freeze into the fast ice of McMurdo Sound, which represents an ideal natural laboratory for this type of measurement. To minimize errors and identify the most robust technique, we will collaborate with colleagues from New Zealand and compare different methodologies for measurement and analysis. We will also assess the impact of ice microstructure (spatial distribution of brine, crystal sizes) and convective processes on the effective rate of heat transfer.

Antarctic data will be compared with arctic thermal conductivity data sets to assess regional contrasts and the impact of different physical processes on heat flow and to arrive at a comprehensive, improved parameterization of ice thermal conductivity for large-scale simulations and GCMs. This component of the work will involve ice-growth modeling and collaboration with the Sea-Ice Model Intercomparison Project Team established under the auspices of the World Climate Research Program. This research will advance and improve

- our understanding of the processes and parameters controlling heat transfer and the thermal conductivity of first-year sea ice,
- techniques for deriving thermal conductivity and heat flow data from thermistor arrays,
- our understanding of sea-ice processes and heat flow through the ice cover in McMurdo Sound,
- parameterizations of thermal conductivity for use in large-scale and high-resolution one-dimensional simulations, and
- the representation of first-year ice thermal properties (both antarctic and arctic) in GCMs. (O–253–M; NSF/OPP 01–26007)

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, South Pole Station.

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)

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

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

The National Oceanic and Atmospheric Administration has been conducting studies to 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)

Antarctic automatic weather station program: 2001–2004.

Charles Stearns and George 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.

Their data 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/S; NSF/OPP 00–88058)

Advanced Microwave Scanning Radiometer (AMSR) sea-ice validation during the *Laurence M. Gould* traverse to Antarctica.

Konrad Steffen, University of Colorado–Boulder.

We intend to make passive microwave measurements onboard the *Laurence M. Gould* while enroute from Puente Arenas, Chile, to Antarctica in August and September 2003. We will use passive microwave radiometers to monitor the sea-ice surface at four frequencies [11.4 gigahertz (GHz), 21 GHz, 35 GHz, and 94 GHz] at horizontal vertical polarizations. The brightness temperatures can then be related to aircraft overflight measurements and to AMSR-E [Advanced Microwave Scanning Radiometer EOS (Earth Observing System)] satellite measurements.

We will also

- make meteorological measurements of temperature, wind speed and direction, humidity, and pressure;
- make latent and sensible heat flux measurements with eddy-correlation instruments to derive the heat fluxes over various types of ice;

- examine short- and long-wave radiation components of incoming and outgoing fluxes;
- gather cloud statistics with an all-sky camera with hemispheric coverage;
- make optical path-length measurements;
- make sea and ice-surface temperature profile measurements along the ship's transect;
- make *in situ* ice thickness and salinity profile measurements of various ice types characteristic of regions along the ship's transect;
- analyze snow layers over sea ice with ground-penetrating radar;
- make spectral reflectance measurements of different snow and ice types for the 300- to 2,500-nanometer (nm) range with 1- to 3-nm spectral resolution.

We also plan to launch about 50 radiosonde balloons to measure the temperature, wind speed and direction, and humidity profile from the surface of the water to about 10 kilometers above it. (O–309–L; NASA award)

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

Anthony Hansen, Magee Scientific Company.

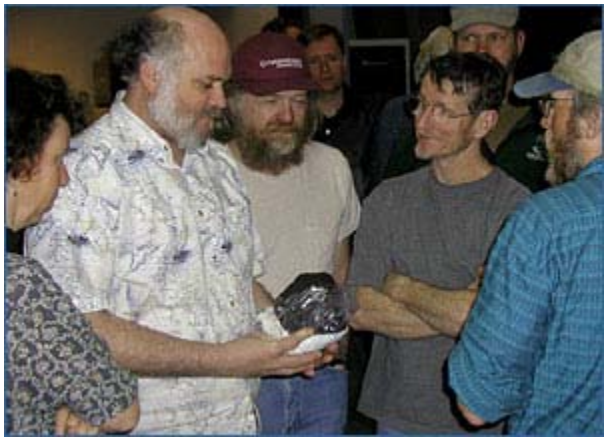
We will develop and test a self-contained, transportable module that will provide a sheltered, temperature-controlled interior environment for standard, rack-mounted equipment. Electric power will be provided by solar panels and a wind generator, backed up by batteries with several days' capacity. The 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 could be placed anywhere it is needed. (O–314–M; NSF/DBI 01–19793)

GEOLOGY AND GEOPHYSICS

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.



Steve Presher, left, a chef at McMurdo Station, inspects a meteorite recovered by the Antarctic Search for Meteorites team during the austral 2002-03 summer season.

NSF photo by Mark Sabbatini

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 them both.

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 geological controls to ice-sheet behavior, and defining geological 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 geological 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 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://www.nsf.gov/cgi-bin/good-bye?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 [http://www.nsf.gov/cgi-bin/good-bye?http://www.arf.fsu.edu/] at Florida State University, 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 geological 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.

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 Antarctic Resource Center (ARC) 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 ARC 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,

- applying new high-accuracy remote-sensing measurement technologies such as airborne laser altimetry and digital cameras, and

- 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; NSF/OPP 02–33246)

The antarctic search for meteorites (ANSMET).

Ralph Harvey, Case Western Reserve University.

Since 1976, ANSMET (the antarctic search for meteorites program) has recovered more than 12,000 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 a meteorite 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 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 2003–2004 field season, ANSMET's main field party (8 people) will work at the LaPaz icefields, approximately 250 miles from Amundsen-Scott South Pole Station. More than 200 meteorites were recovered from the site during reconnaissance visits in 1991 and 2002. This year's field team will begin 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 4 people will conduct high-level reconnaissance at a number of icefields throughout the mid Transantarctic Mountains, from the Miller Range in the north to Roberts Massif in the south. This reconnaissance team will visit poorly known or previously unvisited icefields, recovering meteorites and identifying their potential for more detailed searches during future seasons. (G-057-M and G–058–M; NSF/OPP 99–80452)

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

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

We plan to investigate the Late Mesozoic vertebrate paleontology of the James Ross Basin. 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, 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, are unresolved questions in paleontology. These 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 while marine reptiles swam 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.

Our research will result in important insights about 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 in the United States. (G–061–E; NSF/OPP 00–03844 and NSF/OPP 00–87972)

Calibration of cosmogenic argon production rates in Antarctica.

Paul R. Renne, Berkeley Geochronology Center.

We intend to establish the systematics of cosmogenic argon production required to establish its measurement as a routine surface exposure dating tool analogous to existing methods based on helium-3, beryllium-10, carbon-14, neon-21, and aluminum-26. Cosmogenic argon offers advantages over existing cosmogenic chronometers in that it is stable (hence applicable to long-term or ancient exposure dating) and less prone to diffusive loss than helium or neon.

Argon-38 is produced principally by spallation of calcium and (probably) potassium, and it is most easily measured using neutron-irradiated samples, as has been done routinely on extraterrestrial samples for decades. Our initial measurements on antarctic samples demonstrate the viability of this method for terrestrial samples and suggest an average production rate of more than 100 atoms/gram-calcium/year. Existing data suggest that argon-38/calcium exposure ages younger than 105 years can be accurately determined by this method.

Further work on calcic minerals (apatite, sphene, clinopyroxene, plagioclase, calcite) whose exposure histories are constrained by helium-3 and neon-21 concentration data will be used to determine the calcium-derived production rate. Analogous work on potassium-rich minerals (potassium-feldspars, micas) will be used to constrain the production of argon-38 from potassium, which should theoretically be comparable to that from calcium when the same neutron-activation method is used.

To maximize cosmic radiation dosage for calibration purposes, our analytical work will use existing samples plus new ones to be collected from the McMurdo Dry Valleys of Antarctica. Laboratory studies of the retentivity of argon-38 in appropriate minerals will be used to help evaluate our results and guide future applications. (G–064–M; NSF/OPP 01–25194)

Global climate change and the evolutionary ecology of antarctic mollusks in the Late Eocene.

Daniel Blake, University of Illinois–Urbana, and Richard Aronson, Marine Environmental Science Consortium.

Global climate change in the late Eocene had an important influence in Antarctica. This was the beginning of the transition from a cool-temperate climate to the current one. The cooling trend strongly influenced the structure of shallow-water and antarctic marine communities, and these effects are evident in the ecological relationships among modern species. Cooling reduced the abundance of fish and crabs, which in turn reduced skeleton-crushing predation on invertebrates. Reduced predation allowed dense populations of ophiuroids (brittlestars) and crinoids (sea lilies) to appear in shallow-water settings at the end of the Eocene. These low-predation communities appear as dense fossil echinoderm assemblages in the La Meseta Formation on Seymour Island.

Today, dense ophiuroid and crinoid populations are common in the shallow waters of Antarctica but have generally disappeared from similar habitats at temperate and tropical latitudes. Although the influence of declining predation on antarctic ophiuroids and crinoids is well documented, the effects of cooling on the more abundant mollusks have not been investigated. We will therefore examine the evolutionary ecology of gastropods (snails) and bivalves (clams) in the late Eocene.

We will test a series of hypotheses based on the predicted responses of mollusks to declining temperature and changing levels of predation:

- First, defensive features of gastropod shells, such as spines and ribbing, should decline as the temperature and, therefore, the activity of skeleton-crushing predators declined.

- Second, drilling of bivalve prey by predatory gastropods should increase, since the drillers should themselves have been subject to less predation as the temperature declined. Drilled shells should become more common.

- Third, patterns in the thickness of shells will make it possible to separate the direct physiological effects of temperature (shells are harder to produce at cooler temperatures and so should be thinner) from the indirect effects of temperature (increased drilling predation should result in thicker shells).

Seymour Island contains the only readily accessible fossil outcrops from this crucial period in Antarctica. Global climate change will probably increase upwelling in some temperate coastal regions. Evidence suggests that the resulting decline in sea temperatures could lower predation in those areas. Understanding the response of the La Meseta fauna to cooling in the late Eocene will provide direct insight into the rapidly changing structure of modern benthic communities. (G–065–E; NSF/OPP 99–08856 and NSF/OPP 99–08828)

Boron in antarctic granulite-facies rocks: Under what conditions is boron retained in the middle crust?

Edward Grew, University of Maine.

Trace elements provide valuable information on the changes sedimentary rocks undergo as temperature and pressure increase during burial. One such element, boron, is particularly sensitive to increasing temperature because of its affinity for aqueous fluids, which are lost as rocks are buried. The boron content of unmetamorphosed pelitic sediments ranges from 20 to over 200 parts per million, but rarely exceeds 5 parts per million in rocks subjected to the conditions of the middle and lower crust. Devolatization with loss of aqueous fluid and partial melting with removal of melt have been cited as primary causes for boron depletion in granulite-facies rocks. Despite the pervasiveness of both of these processes, rocks rich in boron are locally found in granulite-facies in the Larsemann Hills along Prydz Bay. More than 20 lenses and layered bodies containing four borosilicate mineral species crop out over a 50-square-kilometer area.

While most investigators have focused on the causes of boron loss, we will use field observations and mapping, chemical analyses of minerals and their host rocks, and microprobe age-dating to investigate how boron is retained during high-grade metamorphism. Our working hypothesis is that a high initial content facilitates retention of boron during metamorphism. For example, in a rock with large amounts of the borosilicate tourmaline (such as strata-bound tourmalinite), the breakdown of tourmaline to melt could result in the formation of prismatine and grandidierite, two borosilicates found in the Larsemann Hills. This situation is rarely observed in rocks with a modest boron content, in which tourmaline breakdown releases boron into partial melts, which in turn remove it when they leave the system.

Strata-bound tourmalinite is associated with manganese-rich quartzite, phosphorus-rich rocks, and sulfide concentrations that could be indicative of a tourmalinite protolith in a highly metamorphosed complex where sedimentary features have been destroyed by deformation. Because partial melting plays an important role in the fate of boron, our research will focus on the relationship between borosilicate units, granite pegmatites, and other granitic intrusives. Our results will provide information on boron cycling at deeper levels in the Earth's crust and on possible sources of boron for granites originating from deep-seated rocks. (G–067–E; NSF/OPP 02–28842)

Improved Cenozoic plate reconstructions of the circum-antarctic region.

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

Well-constrained Cenozoic plate reconstructions of the circum-antarctic region are critical for examining a number of problems of global geophysical importance, among them

- relating plate kinematics to geological consequences in various plate circuits (Pacific–North America, Australia-Pacific);

- understanding what drives plate tectonics (which requires well-constrained kinematic information to distinguish between different geodynamic hypotheses); and

- understanding the rheology of the plates themselves, including the amount of internal deformation they can support and the conditions leading to the formation of new plate boundaries through the breakup of existing plates.

By obtaining better constraints on the motion of the antarctic plate with respect to other plates, and by better quantifying the internal deformation within Antarctica, we can contribute to understanding these fundamental issues.

We will analyze existing data to address several specific issues related to the motion of the antarctic plate. First, we will work on four-plate solutions of Australia–Pacific–West Antarctica–East Antarctica motion to constrain the rotation parameters for separation between East and West Antarctica by imposing closure on the circuit and using relevant marine geophysical data from all four of the boundaries. We will determine the uncertainties in the resulting rotation parameters based on the uncertainties in the data points. These can then be propagated in the plate circuit to address the issues listed earlier. Second, we will use well-navigated transit data from the icebreaking research ship *Nathaniel B. Palmer* to further quantify Pacific–West Antarctica rotation parameters for Tertiary time. These parameters and their uncertainties will be used to assess plate rigidity and will be included in the circuit studies.

We will collect new marine geophysical data (on underway gravity, magnetics, and swath bathymetric data) on *Nathaniel B. Palmer* transit cruises. On one of the cruises, we propose to teach a formal class in marine geophysics to graduate and undergraduate students to integrate teaching activities with the data collection objectives. (G–071–N; NSF/OPP 01–26334 and NSF/OPP 01–26340)

Dry Valley Seismic Project.

Robert 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.

These data will eventually reach the international seismological community; 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. 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)

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

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

We will conduct global positioning system (GPS) measurements of bedrock crustal motions in an extension of the Transantarctic Mountains Deformation Network (TAMDEF) in order 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 will 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)

Mount Erebus Volcano Observatory and Laboratory (MEVOL).

Philip Kyle and Richard 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 will develop 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 societal relevance of volcanology and other aspects of earth science, we expect to continue public outreach through lectures, media interaction, and inquiry response. (G–081–M; NSF/OPP 02–29305)

A global positioning system network to determine crustal motions in the bedrock of the West Antarctic Ice Sheet.

Ian Dalziel and Frederick Taylor, Institute of Geophysics, University of Texas–Austin; Robert Smalley, University of Memphis; and Michael G. Bevis, University of Hawaii.

Motion in the bedrock that underlies the West Antarctic Ice Sheet is suspected from rifting, active volcanism, and uncertainties in global plate circuits, but it is unconstrained. Without reliable data on tectonic and ice-induced crustal motions, we will never be able to fully comprehend the ice sheet's past, present, and future dynamics. Without that knowledge, we can neither develop reliable global change scenarios for the future nor accurately factor the antarctic region into global plate movements. Currently, permanent global

positioning system (GPS) networks that measure bedrock movement are established only on the fringe of the West Antarctic Ice Sheet; they cannot provide the data needed to understand subglacial volcanism, active tectonics, and ice streaming.

Our project is focused on establishing baseline, long-term, reliable geodetic measurements of the crustal motion in the bedrock beneath the West Antarctic Ice Sheet. We are building a West Antarctica GPS Network (WAGN) of at least 15 sites on nunataks across the interior—an area comparable to the area from the Rocky Mountains to the Pacific coast—over 3 years, beginning in the 2001–2002 austral summer.

The first season, we initiated the network and tested the precision and velocities at critical sites. The second season, we built monuments and made initial measurements. If crustal motions are relatively slow, meaningful results will begin to emerge only over the next 5 years or so. Once it is permanently established, however, the network should yield increasingly meaningful results. Indeed, the slower the rates turn out to be, the more important it is to start measuring early.

West Antarctic Ice Sheet bedrock is so scattered and remote that erecting a continuous string of permanent GPS stations is unrealistic. Instead, we are using roving receivers (based in permanent monuments set in solid rock outcrops) in place for only a short time at each site and providing data that can be ranged against continuous data acquired from permanent GPS stations elsewhere. Each of these bases can be converted to a permanent, autonomous station when more logistics and satellite data linkage are in place throughout West Antarctica. When detectable motions occur, we can reoccupy the most critical sites, obtain more reliable velocities, and possibly reoccupy the entire network.

We expect this project to establish important early indicators of crustal plate dynamics beneath the West Antarctic Ice Sheet. As scientists take these into account in refining their models, future measurements and a time-series of the geodetic data should gradually produce a more constrained picture of plate rotations and elastic and viscoelastic motions caused by deglaciation and changes in ice mass in the West Antarctic Ice Sheet. (G–087–M; NSF/OPP 00–03619)

A broadband seismic experiment to investigate deep continental structure across the east-west antarctic boundary.

Douglas Wiens, Washington University, and Andrew Nyblade and Sridhar Anandakrishnan, Pennsylvania State University.

Antarctica's outline looks generally like that of Australia, though half again as large; but beneath its enormous ice sheet lies evidence of its origin. East Antarctica has a bedrock continent-like foundation, while the ice sheet over West Antarctica—a third the area—in fact covers a series of islands. West Antarctica shares a geologic history with the Andes Mountains, the result of plates colliding and subducting. East Antarctica is more like a large chunk that broke free of the supercontinent Gondwanaland and drifted to a new position at the bottom of the world. The boundary between these two regions (with their disparate geologic pedigrees) is called the east-west antarctic boundary, and the crust and upper mantle here reveal many important and interesting distinctions that tell the basic story of the tectonic development of Antarctica.

In November 2000, we began making seismic measurements using 3 different arrays and 44 seismic stations, all geared to evaluating geodynamic models of the evolution of Antarctica. To analyze the data, we use a variety of proven modeling techniques, including body- and surface-wave tomography, receiver function inversion, and shear-wave splitting analysis.

One basic question is, How were the Transantarctic Mountains formed? Though widely considered a classic example of rift-flank uplift, there is little consensus about the exact mechanism. Many theories have been proposed, ranging from delayed-phase changes to transform-flank uplift. All of these make assumptions about the upper mantle structure beneath and adjacent to the rift-side of the mountain front.

Another focus will be the structure of the east antarctic craton, the highest ice block in the world. Was this anomalous elevation a prime driver in the onset of glaciation there? More to the point, how did it arise? Proposed models include isostatic uplift from thickened crust, anomalously depleted upper mantle, and thermally modified upper mantle, as well as dynamic uplift. How far the old continental lithosphere extends is also uncertain. In particular, it is not known whether the old lithosphere extends to the western edge of East Antarctica beneath the crustal rocks deformed during the Ross Orogeny (formation).

When completed and analyzed, this comprehensive set of data and theory testing will enable new maps of the variation in crustal thickness, upper mantle structure, anisotropy, and mantle discontinuity topography across the boundary of East and West Antarctica, providing a much enhanced foundation for understanding

the geodynamics of the region. (G–089–M; NSF/OPP 99–09603, NSF/OPP 00–09648, and NSF/OPP 02–26538)

IRIS—Global seismograph station at South Pole.

Rhett 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 126 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 together continue to 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. (G–090–S; NSF/EAR 00–04370)

Neotectonic structure of Terror Rift, Western Ross Sea.

Terry Wilson, Ohio State University, and Lawrence Lawver, University of Texas–Austin.

Displacements between East and West Antarctica have long been proposed based on global plate circuits, apparent hot-spot motions, geologic grounds, seafloor magnetic anomalies, or paleomagnetism. Such motions require plate boundaries that cross Antarctica, yet these boundaries have never been explicitly defined.

We will attempt to delineate the late Cenozoic boundary between East and West Antarctica along the Terror Rift in the western Ross Sea by using marine and airborne geophysical data to map the fault patterns and volcanic structure along the eastern margin. We will also map the orientations of volcanic fissures and seamount alignments on the seafloor. The volcanic alignments will show the regional extension or shear directions across the rift and the orientations of associated crustal stresses.

Delineation of neotectonic fault patterns will demonstrate whether the eastern margin of the rift forms a continuous boundary and whether the rift itself can be linked with postulated strike-slip faults in the northwestern Ross Sea. We will combine seafloor findings with fault kinematic and stress field determinations from the surrounding volcanic islands and the Transantarctic Mountains.

Over 3 years, we will complete a collaborative structural analysis of existing multichannel and single-channel seismic profiles and aeromagnetic data over the Terror Rift, locating volcanic vents or fissures and any fault scarps on the seafloor and making a preliminary determination of the age and kinematics of deformation in the Terror Rift. We will then carry out multibeam sonar mapping of selected portions of the seafloor and use these data to map the orientations and forms of volcanic bodies and the extent and geometry of neotectonic faulting associated with the Terror Rift.

In summary, we will

- complete a map of neotectonic faults and volcanic structures in the Terror Rift,
- interpret the structural pattern to derive the motions and stresses associated with the development of the rift,
- compare rift structures with faults and lineaments mapped in the Transantarctic Mountains to improve age constraints on the structures, and

- integrate the late Cenozoic structural interpretations from the western Ross Sea with Southern Ocean plate boundary kinematics. (G–099–N; NSF/OPP 01–25624 and NSF/OPP 01–26279)

Geology and geochronology of the Byrd Glacier discontinuity, Antarctica: A pilot study.

Edmund Stump, Arizona State University.

The East Antarctic Ice Sheet breaches the Transantarctic Mountains by way of a handful of outlet glaciers; Byrd Glacier is the largest of these, contributing about a quarter of all the ice moving from there to the Ross Ice Shelf. A major geological discontinuity in the Ross Orogen of the Transantarctic Mountains has been discovered beneath Byrd Glacier.

We will continue the probe into this area by mapping the Byrd Group (Early Cambrian Shackleton limestone and younger Douglas conglomerate) for structure and by trying to develop a basis for understanding its kinematic evolution. Another target of interest is Mount Madison; its geochronology and structural and metamorphic history should be revealed from samples of outcropping, amphibolite-grade metamorphic rocks (Selbourne marble).

Using snowmobiles and supported by helicopters, we will also collect igneous and high-grade metamorphic rocks (Horney Formation) in the Britannia Range and will investigate Shackleton limestone. We hope to determine the thermochronology of Selbourne marble and to further constrain the provenance and age of the Douglas conglomerate.

All rock samples will be subjected to followup studies. Structural data will be reduced at Arizona State University, metamorphic studies of Selbourne marble will be conducted at the University of Siena, and isotopic studies will be done at both Ohio State University (argon-40/argon-39, Sm-Nd) and the University of Kansas (U-Pb). (G–116–O; NSF/OPP 99–09463)

Geomagnetic field as recorded in the Mount Erebus Volcanic Province: Key to field structure at high southern latitudes.

Lisa Tauxe, Hubertus Staudigel, Catherine Constable, and Anthony Koppers, Scripps Institution of Oceanography, University of California–San Diego; and Philip Kyle and William McIntosh, New Mexico Institute of Mining and Technology.

We aim to use lava flows from the Mount Erebus Volcanic Province to study the magnetic field of the Earth over the past 5 million years in order to test models of its geomagnetic dynamo. Paleomagnetic data (directions of ancient geomagnetic fields obtained from rocks) play an important role in a variety of geophysical studies of the Earth, including plate tectonic reconstructions, magnetostratigraphy, and studies of the behavior of the ancient geomagnetic field (called paleogeomagnetism).

Over the past four decades, the key assumption in many studies has been that the average direction of the paleomagnetic field corresponds to one that would have been produced by a geocentric axial dipole (analogous to a bar magnet at the center of the Earth) and that paleoinclinations (the dip of magnetic directions from rocks) provide data of sufficient accuracy to enable them to be used in plate reconstructions. A recent reexamination of the fundamental data underlying models of the time-averaged field has shown that the most glaring deficiency in the existing database is a dearth of high-quality information, including paleointensity data, from high latitudes.

We will therefore undertake a sampling and laboratory program on suitable sites from the Mount Erebus Volcanic Province in order to produce the quality data from high southern latitudes that are essential to an enhanced understanding of the time-averaged field and its long-term variations. (G–182–M; NSF/OPP 02–29403 and NSF/OPP 02–29604)

Shackleton Glacier area: Evolution of vegetation during the Triassic.

Edith Taylor and Thomas Taylor, University of Kansas–Lawrence.

The rocks of the central Transantarctic Mountains have been a source of fossil discoveries over the past 30 years. The rare juxtaposition of sites that include many different types of plant preservation, the exceptional quality of the fossils, and the biodiversity of the sites make this area unique. The Paleozoic/Mesozoic transition is a critical time in plant evolution. A unique variety of seed plant groups existed, and several have been suggested as the ancestors of flowering plants. There was also a massive floral change from the Permian to the Triassic.

While most fossil plants occur as disarticulated leaves, stems, and reproductive organs, many in the Shackleton Glacier area are partially articulated, thus making it possible to gain a more accurate picture of the entire plant and its place in the ecosystem. We will examine Triassic floras from two sites in the Shackleton Glacier area (Collinson Ridge and an unnamed ridge southeast of Schroeder Hill). In addition to compression fossils, the latter also includes some permineralized peat and fossil stumps. The Collinson Ridge site is important because it contains fossil peat and logs in presumably Lower Triassic rocks. Preliminary analysis of petrified material collected during the 1995–1996 field season, however, suggests that perhaps it is Late Permian rather than Early Triassic, as would be expected. It is therefore important to elucidate the biostratigraphy of this area because the position of the Permian-Triassic boundary is crucial in understanding the timing of terrestrial extinctions around it. Further collecting at both of these sites and analysis of the fossil material in the laboratory will address these discrepancies and yield important new information about Triassic plant evolution.

Paleobotany is ideally suited to education and outreach. Workshops and temporary exhibits on antarctic science have been developed through programs sponsored by the University of Kansas Natural History Museum and Biodiversity Research Center, and we will continue this activity. Student involvement has also been extensive and will be continued. (G–293–M; NSF/OPP 02–29877)

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

Bjorn Johns, University Navstar Consortium (UNAVCO/UCAR).

UNAVCO provides year-round support for scientific applications of the global positioning system (GPS) to the U.S. Antarctic Program, which is supported and managed by the National Science Foundation's Office of Polar Programs. This support includes preseason planning, field support, and postseason followup, as well as development work for new applications. UNAVCO maintains a satellite facility at McMurdo Station during the austral summer research season, providing a full range of support services, such as geodetic GPS equipment, training, project planning, field support, technical consultation, data processing, and data archiving.

UNAVCO also operates a community differential GPS base station that covers McMurdo Sound and Taylor Valley, provides maintenance support to the MCM4 continuous GPS station as contractual support to the National Aeronautics and Space Administration's GPS Global Network, and supports remote continuous GPS stations for scientific investigations.

Using GPS, vector baselines between receivers separated by 100 kilometers or more are routinely measured to within 1 centimeter (that is, 100 parts per billion). UNAVCO is also able to support researchers who are investigating global, regional, and local crustal motions where maximum accuracy (in the millimeter range) of baseline measurement is required. GPS measurements using portable equipment can be completed in a few hours or less. Such expediency lends itself to research applications in global plate tectonics, earthquake mechanics, volcano monitoring, and regional tectonics. (G–295–M; NSF/EAR 99–03413)

Vertebrate paleontology of the Triassic to Jurassic sedimentary sequence in the Beardmore Glacier area of Antarctica.

William Hammer, Augustana College.

During a 3-year study, we will investigate fossils from Triassic and Jurassic dinosaurs and other vertebrates in the central Transantarctic Mountains. A field program to search for Upper Triassic to Jurassic fossil vertebrates in the Beardmore Glacier region will be carried out in the 2003–2004 austral summer. Initially, we will concentrate our efforts on the Hanson Formation, which has produced the only Jurassic dinosaur fauna in Antarctica. We will then further excavate the Hanson dinosaur locality on Mount Kirkpatrick and will follow that with an extensive search of other exposures of the Hanson, Falla, and Upper Fremouw Formations in the Beardmore area.

Our field party will operate for 3 to 4 weeks out of a small helicopter camp in the Beardmore area. The field party will consist of six persons, to allow two groups of three to work independently at different sites. One group will excavate the Mount Kirkpatrick site, while the other reconnoiters. In addition to collecting new specimens, we will interpret the depositional settings for each of the vertebrate sites. Our second and third years will be dedicated to preparing and studying the vertebrates.

Antarctic vertebrates provide a unique opportunity to study the evolutionary and biogeographic significance of high-latitude Mesozoic fauna, and this project should result in significant advances in knowledge. (G–298–M; NSF/OPP 02–29698)

BEARDMORE GLACIER REGION PROJECTS

River-like glaciers flow through the Transantarctic Mountains towards the Ross Ice Shelf.

NSF photo by Josh Landis

Late Paleozoic-Mesozoic fauna, environment, climate, and basinal history: Beardmore Glacier area, Transantarctic Mountains.
Molly Miller, Vanderbilt University, and John Isbell, University of Wisconsin-Milwaukee.

We will investigate paleoenvironmental conditions during the late Paleozoic and Mesozoic in central interior Antarctica. The 4-kilometer-thick sequence of sedimentary rocks in the Beardmore Glacier area, known as the Beacon Supergroup, records 90 million years of Permian through Jurassic history of this high-paleolatitude sector of Gondwanaland. The sequence accumulated in a foreland basin with a rate of subsidence approximately equal to the rate of deposition. The deposits have yielded diverse vertebrate fossils, fossil forests, and exceptionally well preserved plant fossils that give a unique glimpse of glacial, lake, and stream/river environments and ecosystems and provide an unparalleled record of the depositional, paleoclimatic, and tectonic history of the area.

We plan to integrate sedimentologic, paleontologic, and ichnologic observations to answer the following focused questions:

- What are the stratigraphic architecture and alluvial facies of Upper Permian to Jurassic rocks in the Beardmore Glacier area?
- In what tectonostratigraphic setting were these rocks deposited?
- Did vertebrates inhabit the cold, near-polar Permian floodplains, as indicated by vertebrate burrows, and can these burrows be used to identify for the first time the presence of small early mammals in Mesozoic deposits?
- How did bottom-dwelling animals in lakes and streams use substrate ecospace, how did ecospace use at these high paleolatitudes differ from use in equivalent environments at low paleolatitudes, and what does burrow distribution reveal about the seasonality of river flow and thus about paleoclimate?

Answers to these questions will

- clarify the paleoclimatic, basinal, and tectonic history of this part of Gondwanaland;
- elucidate the colonization of near-polar ecosystems by vertebrates;
- provide new information on the environmental and paleolatitudinal distributions of early mammals; and
- allow semiquantitative assessment of the activity and abundance of bottom-dwelling animals in different freshwater environments at high and low latitudes.

We expect this project to contribute significantly to an understanding of paleobiology and paleoecology on a high-latitude floodplain during a time in Earth's history when the climate was much different than it is today. (G-094-M; NSF/OPP 01-26146 and NSF/OPP 01-26086)

Permian and Triassic floras from the Beardmore Glacier region: Icehouse to greenhouse?

Edith Taylor and Thomas Taylor, University of Kansas-Lawrence.

Over the past 30 years, the rocks of the central Transantarctic Mountains have been a source of outstanding plant fossil discoveries, including Permian and Triassic permineralized peat, fossil forests silicified in growth position, and compression floras with cuticular preservation. The rare juxtaposition of sites that include many different types of plant preservation, its exceptional quality, and the richness of the sites make this area unique.

We will collect Permian and Triassic plant megafossils from the Beardmore Glacier area (compression floras, especially those from Graphite Peak, and permineralized peats from Skaar Ridge and Fremouw Peak, both near Walcott Névé). Since permineralizations preserve a three-dimensional record of plant organs, they are important in understanding the basic morphology and anatomy of fossil plants, as well as detailing relationships among groups. The data provided by the juxtaposition of plant fossils preserved as permineralizations and compressions have already contributed greatly to our understanding of late Paleozoic–early Mesozoic plant evolution.

The Permian and Triassic represent an important time in plant evolution, and one about which we still know relatively little. The glossopterid seed ferns in the Permian and the corystosperms in the Triassic were the dominant plant groups in Gondwana. Since both groups had enclosed seeds, they have been proposed at one time or another as possible ancestors of flowering plants and have figured prominently in phylogenetic analyses of seed plants. Only through a combination of permineralizations and compressions is it possible to reveal a complete picture of fossil plants and, more important, to understand their position in seed plant evolution.

We will collect plants and silicified logs from Graphite Peak, which is believed to contain the Permian/Triassic boundary. Silicified logs have been noted in the lower Buckley Formation at this site, and these will be collected and examined for tree rings, which can be compared with tree rings in Late Permian wood (upper Buckley) from nearby Mount Achernar. The Late Permian has been assumed to be much warmer than the Early-Middle Permian, and this should be reflected in the rings' width and structure.

Our findings should lead to significant improvements in knowledge of plant evolution and paleoenvironmental conditions during the critical Permian to Triassic interval. (G–095–M; NSF/OPP 01–26230)

Geophysical mapping of the East Antarctic Shield adjacent to the Transantarctic Mountains.

John Goodge, University of Minnesota, and Carol Finn, U.S. Geological Survey-Denver.

The East Antarctic Shield is one of Earth's oldest and largest cratonic assemblies. Interest in the evolution of the shield has been rekindled over the past decade by tectonic models linking East Antarctica with other Precambrian crustal elements in the Rodinia and Gondwanaland supercontinents. It has been postulated that the Pacific margin of East Antarctica was rifted from Laurentia during the late Neoproterozoic breakup of Rodinia; it then developed as an active plate boundary during the subsequent amalgamation of Gondwanaland. A better understanding of the geological evolution of the shield is therefore critical for studying Precambrian crustal evolution in general, as well as resource distribution, biosphere evolution, and glacial and climate history during later periods. Because of nearly complete coverage by continental-size ice sheets, however, Antarctica remains the single most geologically unexplored continent. Also, little is known about the composition and structure of the shield's interior.

Therefore, we will conduct an airborne magnetic survey (coupled with ground-based gravity measurements) across an important window into the shield where it is exposed in the Nimrod Glacier area of the central Transantarctic Mountains. Specific goals are to

- characterize the magnetic and gravity signature of the east antarctic crustal basement exposed at the Ross margin,
- extend magnetic data westward along a corridor across the East Antarctic Ice Sheet to image the crust in ice-covered areas,
- obtain magnetic data over the Ross Orogen to image the ice-covered boundary between basement and supracrustal rocks, and

- use the shape, trends, wavelengths, and amplitudes of magnetic anomalies to define magnetic domains in the shield.

Our survey (to be done in collaboration with German colleagues) will, for the first time, use geophysical methods to characterize the shield terrain in this sector. This baseline over the exposed shield will allow for a better interpretation of geophysical patterns in other ice-covered regions and can be used to target future investigations. Once the survey is done, we will then perform data reduction, interpretation, and geological correlation.

This research will lead to new basic knowledge about the antarctic continent, which in turn may help with applied research in other fields such as the glacial history of Antarctica. (G-291-M; NSF/OPP 02-30280 and NSF/OPP 02-32042)

Shackleton Glacier area: Evolution of vegetation during the Triassic.

Edith Taylor and Thomas Taylor, University of Kansas-Lawrence.

The rocks of the central Transantarctic Mountains have been a source of fossil discoveries over the past 30 years. The rare juxtaposition of sites that include many different types of plant preservation, the exceptional quality of the fossils, and the biodiversity of the sites make this area unique. The Paleozoic/Mesozoic transition is a critical time in plant evolution. A unique variety of seed plant groups existed, and several have been suggested as the ancestors of flowering plants. There was also a massive floral change from the Permian to the Triassic.

While most fossil plants occur as disarticulated leaves, stems, and reproductive organs, many in the Shackleton Glacier area are partially articulated, thus making it possible to gain a more accurate picture of the entire plant and its place in the ecosystem. We will examine Triassic floras from two sites in the Shackleton Glacier area (Collinson Ridge and an unnamed ridge southeast of Schroeder Hill). In addition to compression fossils, the latter also includes some permineralized peat and fossil stumps. The Collinson Ridge site is important because it contains fossil peat and logs in presumably Lower Triassic rocks. Preliminary analysis of petrified material collected during the 1995-1996 field season, however, suggests that perhaps it is Late Permian rather than Early Triassic, as would be expected. It is therefore important to elucidate the biostratigraphy of this area because the position of the Permian-Triassic boundary is crucial in understanding the timing of terrestrial extinctions around it. Further collecting at both of these sites and analysis of the fossil material in the laboratory will address these discrepancies and yield important new information about Triassic plant evolution.

Paleobotany is ideally suited to education and outreach. Workshops and temporary exhibits on antarctic science have been developed through programs sponsored by the University of Kansas Natural History Museum and Biodiversity Research Center, and we will continue this activity. Student involvement has also been extensive and will be continued. (G-293-M; NSF/OPP 02-29877)

Terrestrial paleoecology and sedimentary environment of the Meyer Desert Formation, Beardmore Glacier, Transantarctic Mountains.

Allan Ashworth, North Dakota State University.

Terrestrial fossils recovered from the Meyer Desert Formation are providing paleoclimatic information about the interior of Antarctica before the growth of the great ice sheets. The site is located on the Upper Beardmore Glacier, about 500 kilometers from the South Pole. Southern beech wood and leaves were discovered many years ago, but since 1995, the fossils have included the seeds of several species of vascular plants, including buttercups; the stems and leaves of several species of mosses; body parts of beetles; a puparium of a higher fly; shells of freshwater mollusks; valves of an ostracod; and a fish tooth. The largest fossils at the site are cushions of vascular plants buried in their growth positions by sediments of glacial outwash.

These sediments were deposited in stream channels and shallow pools associated with moraines that had been colonized by tundra-like vegetation harboring insects and mollusks. The fossils provide the best evidence so far of how much heat the atmosphere near the South Pole can hold.

Although the fossils are fragmentary, they are more closely related to living terrestrial and freshwater organisms than any other fossils found in Antarctica. They are most probably the direct descendants of an ancient biota that was part of Gondwanaland. Until the discovery of the Meyer Desert Formation, no fossils of terrestrial organisms, except for pollen and spores, were available to answer questions about the evolutionary relationships between organisms distributed in southern South America, Australia, New Zealand, and the subantarctic islands.

We will revisit the Meyer Desert Formation to locate and sample new fossiliferous horizons, construct an accurately scaled and correlated cross-section of the complex facies, and collect samples for a pilot project to date the deposits directly. Collectively, these studies will provide information that should help address larger questions about the size and dynamics of the East Antarctic Ice Sheet during the Neogene.

There is extensive public interest in Antarctica, in part because of the romance of exploration but also because of the threat of global warming and the potential instability of the West Antarctic Ice Sheet. Because Antarctica exerts a huge influence on the Earth's climate, oceanic circulation, and sea level, knowledge about warmer climates during the Neogene is vital. (G-294-M; NSF/OPP 02-30696)

Paleobiology and taphonomy of exceptionally preserved fossils from Jurassic lacustrine deposits, Beardmore Glacier area and southern Victoria Land, Antarctica.

Loren Babcock, Ohio State University.

Sedimentary interbeds of the Kirkpatrick Basalt represent unusual, exceptionally well preserved deposits, characterized by the presence of a variety of non-biomineralizing (so-called soft-bodied) organisms. Fieldwork in previous decades resulted in the discovery of abundant remains of conchostracans (bivalved arthropods having non-mineralized exoskeletons) and fishes; less common remains of various arthropods such as insects, syncarids, and isopods; and plant fragments. The arthropod and fish fossils range in preservational quality from disarticulated pieces to articulated remains comparable to the finest in the fossil record.

Present indications are that the Kirkpatrick lake deposits offer important windows into the evolutionary history of high-latitude, freshwater ecosystems of the middle Mesozoic. Paleoecologic and taphonomic study of these deposits can be expected to provide additional clues to the general conditions under which exceptional preservation of non-mineralized skeletal parts, and perhaps soft parts, occurred in the geologic past. This is significant because nearly all of our current understanding of conditions surrounding exceptional preservation has been derived from studies of marine deposits, marginal-marine deposits, or freshwater deposits from low to middle paleolatitudes.

Our principal objectives are to

- collect and systematically document the biota of the sedimentary interbeds of the Kirkpatrick sites in the Beardmore Glacier area and southern Victoria Land;
- document and interpret taphonomic information on the Kirkpatrick sites, including diagenetic alteration of fossils;
- describe and interpret trace fossils that are associated with the body fossils; and
- document and interpret the stratigraphic and sedimentologic context of exceptional preservation.

Considerable importance attaches to the Jurassic sites in the Transantarctic Mountains, because few sites from aqueous ecosystems of high-paleolatitude areas are known to contain non-biomineralized fossils. Completion of this study will result in a more complete understanding of the biota and paleoecology of high-latitude lake ecosystems of the middle Mesozoic. The Kirkpatrick sites will also provide information useful for interpreting Jurassic biotas in a global context. Data from this study are expected to provide information on the fundamental question of why exceptional preservation of organisms has occurred in freshwater, high-latitude settings. (G-297-M; NSF/OPP 02-29757)

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William Hammer, Augustana College.

During a 3-year study, we will investigate fossils from Triassic and Jurassic dinosaurs and other vertebrates in the central Transantarctic Mountains. A field program to search for Upper Triassic to Jurassic fossil vertebrates in the Beardmore Glacier region will be carried out in the 2003-2004 austral summer. Initially, we will concentrate our efforts on the Hanson Formation, which has produced the only Jurassic dinosaur fauna in Antarctica. We will then further excavate the Hanson dinosaur locality on Mount Kirkpatrick and will follow that with an extensive search of other exposures of the Hanson, Falla, and Upper Fremouw Formations in the Beardmore area.

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specimens, we will interpret the depositional settings for each of the vertebrate sites. Our second and third years will be dedicated to preparing and studying the vertebrates.

Antarctic vertebrates provide a unique opportunity to study the evolutionary and biogeographic significance of high-latitude Mesozoic fauna, and this project should result in significant advances in knowledge. (G-298-M; NSF/OPP 02-29698)

Permian-Triassic mass extinction in Antarctica.

Gregory Retallack, University of Oregon; Luann Becker, University of California-Santa Barbara; and Hope Jahren, Johns Hopkins University.

We will study fluvial sediments in Antarctica for evidence of what caused the greatest mass extinction in the history of life on Earth. The Permian-Triassic boundary was, until recently, difficult to locate and thought to be unequivocally disconformable in Antarctica. New studies, however (particularly those using carbon isotopic chemostratigraphy, and paleosols and root traces as indicators), together with improved fossil plant, reptile, and pollen biostratigraphy, now suggest that the precise location of the boundary might be identified; these studies have also led to local discovery of iridium anomalies, shocked quartz, and fullerenes with extraterrestrial noble gases. These anomalies are associated with a distinctive claystone breccia bed, similar to strata known in South Africa and Australia, and accepted as evidence of deforestation.

There is already much evidence from Antarctica and elsewhere that the mass extinction on land was abrupt and synchronous with extinction in the ocean. What led to such death and destruction? Carbon isotopic values are so low in these and other Permian-Triassic boundary sections that there was likely to have been some role for catastrophic destabilization of methane clathrates. Getting the modeled amount of methane out of likely reservoirs would require such catastrophic events as a meteor impact, flood-basalt eruption, or collapse of the continental-shelf, which have all been implicated in the mass extinction and for which there is independent evidence. Teasing apart these various hypotheses requires careful reexamination of beds that appear to represent the Permian-Triassic boundary and search for more informative sequences, as was the case for the Cretaceous-Tertiary boundary.

Our research on the geochemistry and petrography of boundary beds and paleosols; on carbon isotopic variation through the boundary interval; and on fullerenes, iridiums, and helium is designed to test these ideas about the Permian-Triassic boundary in Antarctica and to shed light on the processes that contributed to this largest of mass extinctions. We will conduct our fieldwork in the central Transantarctic Mountains and in southern Victoria Land, with an initial objective of examining the stratigraphic sequences for continuity across the boundary. Such continuity is critical for the work to be successful. If fieldwork indicates sufficiently continuous sections, a full analytical program will follow. (G-299-M; NSF/OPP 02-30086, NSF/OPP 02-29917, and NSF/OPP 02-29136)

GLACIOLOGY

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.

Near the Erebus Glacier tongue on Ross Island, Antarctica

NSF photo by Melanie Conner

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.

U.S. component of the International Trans-Antarctic Scientific Expedition: South Pole to northern Victoria Land traverse.

Paul Mayewski and Gordon Hamilton, University of Maine.

We will operate a science management office for a pilot ice-core drilling and analysis program to test the feasibility of obtaining well-dated, high-resolution isotope and chemistry records from East Antarctica. Shallow ice cores will be obtained from two locations:

- 100 kilometers from the South Pole toward the Pole of Inaccessibility, as an extension of the Byrd Station-to-South Pole International Trans Antarctic Scientific Expedition (ITASE) traverse; and
- Taylor Dome, near the original deep-coring site.

AGO 3 and AGO 4 (automated geophysical observatories) may also be sampled as part of a logistics traverse to these sites.

All of the cores collected will be examined at very high resolution and analyzed for major ions. Results from this calibration work, along with those from another project that is analyzing stable isotopes, will be used to

help plan a larger program, with the objective of mapping the spatial expression of climate variability in East Antarctica.

In addition, we will organize a community workshop to coordinate the second phase of U.S. ITASE, as well as one workshop a year, for 2 years, dedicated to writing and preparing scientific papers from phase 1 of U.S. ITASE. Further, we will use satellite image mapping to select routes for the follow-on traverse in East Antarctica. We also will produce a summary that will be made available to the community to help with planning related field programs such as deep ice radar, firn radar profiling, atmospheric chemistry, ice coring, snow surface properties for satellite observations, ice surface elevation, and mass balance. (I–153–M; NSF/OPP 02–29573)

Dynamics and climatic response of the Taylor Glacier system.

Kurt Cuffey, University of California–Berkeley, and David Morse, University of Texas–Austin.

Taylor Glacier drains the Taylor Dome region of the East Antarctic Ice Sheet and terminates in Taylor Valley, one of the ice-free or dry valleys of southern Victoria Land. This glacier provides a crucial link between two intensively studied antarctic environments: the Taylor Dome, from which a 130,000-year ice-core paleoclimate record has recently been extracted, and the dry valleys, a pivotal ecological research site and a focus of geomorphology and glacial geology studies.

The goal of our research is to significantly improve our understanding of how Taylor Glacier flows and responds to changes in climate. It has been widely recognized that such information is central to understanding the changing physical environment of the Taylor Valley ecosystem and is required for linking interpretations of the Taylor Dome paleoclimate record to interpretations of the geomorphology and glacial geology of the dry valleys. This work will thus make an important contribution to ongoing efforts to exploit the Taylor Dome–dry valleys system to build a uniquely comprehensive view of regional long-term environmental changes.

Our work has two complementary components: field research and numerical modeling. Two field seasons will be used to measure velocity, surface strain rate, mass balance, ice thickness, glacier bed reflectance, and subglacial topography along a nearly complete longitudinal transect of the Taylor Glacier and along select cross-valley transects as well. We will use this information to constrain numerical models of ice and heat flow for the Taylor Dome–Taylor Glacier system. These calibrated models will be used in turn to analyze the time-dependent response of the glacier to changes in climate. The synthesis of these results will be aimed at improving our understanding of the glacial geomorphology of Taylor Valley and at illuminating impacts on the Taylor Valley lakes ecosystem. (I–161–M; NSF/OPP 01–25579 and NSF/OPP 01–26202)

South Pole atmospheric nitrate isotopic analysis (SPANIA).

Mark Thiemens and Joel Savrino, University of California–San Diego.

Despite decades of research, several important issues in antarctic atmospheric science are presently inadequately resolved, including quantifying the sources of nitrate aerosols over time. Today, little is known about past denitrification of the stratosphere in high-latitude regions. This lack of knowledge significantly limits our ability to understand the chemical state of ancient atmospheres and therefore evaluate present and past-coupled climate/atmosphere models. The role of nitrogen in environmental degradation is well known, and atmospheric aerosols have now been shown to have a mass-independent oxygen isotopic content.

We will therefore perform a detailed laboratory analysis of the mass-independent isotopic composition of processes associated with atmospheric nitrate trapped in the snow pack at the South Pole. Specifically, we will test whether the oxygen isotopes ^{16}O, ^{17}O, and ^{18}O of nitrate can be used to probe the denitrification of the antarctic stratosphere.

We will also investigate the stable oxygen isotope ratios of nitrate collected both in real time and from the snow in Antarctica. Full-year nitrate aerosol collections, with resolution time horizons of a week, will be performed at the South Pole. Weekly aerosol collections will help us identify any seasonal trend in the ^{17}O excess anomaly and eventually link it to the denitrification of the antarctic stratosphere.

In addition, we will use this data set to test our assumption that the oxygen isotopic anomaly of nitrate is mainly formed in the stratosphere and is well preserved in the snow pack. If this is true, we will for the first time resolve an atmospheric signal extracted from a nitrate profile. The snow pit will allow us to see any trend in the data over a time span of many decades. (I–165–M/S; NSF/OPP 01–25761)

Late Quaternary history of Reedy Glacier.

John Stone, University of Washington, and Brenda 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.

Over two field seasons, we will map, date, and correlate moraines at sites along the length of the glacier. We will 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)

Refining a 500,000-year climate record from the Mount Moulton blue ice field in West Antarctica.

Todd Sowers, Pennsylvania State University; William C. McIntosh and Nelia W. Dunbar, New Mexico Institute of Mining and Technology; and James White, University of Colorado–Boulder.

The summit crater of Mount Moulton contains a 600-meter-thick, horizontally exposed section of ice with intercalated tephra layers from nearby Mount Berlin. Argon-40/argon-39 dating of the thick, near-source tephra indicates that the age of the horizontal ice section ranges between 15,000 and 492,000 years. Thus, the Mount Moulton site offers an unparalleled repository of ancient West Antarctic snow and trapped air that can be used to investigate climate over much of the past 500,000 years. The planar nature and consistent dips of the tephra layers suggest that although the ice section has thinned, it is otherwise undeformed.

We visited the Mount Moulton site during the 1999–2000 field season, at which time we collected a horizontal core representing approximately 400 meters of ice, ranging from 15,000 to more than 480,000 years old. In addition to this horizontal core, we took samples at various depths to test the quality of the climate record in the ice. We also collected 40 intercalated tephra layers to provide a chronology for the ice section. The results of this first effort are extremely encouraging. There is clearly a usable record of past climate extending back beyond 140,000 years.

There is work to do, however, to realize the full potential of this horizontal ice core. The elemental and isotopic composition of trapped gases suggests some contamination by modern air. Since gas cross-dating of ice cores is the current standard by which climate records are compared, we need to understand why and how the gas record is compromised before adding Mount Moulton to our arsenal of ice-core paleoclimate records.

Our research has the following objectives:

- to evaluate more thoroughly the integrity of the climatic record through shallow drilling of blue ice, as well as the snow field upslope from this area;
- to improve the radioisotopic dating of specific tephra layers;
- to obtain baseline information about modern snowfall deposition, mean annual temperature, and wind pumping around the summit of Mount Moulton; and

- to study how firn densification differs when surface accumulation changes from net accumulation to net ablation. (I–177–M; NSF/OPP 02–30021, NSF/OPP 02–30348, and NSF/OPP 02–30316)

Glaciology of blue ice areas in Antarctica.

Gordon Hamilton, University of Maine.

A horizontal ice core was collected at the Mount Moulton blue ice field in West Antarctica, and preliminary analyses of the sample suggest that a climate record of roughly 500,000 years is preserved in the ice there. We aim to contribute to the understanding of the Mount Moulton record by assessing the possibility that the ice-flow record has been deformed.

Specifically, we will

- resurvey an existing global positioning system (GPS) grid to determine ice velocities and strain rates,
- use ground-penetrating radar (GPR) to image the internal stratigraphy of the ice,
- use GPR to map subglacial topography, and
- collect two firn ice cores to determine stratigraphic continuity and modern accumulation rates.

In addition, we will build on the recognition of blue ice areas as archives of long climate records by conducting reconnaissance studies for a potential horizontal ice-core location in the Allan Hills of East Antarctica. We will

- resurvey an existing GPS to confirm earlier ice-velocity measurements and calculate strain rates,
- survey several profiles using GPR to image internal stratigraphy and bedrock geometry,
- collect one or two shallow firn cores to study accumulation rates,
- conduct dielectric profiling to study stratigraphic continuity over a 1- to 2-kilometer profile, and
- collect meteorites.

By collecting relevant measurements of ice flow and subglacial topography and taking samples of material, we will be able to assess the preservation of the stratigraphic sequences and contribute to the understanding of blue ice areas. (I–178–M; NSF/OPP 02–29245)

How thick is the convective zone? A study of firn air in the megadunes near Vostok.

Jeffrey Severinghaus, University of Rhode Island.

In the megadunes, extremely low snow accumulation rates lead to structural changes (large grains, pipes, and cracks) that make the permeability of firn-to-air movement orders of magnitude higher than normal. The unknown thickness of the convective zone has hampered the interpretation of ice-core nitrogen/argon isotope ratios as indicators of past firn thickness, which is a key constraint on the climatically important variables of temperature, accumulation rate, and gas age–ice age difference. We will therefore study the chemical composition of air in the snow layer (firn) in a region of megadunes near Vostok Station to test the hypothesis that a deep convective zone of vigorous wind-driven mixing can prevent gas fractionation in the upper third of the polar firn layer. Studying this extreme end-member example will better define the role of the convective zone in gas reconstructions.

We will pump air from a profile of about 20 depths in the firn to definitively test for the presence of a convective zone based on how well inert gas isotopes fit a molecular- and eddy-diffusion model. Permeability measurements on the core and two-dimensional air flow modeling will permit a more physically realistic interpretation of the isotope data and will relate mixing vigor to air velocities. We will also test a new proxy indicator of convective zone thickness on firn and ice-core bubble air; this indicator is based on the principle that isotopes of slow-diffusing heavy noble gases (krypton, xenon) should be more affected by convection than isotopes of fast-diffusing nitrogen.

Finally, we intend to test the hypothesis that the megadunes and a deep convective zone existed at the Vostok site during glacial periods; this would explain the anomalously low nitrogen/argon isotope ratios in the Vostok ice-core glacial periods. Our work will clarify phase relationships of greenhouse gases and temperature in ice-core records, with implications for understanding past and future climates. (I–184–M; NSF/OPP 02–30452)

Characteristics of snow megadunes and their potential effects on ice-core interpretation.
Theodore A. Scambos, University of Colorado–Boulder; Mary Albert, U.S. Cold Regions Research Laboratory; Mark Fahnestock, University of New Hampshire; and Christopher Shuman, National Aeronautics and Space Administration/Goddard Space Flight Center.

Vast portions of the east antarctic plateau are covered by snow megadunes: trough-and-crest features that appear to result from vigorous surface-atmosphere interaction. A study of these features will lead to an improved understanding of their formation and characteristics, which may help identify megadune-altered ice in ice cores.

Megadunes today extend over 500,000 square kilometers (km). The climatology of dunefields, characterized by low accumulation and consistent katabatic winds, suggests that they may have been even more extensive in the past. Megadunes have amplitudes of 2 to 5 meters and wavelengths of 2 to 5 kilometers, and are slightly asymmetric, with shorter upwind faces. The crests, up to 100 km long, are perpendicular to local katabatic wind flow. Satellite images show that the dune pattern remains unchanged for decades. Near-zero accumulation rates imply that snow remains near the surface and susceptible to modification for many years, both through surface exposure and subsurface ventilation. We suspect that megadunes are formed by a sublimation/vapor-redeposition process that operates in a standing wave airflow pattern set up over the snow. The climate record eventually preserved beneath dunefields is thus unlikely to represent the regional conditions of deposition, but the degree of modification is unknown.

Over two successive seasons, we will study an area within the large, well-developed megadune field southeast of Vostok Station in East Antarctica. Our objectives are to determine the physical characteristics of the firn across the dunes and to install instruments to measure the time variation of near-surface wind and temperature with depth to test and refine our hypotheses on megadune formation. Field study will consist of surface, snowpit, and shallow core sampling; ground-penetrating-radar profiling; topographic and ice-motion surveys; automatic weather station installation; accumulation/ablation measurements; subsurface temperature; and firn permeability.

We will also continue our remote-sensing study of the dunes across the continent, as well as earlier studies of dune characteristics, and will model diffusion, ventilation, and vapor transport processes within the dune firn as well.

Megadunes are a manifestation of an extreme terrestrial climate (the limit of cold and dry) and may provide insights on past terrestrial climate or processes active on other planets. Megadunes are likely to represent an end-member in firn diagenesis and as such may have much to teach us about the processes involved. (I–186–M; NSF/OPP 01–25570, NSF/OPP 01–25276, NSF/OPP 02–25992, and NSF/OPP 01–25960)

Earth's largest icebergs.
Douglas MacAyeal, University of Chicago; Charles Stearns, University of Wisconsin–Madison; and Emile Okal, Northwestern University.

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/amrc/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 02–30028, and NSF/OPP 02–29492)

Dry valleys Late Holocene climate variability.

Karl Kreutz and Paul 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 instrumental 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)

Millennial-scale fluctuations of dry valleys lakes: Implications for regional climate variability and the interhemispheric (a)synchrony of climate change.

Brenda L. Hall, University of Maine, and Glenn Berger, University of Nevada, Desert Research Institute.

What drives glacial cycles? Most researchers agree that Milankovitch seasonal forcing paces the ice ages, but how these changes are leveraged into abrupt global climate change remains unknown. A current popular view is that the climate of Antarctica and the Southern Ocean leads that of the rest of the world by a few thousand years or more. The character of deglaciation in Antarctica is that of a long gradual warming, rather than an abrupt change, although the paleoclimate record is not well defined. The most persistent challenge to the asynchrony hypothesis is the Taylor Dome ice core. Revision to the chronology has shown that the original interpretation of rapid climate change synchronous with deglaciation in Greenland was probably an artifact of very low accumulation rates.

Millennial-scale fluctuations of high-level, closed-basin, amplifier lakes in the dry valleys of Antarctica can shed some light on this issue: some 150 radiocarbon dates of algae from deltas and shorelines record rapid oscillations of these high-elevation lakes that extend through the Holocene. This record has the potential to form an independent data set with which to test the synchrony of abrupt climate changes in Antarctica. However, this approach has several shortcomings, including the fact that the record in the Holocene and earlier is unclear, a lake-level record based on geomorphological features alone is discontinuous, and only levels higher than the present lakes are recorded.

The ideal way to address these problems is to integrate the geomorphological record with a series of cores taken from lake bottoms. Using an approach designed to extract the greatest possible amount of data, we will obtain transects of long cores from Lakes Fryxell, Bonney, Joyce, and Vanda. Estimates of hydrologic changes will come from different proxies. Chronology will come from the dating of carbonates, as well as luminescence sediment dating. Evaluation of the link between lake level and climate will come from modeling.

Combination of the more continuous lake-core sequences with the spatially extensive geomorphological record will result in an integrated data set that extends back at least 30,000 years. This record will be compared with dry valley glacier records and ice cores to address questions of regional climate variability and then with other Southern and Northern Hemisphere records to assess the interhemispheric synchrony or asynchrony of climate change. (I–196–M; NSF/OPP 01–24014 and NSF/OPP 01–24049)

Tidal modulation of ice stream flow.
Sridhar Anandakrishnan, Richard Alley, and Donald Voigt, Pennsylvania State University, and Robert Bindschadler, National Aeronautics and Space Administration/Goddard Space Flight Center.

We will investigate the new-found, startling sensitivity of major west antarctic ice streams to tidal oscillations in order 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 propagation of signals. 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 kilometers apart on each stream will measure Whillans and ice stream D. These packages will be deployed at sites selected by satellite imagery and will operate autonomously for two lunar cycles to study the sensitivity of the streams to spring and neap tides. Also, we will examine existing data sets for clues to the mechanisms involved and develop preliminary models.

During the second and third seasons, we will examine in greater detail the tidal behavior of Whillans and D. We will especially focus 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)

Western divide WAISCORES (Western Antarctic Ice Cores) site selection.
Howard B. Conway and Edwin Waddington, University of Washington.

The West Antarctic Ice Cores (WAISCORES) community has identified the western divide, between the Ross embayment and the Amundsen Sea, as the region for the next deep-ice core. The Ice Core Working Group (ICWG) has developed a document titled *WAISCORES: Science and Implementation Plan, 2000* that outlines the objectives of the drilling and the physical and chemical properties the core must have to achieve those objectives.

The divide region spans more than 40,000 square kilometers, and preliminary site selection using airborne geophysical methods is now underway. This work has identified several potential drilling sites where the climate record should be best preserved throughout its long history of ice dynamics. We will make a suite of ground-based geophysical measurements to map spatial variations of iceflow, accumulation rate, internal layering, and ice thickness at two of the most promising sites. Our main investigative tools are high- and low-frequency ice-penetrating radar, repeat global positioning system surveys to calculate the present-day surface velocity field, synthetic aperture radar interferometry to calculate the regional velocity field, and short firn cores to calculate present-day accumulation rates.

Beyond the initial mapping and interpretation of internal layers and surface velocity, the measurements will be used to constrain our iceflow modeling. In particular, we will use these measurements and models to identify the specific site that is most likely to satisfy the following ICWG criteria:

- minimal disturbance from an iceflow,
- a record that extends back at least 50,000 years, and
- countable annual layers back 20,000 years.

A fourth criterion (good preservation of chemical species) will be addressed by others.

The first criterion (minimal disturbances) will be evident from the patterns of radar-detected internal layers. To address the other two, we will use the measurements as input for time-dependent iceflow and temperature models that predict depth variations of age, layer thickness, and temperature. The mismatch between the model predictions and the data eventually recovered from the core will help infer thinning and

climate histories for the region, in addition to yielding an estimate of expected conditions before drilling. The information we gather will help guide site selection for drilling. (I–209–M; NSF/OPP 00-87345)

Glacial history of Ridge AB.

Howard Conway, University of Washington.

Scientists do not fully understand how the configuration and activity of the drainage system of the West Antarctic Ice Sheet are changing. For the following reasons, Ridge AB constitutes a key area for studying this issue:

- While previous studies of inter–ice stream ridges in West Antarctica have revealed much about the history of the surrounding ice streams, there remains an information gap in the southern sector of the ice sheet. We believe that a targeted study of Ridge AB will reveal new information about recent changes in the configuration and activity of ice streams A and B.

- Geologic evidence from Reedy Glacier indicates that the ice near Ridge AB was about 700 meters (m) thicker during the last glacial maximum. This helps constrain the magnitude of thinning that has occurred through the Holocene and opens the possibility of linking the history of the West Antarctic Ice Sheet to the geologic record in the Transantarctic Mountains.

We will begin by using high- and low-frequency radar systems, global positioning system surveying methods, and short (20-m) firn cores to map spatial variations of internal layering, buried crevasses, surface velocity, and accumulation rate. We will then put these diagnostic measurements into ice-flow models to infer the glacial history of Ridge AB and the surrounding ice streams. We will interpret this history in the context of the histories that are emerging from the other inter–ice stream ridges, as well as the geologic evidence from Reedy and other outlet glaciers in the Transantarctic Mountains. These explorations and analyses will enhance scientific understanding of the evolution of the drainage system of the West Antarctic Ice Sheet. (I–210–M; NSF/OPP 00–87144)

Glacier change in the southern Indian Ocean: Brown Glacier, Heard Island.

Martin Truffer, University of Alaska–Fairbanks.

Heard Island, which is located in the southern Indian Ocean, is a small (367-square-kilometer) subantarctic island consisting of a 2,700-meter-high composite volcano that is glacierized on all sides. Our intent is to help establish a baseline profile of Heard Island glaciers by measuring some basic glaciological parameters (mass balance, flow velocity, ice thickness) in order to relate the observed changes in the glacier to climate and thus provide an important indicator of climate change in one of the most remote and least visited places on the planet. Specifically, our objective is to determine the current mass balance, geometry, and flow regime of Brown Glacier. Documenting glacier change fills an important gap in the picture of global climate change. Heard Island is one of only a few landmasses at this latitude, and its elevation range makes it a prime candidate for glacier study. It is also a World Heritage site, and it is believed that no human-introduced plant or animal life exists there.

This is a collaborative project with the Australian Antarctic Division (AAD), which will be responsible for logistics and some personnel, and provides an excellent opportunity for U.S. involvement in an area where it would be nearly impossible to operate without local collaboration. The AAD, which has a long history of successful collaboration with U.S. investigators, concentrates its work in and around the eastern part of the continent and therefore complements U.S. work in the western part of Antarctica.

Much of the work is interdisciplinary, such as the study of plant recolonization after glacial retreat, and the field team includes geologists, glaciologists, and plant and wildlife biologists. The results will be published in peer-reviewed journals and will be the subject of lectures to the general public. The work will also be part of a doctoral dissertation at the University of Tasmania in Hobart, Australia, and will thus contribute to the education of a young scientist. (NSF/OPP 03–35936)

ARTISTS AND WRITERS PROGRAM

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.

Mary Miller, right, answers questions from museum patrons in San Francisco as Julie Kanop films a live webcast at McMurdo Station. Both women were participants in the Artists and Writers program, sponsored by the National Science Foundation.

NSF photo by Melanie Conner

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 and a list of past participants can be found at http://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 NSF's selections. The applicants who are chosen receive field support (including air travel from the United States), but no direct NSF funds. 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 next application deadline, for participation in the 2005–2006 austral summer season, will be early June 2004.

Palmer Station children's novel.
Lucy Bledsoe.

Ms. Bledsoe is planning to write a novel for children in the middle grades. It would depict the contemporary adventure of scientific exploration taking place at and from Palmer Station. She will interview and observe the daily work of scientists working from the Station and will accompany them into the field and out on zodiacs. Because her readers will be particularly interested in wildlife, she will work especially closely with biologists and also plans to observe scientists working on a research vessel to broaden the scope of the novel or to gather data for a separate novel. In addition, she will camp on Torgersen Island and at Old Palmer. (W–218–P)

Ice through the Ages: A nonfiction young adult book.
Jennifer Armstrong.

Ms. Armstrong is writing a book about ice. To do her research, she plans to visit, by fixed-wing aircraft and helicopter, sites where work on and in ice is taking place. She also plans to use a field camp kit to make occasional visits to remote camps. (W–219–M)

Soil biodiversity book.
Yvonne Baskin.

Ms. Baskin plans to gather material for a book on global soil biodiversity by working closely with the members of project B–420–M and by taking mostly day trips out of McMurdo Station. She plans to spend approximately 3 to 4 weeks in January and February 2004 observing and working at field sites with soil ecologists and other researchers from the McMurdo Dry Valleys Long-Term Ecological Research Program. She also intends to accompany researchers on a sampling trip to Battleship Promontory and observe sample processing in Crary Laboratory. (W–220–M)

History of science in Antarctica.
Edward Larson.

Dr. Larson, a science historian, plans to prepare a book and articles geared to a broad audience on the history of scientific research in Antarctica. His research will primarily involve inspecting libraries and archives at McMurdo Station, interviewing scientists and observing them at work, and experiencing the places where they work, including South Pole Station. He also plans day trips to historically important research sites, such as the dry valleys and the ice shelf, and to research vessels. Further, he plans to accompany or visit scientists working in the field, particularly at sites where research on the environment is taking place. Because the book will begin with the Wilkes Expedition, which marks the launching of antarctic research funded by the U.S. government, he hopes to visit the Wilkes Land coast. (W–221–M)

The Fallen Sky: Eccentrics and Scientists in Pursuit of Shooting Stars: Field work with Antarctic Search for Meteorites main party and reconnaissance team, under the supervision of Dr. Ralph Harvey, ANSMET PI, 2003–2004.
Christopher Cokinos.

During the 2003–2004 field season, Mr. Cokinos will be traveling as a regular member of the Antarctic Search for Meteorites (ANSMET) main party and reconnaissance team in order to write a concluding section for a nonfiction book on meteorites and the stories behind those who study them. He therefore plans to experience ANSMET operations and field conditions and to record activities, impressions, descriptions, and quotes. He will use the data he gathers as a basis for two or three chapters on the search for meteorites in Antarctica, relating that search to what they tell us about the origins of the solar system, the flux of meteorite falls over time, allegations of biological activity recorded in meteorites, and the chemistry of organic materials contained in them.

He intends to spend approximately 3 weeks in the field with the main search team and another 3 weeks with the reconnaissance team. Quick 1-day tours of sites of historic importance to meteorites (the Allan Hills main icefield, the Allan Hills west icefield, and the Elephant Moraine) are also slated. (W–223–M)

Field Guide to Antarctic Features: McMurdo Sound Region.
Lawrence Conrad.

From 15 September 2003 until 20 February 2004, Mr. Conrad intends to photograph about 1,000 named features from a total of about 2,000 views to use in a geographically arranged, historical gazetteer of the McMurdo region. The area to be covered consists of Ross Island to the seaward edge of the polar plateau, Nordenskjöld Ice Tongue to the Koettlitz Névé. (W–224–M)