National Science Foundation
WHERE DISCOVERIES BEGIN

U.S. Antarctic Program, 2006–2007

A Zodiac boat near an iceberg. (*NSF/USAP photo by Zee Evans*)

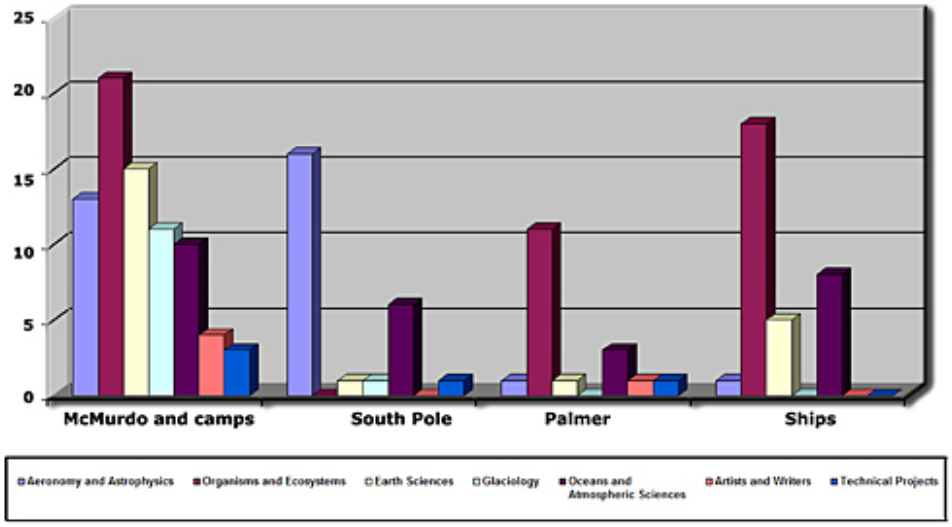
As part of the U.S. Antarctic Program, nearly 700 researchers and special participants will conduct 165 projects during the 2006–2007 austral summer, with some projects continuing through the austral winter. Supported by over 2,000 civilian contract employees and U.S. military personnel, these researchers 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*—and the Swedish icebreaker *Oden*.

These projects, funded and managed by the National Science Foundation (NSF), are part of the international effort to understand the antarctic and its role in global processes. NSF supports research that can best be performed or can only be performed in Antarctica. Besides research projects, NSF's Office of Polar Programs (OPP) and the Directorate for Human Resources support PolarTREC (Teachers and Researchers Exploring and Collaborating; http://www.polartrec.com/), a teacher enhancement program administered by the Arctic Research Consortium of the U.S. PolarTREC strives to advance polar science education by bringing K–12 educators and polar researchers together in hands-on field experiences in the Arctic and Antarctic. For its first antarctic activity, PolarTREC will support two teachers, Allan Miller and Ute Kaden, during an international oceanographic cruise of the Swedish icebreaker *Oden*. The scientific objectives of the cruise are monitoring wildlife, including seals, cetaceans, seabirds, and penguins; surveying sea ice and meteorological conditions; mapping the chemical, thermal and bathymetric properties of the ocean; and measuring the abundance of plankton and nutrients in the ocean. The research will be conducted while the *Oden* is in transit from Chile to McMurdo Station where the ship will assist in annual icebreaking activities.

Another OPP program—the Antarctic Artists and Writers Program (NSF 07-550)—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 07-549). Operational resources in Antarctica are also used to support scientists from other Federal agencies.

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



During the 2006–2007 austral summer, 77 projects will be based at McMurdo Station or at remote field sites, 32 will be supported on research ships, 25 will work at Amundsen-Scott South Pole Station, and 18 will work in and around Palmer Station.

Science highlights

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

Organisms and ecosystems

- **Long-term ecological research (LTER).** Two sites in Antarctica—one in the McMurdo Dry Valleys (NSF/OPP 04-23595) and the other along the west coast of the Antarctic Peninsula centered on Palmer Station (NSF/OPP 02-17282)—are among the world's 26 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://pal.lternet.edu/; McMurdo LTER, http://www.mcmlter.org/)
- **Weddell seal population dynamics.** Weddell seals have been studied in McMurdo Sound since 1968; this constitutes one of the longest intensive field investigations of long-lived mammals anywhere. More than 16,800 animals have been tagged, and almost 162,000 resightings have been recorded. The project is a resource for understanding the population dynamics not only of Weddell seals, but also of other species of terrestrial and marine mammals. New work this season includes assessing the role of food resources in limiting the population. (NSF/OPP 02-25110; www.homepage.montana.edu/~rgarrott/index.htm)
- **Protein function in cold-adapted fish.**Antarctic fish live in an unusually cold environment where basic processes such as protein synthesis are thermodynamically challenging. Researchers are examining whether antarctic fish have unique adaptations for making proteins and are uncovering the genetic basis for these functions.Comparative studies with temperate fish will help to illuminate the evolutionary pathways of cold-adaptation and life in extreme environments. (B-134-M; NSF/OPP 04-40799)

Ocean and atmospheric sciences

- **Monitoring for climate change.**A team of scientists from the National Oceanic and Atmospheric Administration (NOAA) are measuring 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 researchers to determine the rates at which concentrations of these atmospheric constituents change; they also point to likely sources, sinks, and budgets. NOAA scientists collaborate with climate modelers and diagnosticians to explore how the rates of change for these parameters affect climate. (NSF/NOAA agreement)
- **Primary and Secondary Production Measurements Along the Western Antarctic Coastline on the *Oden.*** The western antarctic coastline, notoriously understudied, is thought to play a large role in the Southern Ocean for global carbon cycling. The *Oden* transit cruise is an ideal opportunity to collect data in this undersampled region, from the western Antarctic Peninsula to Ross Island. The information will augment data obtained in adjacent regions during the conduct of two major ocean programs, Southern Ocean GLOBEC (Global Ocean Ecosystem Dynamics) and Southern Ocean JGOFS (Joint Global Ocean Flux Study). Underway measurements of primary and secondary production will establish a baseline for future cruises. Concurrently observations will be made of marine mammals, sea birds and ice conditions. The overall goal is to understand how the sea ice edge dynamics influence both primary and secondary production, particularly with respect to larval krill dynamics. (NSF/OPP 07-08292)

Aeronomy and astrophysics

- **A 10-meter telescope for South Pole Station—South Pole observations to test cosmological models.** Much of the mass in the Universe is made up of dark matter, which emits little or no light or other electromagnetic radiation and makes its presence known only through the gravitational force it exerts on luminous matter. The University of Chicago continues to lead a consortium of six institutions to design and use a 10-meter off-axis telescope located at Amundsen-Scott South Pole Station to survey galaxy clusters. This survey will allow them to study integrated cluster abundance and its red shift evolution and will give precise cosmological constraints, completely independent of those from supernova distance and cosmic microwave background anisotropy measurements. The telescope will be constructed in the 2006–2007 austral summer and begin observations during the 2007 austral winter. (NSF/OPP 01-30612; http://astro.uchicago.edu/scoara/may2004workshop/TALKS/spt-carlstrom)
- **IceCube.** During the 2006–2007 austral summer, a consortium led by the University of Wisconsin-Madison will continue construction of the IceCube Observatory at the South Pole. IceCube is a neutrino telescope that will be buried 1.4 to 2.4 kilometers under the ice and will be used during the austral summers over 5 years. The detector will consist of 4,800 optical modules deployed on 80 vertical strings. AMANDA (antarctic muon and neutrino detector array) is the prototype for this international collaborative effort. Using neutrinos as cosmic messengers, IceCube will open unexplored wavelength bands and will answer such fundamental questions as what the physical conditions in gamma ray bursts are and whether the photons originating in the Crab supernova remnant and near the supermassive black holes of active galaxies are of hadronic (derived from subatomic particles composed of quarks) or electromagnetic origin. The telescope will also be used to examine the particle nature of dark matter, aid in the quest to observe supersymmetric particles, and search for compactified dimensions. (NSF/OPP 03-31873; http://icecube.wisc.edu)

Glaciology

- **WAIS Divide.** This 5-year science program, involving a dozen research teams, will develop a detailed record of greenhouse gases for the last 100,000 years; determine if changes in the northern and southern hemispheres initiated climate changes over the last 100,000 years; investigate past and future changes in the West Antarctic Ice Sheet; and study the biology of deep ice. A 45-person camp to support the drilling program was established during the 2005–2006 austral summer at a site on the West Antarctic ice sheet divide. At this camp a 184-foot steel arch building will house the drilling and core processing facilities for the deep drilling project, which will collect a 3,400-meter ice core to bedrock. The project's objective is to develop climate records with an absolute, annual-layer-counted chronology for the most recent 40,000 years. Lower temporal resolution records will extend to about 100,000 years before present. These records will enable comparison of environmental conditions between the northern and southern hemispheres and study of greenhouse gas concentrations in the paleo-atmosphere with a greater level of detail than previously possible. (http://www.dri.edu/People/kendrick/WDSprojmain.htm; http://www.ig.utexas.edu/research/projects/waiscores/wais00-poster/wais00_main.htm)
- **Earth's largest icebergs.** Icebergs released by the antarctic ice sheet represent the largest movements of fresh water within the natural environment. Several of these icebergs 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. Researchers from the University of Chicago, Northwestern University, and the University of Wisconsin-Madison will study the drift and breakup of the Earth's largest icebergs in an attempt to understand 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, as well as the processes by which icebergs generate globally far-reaching ocean acoustic signals that are detected by seismic-sensing networks. 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. (NSF/OPP 02-29546, NSF/OPP 02-29492, and NSF/OPP 02-30028)

Earth sciences

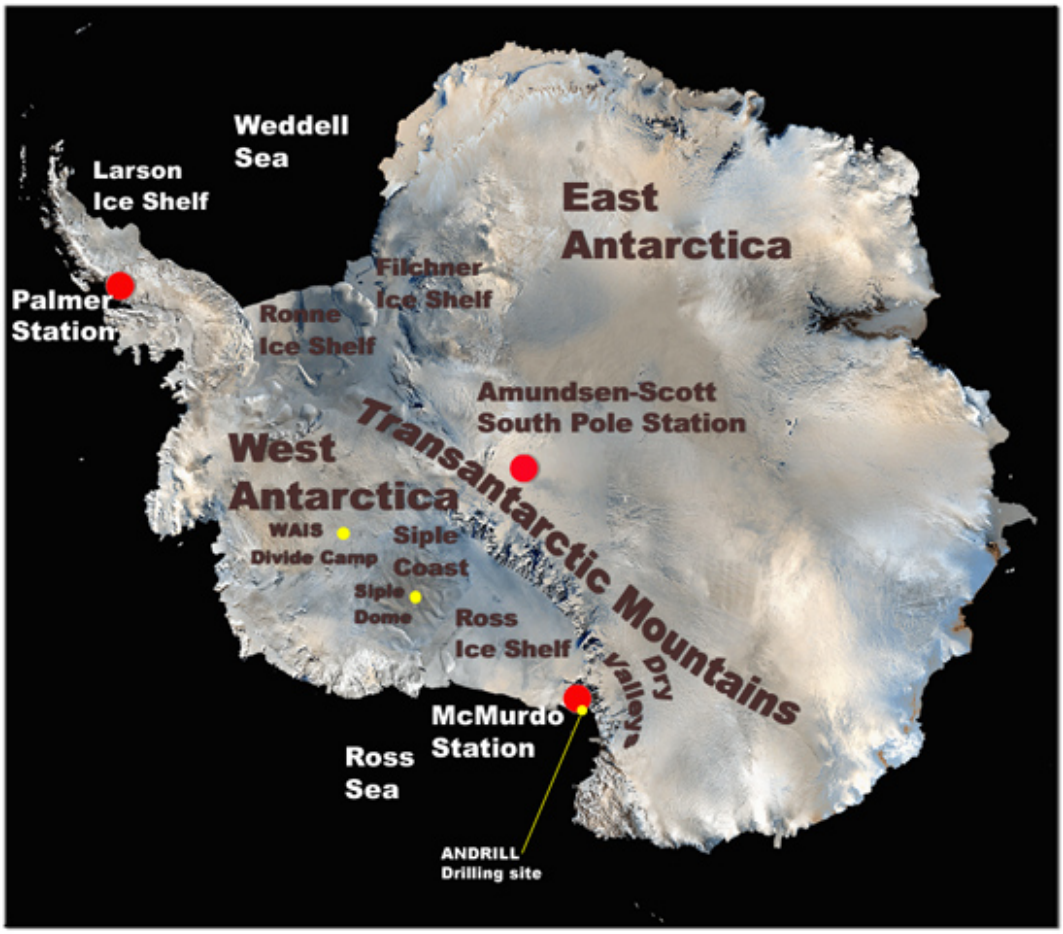
- **Antarctic Drilling (ANDRILL)**. ANDRILL, an international program representing over 150 scientists from Germany, Italy, New Zealand, the United Kingdom, and the United States, is designed to investigate Antarctica's role in Cenozoic global environmental change. ANDRILL will obtain a record of important Eocene, Neogene, and Holocene stratigraphic intervals in high southern latitudes. This research will contribute to the development of strategies to cope with future climate change, provide insight into relationships between ice-sheet fluctuations and volcanic and seismic hazards, and improve models of glacially influenced sedimentary rift basins. It will also contribute to other international science goals, bring together international teams, and provide opportunities to share antarctic earth science with the global community. ANDRILL will foster strong partnerships with established educational programs to develop a broad array of activities designed to educate policymakers, K– teachers, students, and the community at large. (NSF 03-42484; http://andrill.org)
- **Age, origin, and climate significance of buried ice.**Buried ice deposits are potentially a far-reaching archive of atmosphere and climate on Earth, extending back for many millions of years. These deposits are also terrestrial analogs to widespread, young buried ice on the Martian surface as identified by recent data from Mars Odyssey. This project will evaluate the age, origin, and climatic significance of buried ice in the western Dry Valleys region. Microclimates of the Dry Valleys hold implications for landscape evolution and climate change on Mars. The Antarctic Dry Valleys are commonly viewed as a relatively fixed cold polar desert with little internal variation. Recent analyses have shown that there are three fundamentally different microclimate zones within this general 'stereotypical' cold polar desert, and that these may hold the keys to climate change on Mars. (NSF/OPP 03-38291; http://people.bu.edu/marchant/)

Other programs

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

Artist/Writer	Project Title	Event Number
Anne Aghion	Work and Days: An Antarctic Chronicle	W-218-M
Lita Albuquerque	Stellar Axis: Antarctica	W-221-M
Xavier Cortada	Antarctic art message mural	W-217-M
Werner Herzog	The inner landscape (feature film)	W-219-M
David Ruth	Antarctic ice: Sculpture in cast glass	W-220-P

U.S. Antarctic Program, 2006–2007: Sites of Major Activities



McMurdo, Amundsen-Scott South Pole, and Palmer Stations operate year-round. During the 2006–2007 austral summer, four major field camps will operate in West Antarctica (Byrd Surface, Siple Dome, Western Antarctic Ice Sheet (WAIS) Divide, and Taylor Dome). Smaller camps will operate in the McMurdo Dry Valleys and Transantarctic Mountains regions. Six automated geophysical observatories and more than 100 automated weather stations operate year-round. The weather stations involve international collaboration with the Italian, German, Australian, and British programs. The map shows U.S. Antarctic Program locations during the 2006–2007 season.

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AERONOMY AND ASTROPHYSICS

Transporting the 10-meter dish to be installed on the pedestal at Amundsen-Scott South Pole Station. This new telescope will gather information on cosmic microwave background radiation. (*NSF/USAP photo by Bill Johnson*)

Overview

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

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

- **The stratosphere and the mesosphere:** In these lower regions, current research focuses on stratospheric chemistry and aerosols, particularly those implicated in the ozone cycle.
- **The thermosphere, the ionosphere, and the magnetosphere:** These higher regions derive many characteristics from the interplay between energetically charged particles (ionized plasmas in particular) and geomagnetic/geoelectric fields. The upper atmosphere, particularly the ionosphere, is the ultimate sink of solar wind energy transported into the magnetosphere just above it. This region is energetically dynamic, with resonant wave-particle interactions and joule heating from currents driven by electric fields.
- **The galaxy and the Universe beyond, for astronomical and astrophysical studies:** Many scientific questions, including a particular interest in the Sun and cosmic rays, extend beyond the magnetosphere. 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 the interdisciplinary study of geosphere/biosphere interactions in the middle and upper atmosphere, and improves the understanding of the critical processes of solar energy in these regions.

An example of the unique conditions that can be exploited for science is the IceCube Neutrino Observatory (under construction).This observatory relies on photo detectors buried up to 2.5 kilometers deep in the ice sheet at South Pole Station to detect high-energy neutrinos that can be used to image portions of the Universe normally obscured to light and ordinary electromagnetic radiation. Another example is the Center for Astrophysical Research in Antarctica (CARA), which was active at South Pole in the 1990s and phased out in 2001. However, the center's outstanding research activity led to the development of the 10-meter South Pole Radio Telescope, which will study cosmic microwave background radiation—the residual energy from the Big Bang—with unprecedented accuracy.

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).

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

The cosmic microwave background (CMB) provides three strong but circumstantial pieces of evidence that the visible Universe was created by the superluminal

inflation of a tiny volume of space. They are as follows:

- 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 was deployed and commissioned during 2004-2005. After BICEP was unpacked and prepared for initial cooldown, the optical loading, bandpass, and noise characteristics of the detector array and modulation systems were tested under realistic conditions. The next steps will be erecting the groundshield, refining the pointing model of the mount, and mapping the beams of the 96 detectors before testing on galactic sources and dark fields begins. During November working in the Dark Sector Laboratory (DSL), researchers will refurbish the BICEP receiver and upgrade the focal plane insert. The receiver, which will be cooled and tested in the BICEP lab, will be reinstalled on the BICEP telescope mount in late December and tested for mechanical, cryogenic, and electronic noise performance in simulated observing conditions. From early January through early February, researchers will calibrate the instrument, using sources mounted on the roof of DSL as well as astronomical sources. From early February through the end of the summer, researchers will optimize astronomical calibrations as the telescope is placed in winter operations mode.

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

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)

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

Antony C. Fraser-Smith, Stanford University.

Since it was discovered in the 1930s that natural phenomena emit the lowest form of electromagnetic energy (radio waves), the field of radio astronomy has joined the effort to analyze both atmospheric and extraterrestrial signals. The extremely-low-frequency and very-low-frequency (ELF/VLF) record of data collected at Arrival Heights, Ross Island, Antarctica—chosen because it is unusually free from human electromagnetic interference—now extends unbroken since the austral summer of 1984-1985. An identical system has been operating at Stanford University for almost the same period, thus providing a mid-latitude comparison data set.

Because the Arrival Heights radiometer has been operating for so many years, studies of longer-term variations can now be done. The data also help improve the statistical reliability of shorter-term variations. The difficulty of making long-term observations, particularly at remote locations, means that the Arrival Heights measurements increase in scientific value as the radiometer continues to operate.

Since the predominant source of ELF/VLF radio noise is thunderstorms occurring in the tropics, the Arrival Heights and Stanford systems provide alternate views of this activity. If thunderstorm activity depends on the temperature of the tropical atmosphere, as has been argued, the long-term statistical measurements of ELF/VLF radio noise made by the Arrival Heights and Stanford systems can provide independent information about global warming. Moreover, our radiometer measurements supplement those made by automatic geophysical observatories.

Because of its remote location, Arrival Heights has such a low background noise level that important new measurements are being made on weak ELF signals. The Schumann resonances, for example, which are so weak that observation is severely affected by the noise usually encountered in developed areas, are easily measured at Arrival Heights.

Since the 2001-2002 austral summer, our program has provided new information on the long-term variations in the noise at various frequencies throughout the ELF/VLF range, while at the same time providing an opportunity for more detailed studies of phenomena such as the Schumann resonances and the propagation of ELF radio waves from the few human sources around the world. There is also a possibility that the longer-term observations will prove useful in studies of global change. (A-100-M; NSF/OPP 01-38126)

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

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

The Earth's magnetic field arises from its mass and motion around the polar axis creating 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 between 0.1 second and 1,000 seconds. It is known that magnetic variations can significantly affect power grids and pipelines. We plan to use magnetometers (distributed at high latitudes in both the antarctic and arctic regions) to learn more about how variations in the solar wind can affect the Earth and anthropogenic systems.

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

Austral high-latitude atmospheric dynamics.

Gonzalo Hernandez, University of Washington.

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

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

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

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

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

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

We will continue our studies of 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) form the basis of our investigations. However, our research also involves extensive collaboration with other investigators using complementary data sets. Our previous work has provided insights into high-latitude substorm dynamics, magnetic variations, day- and night-side absorption spike events, traveling convection vortices, pulsating auroral particle precipitation, ionospheric transient and cusp-latitude absorption events, the origin of auroral radio emissions, and the possible application of riometry to the study of the Martian ionosphere.

Riometers measure the relative opacity of the ionosphere. Working at both McMurdo and South Pole Stations, we maintain and use an Imaging Riometer for Ionospheric Studies (IRIS) system , broad-beam riometers, and auroral photometers. These instruments, which work synergistically with other instruments operated at various sites by other investigators, also provide the data acquisition systems for the common recording of geophysical data at South Pole and McMurdo Stations and the provision of these data to collaborating investigators. To enhance their usefulness and timeliness to the general scientific community, data are made available in near real time on the Internet.

We will also continue imaging riometer measurements at Iqaluit (Northwest Territories) in the Arctic, the nominal magnetic conjugate point of South Pole Station. Further, we will participate in and contribute to several major science initiatives and National Space Weather programs. A primary focus of our analysis over the next year will be coordinated ground- and satellite-based studies of Sun-Earth connection events. Specifically, we will be able to combine ground-based data sets with Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) satellite data when the spacecraft is ideally situated at apogee over the Southern Hemisphere. These disparate activities have the common goal of enhancing scientific understanding of the relevant physical processes and forces that drive the observed phenomena, both internal (magnetospheric/ionospheric instabilities) and external (solar wind/interplanetary magnetic field variations). From such knowledge may emerge an enhanced forecasting capability. Many atmospheric events can have negative technological or societal impacts that accurate forecasting could ameliorate. (A-111-M/S; NSF/OPP 03-38105)

Polar Experiment Network for Geospace Upper-Atmosphere Investigations: PENGUIn—A new vision for global studies.

Allan T. Weatherwax, Siena College.

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

We will investigate, from Antarctica and nominally conjugate regions in the Arctic, the multiscale electrodynamic system that comprises Earth's space environment. Our plan entails the following:

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

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

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

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

Solar and heliospheric studies with antarctic cosmic rays.

John W. Bieber, William H. Matthaeus, and K. Roger Pyle, University of Delaware, Bartol Research Institute, 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. Neutron monitors, which are deployed in Antarctica and are part of a global network of nine stationary monitors and two transportable ship-borne monitors, provide a vital three-dimensional perspective on this shower and how it varies along all three axes. Accumulated neutron-monitor records (begun in 1960 at McMurdo Station and in 1964 at Amundsen-Scott South Pole Station) provide a long-term historical record that supports efforts to understand the nature and causes of solar/terrestrial and cosmic ray variations as they are discerned over the 11-year sunspot cycle, the 22-year Hale cycle, and even longer time scales. Data from the neutron monitors in this network will be combined with data from other ground-based and spacecraft instruments in various investigations of cosmic rays in relation to the Sun and solar wind. Specific objectives include the study of acceleration and transport of solar energetic particles, the scattering of cosmic rays in the solar wind, and the use of cosmic-ray observations for space weather forecasting.

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

RICE: Radio-Ice Cherenkov Experiment.

David Z. Besson, University of Kansas-Lawrence.

We live at the dawn of the era of ultra-high-energy astronomy. Celestial accelerators, achieving energies 109 times higher than previously possible, can produce protons, photons, and neutrinos. Neutrinos are elementary particles with no electrical charge and very little mass. At the highest energies, neutrinos are the only particles that can elude the cosmic microwave background and penetrate, undeflected by magnetic fields, to Earth.

Radio-Ice Chrenkov Experiment (RICE) is aimed at measuring high-energy neutrinos by detecting Cherenkov radiation, which is visible as a blue glow and results from collisions of very-high-energy neutrinos with ice or rock. RICE is designed to detect the compact electromagnetic cascades that produce Cherenkov radiation. At such high energies, radio detection of cascades is more efficient than optical-based detection.

We will work with the researchers on the IceCube drilling project, which began in 2004 (see A-333-S); specifically, we will deploy radio receivers in IceCube holes, thereby increasing RICE's sensitivity to neutrinos by at least two orders of magnitude. Deploying three radio receiver clusters (with two dual-polarization, high-bandwidth antennas per cluster) per hole will allow us to conduct radioglaciology measurements in addition to astrophysics experiments. We will also design the radio array for coincident (RICE plus IceCube) electromagnetic cascade detection, and special hardware will allow microsecond time-scale elimination of the surface anthropogenic backgrounds that have proved a problem in the past.

RICE data from the past 4 years have allowed the most detailed study of in situ radio detection systematics thus far. We have presented these data in two recent publications on the electrodynamics of the expected radio frequency pulse and two publications on RICE simulation and calibration and limits on the neutrino flux. Those limits were based on just 3 percent of the RICE data set. Expanded results based on 50 percent of the data set and improving on those limits by an order of magnitude, as well as results on the first in situ measurements of the polar dielectric constant, are being prepared for journal submission. Other studies are well underway. Our data and results will contribute greatly to the knowledge of astrophysics and ultra-high-energy astronomy. (A-123-S; NSF/OPP 03-38219)

Exploratory measurement of attenuation and reflection properties of the Ross Ice Shelf at radio frequencies between 100 MHz and 1 GHz.

Steven W. Barwick, University of California, Irvine.

We will measure the attenuation and reflection properties of the Ross Ice Shelf near McMurdo Station at radio frequencies between 100 MHz and 1 GHz. In addition, the project will measure both continuous and episodic radio frequencies. This information is vital to the development of the Antarctic Ross Iceshelf Antenna Neutrino Array (ARIANNA), a high-energy neutrino concept that uses the Ross Ice Shelf and requires a medium with low losses of signal strength due to absorption and good reflection from the ice-water interface.

ARIANNA capitalizes on several remarkable properties of the Ross Ice Shelf:

- the shelf ice is relatively transparent to electromagnetic radiation at radio frequencies; and
- the water-ice boundary creates a good mirror to reflect radio signals from neutrinos propagating in any downward direction relative to the ice surface.

As a result, ARIANNA can survey more than half the sky for point and diffusely distributed sources of ultra-high energy neutrinos.

We have identified several potential sites for ARIANNA and will take measurements at one or more locations. (A-127; NSF/OPP 06-09489)

Direction-finding measurements of low-frequency/medium-frequency/high-frequency (LF/MF/HF) auroral radio emissions at South Pole Station.

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

The Earth's aurora naturally emits low-, medium-, and high-frequency (LF/MF/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. Using an electromagnetic waveform receiver that we designed and constructed at South Pole Station, we will focus 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 narrow-band emission generated near or at the second and third harmonics of the electron cyclotron frequency.

Because the broadcast bands found in the Northern Hemisphere are lacking in Antarctica, automatic wave-detection algorithms are more effective. Auroral roar has been found to be occasionally modulated (a phenomenon called flickering auroral roar). Our receiver will enable us to discover how common flickering auroral roar is, the conditions under which it occurs, what the frequencies are, and how the amplitude and frequency vary. Between 15 and 30 percent of auroral hiss events cannot be observed 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 like that of auroral kilometric radiation and whistler-mode waves in the same frequency range detected in the lower ionosphere.

Despite its extensive application for communications, the LF/MF/HF band has not been extensively 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 the 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 radiation processes at close range. (A-128-S; NSF/OPP 04-42369)

The antarctic investigations of upper atmospheric disturbances over the South Pole Station.

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

We are investigating solar-terrestrial interactions involving atomic, molecular, and plasma processes in the upper atmosphere above the geographic South Pole. Using electro-optical remote-sensing facilities at Amundsen-Scott South Pole Station, we are measuring the effects of solar disturbances on the composition, dynamics, and thermodynamics of the antarctic thermosphere, mesosphere, and stratosphere. We are particularly interested in understanding five processes

- the source(s) and propagation of antarctic F-region patches;
- variations in the antarctic E-region oxygen/nitrogen ratio;
- antarctic middle atmosphere disturbances generated by Stratospheric Warming Events and energetics of the coupling among the mesosphere and lower thermosphere (MLT) regions with the stratosphere through enhanced gravity waves in SWE;
- the antarctic thermospheric response to Solar Magnetic Cloud/Coronal Mass Ejection events;
- the effects of Joule heating on the thermodynamics of the antarctic F-region.

Data for studies of these five aeronomic processes will come from two sets of remote-sensing instruments—auroral emissions brightness measurements from the sun-synchronous Meridian Scanning Photon Counting Multichannel photometer; and airglow and auroral emission spectra recorded continuously during the austral winter with a high-resolution Infrared Michelson Interferometer and Visible/Near-Infrared CCD spectrographs. From about March through September of each year, such polar studies are only feasible at South Pole Station because arctic stations are continuously sunlit. Changes in airglow temperature, from different MLT heights, permit studies of the dynamical effects of planetary, tidal and gravity waves that propagate in the MLT regions as well as non-linear interactions among these waves. Like-wise, coupling of different atmospheric regions over SPS, through enhanced gravity wave activities during SWE that lead to a precursor as mesospheric cooling, can be investigated through the observed changes in MLT kinetic air temperature and density. (A-129-S; NSF/OPP 03-37618)

Measurements addressing the initial stages of ozone recovery, the nucleation of, index of refraction of, and existence of large PSC particles

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

In the past 20 years stratospheric ozone has rapidly declined above Antarctica in the spring due to halogens released into the atmosphere since the 1930s.

Coupling halogen releases with cold austral polar stratospheric temperatures, which lead to the formation of clouds with surfaces to convert inactive to active chlorine, sets the stage for rapid chlorine-induced, catalytic conversion of ozone to diatomic oxygen as sunlight returns to the polar winter stratosphere. These interactions formed the "ozone hole" that reached unprecedented minimums in the late 1990s as stratospheric chlorine peaked.

We will to continue in situ balloonborne ozonesonde measurements through 2008. These ozone measurements, begun in 1986, documented the decline and minimum in ozone observed as chlorine increased and reached its maximum in the 1990s. The emphasis of our research is now shifting to observing the first signs of ozone recovery. Ozonesondes are uniquely capable of observing in the altitude range suffering the greatest chemical loss, and thus able to separate chemical and transport effects. Thus these instruments may be among the first to establish the ozone benefits resulting from declining chlorine.

During 2007 we will collaborate with European colleagues in a second international Antarctic campaign to test 3D chemical transport modeling of ozone loss. This campaign will occur as part of the International Polar Year and will consist of a second year of winter/spring ozone measurements from McMurdo. Laboratory investigations of the chemistry within electrochemical cell ozonesondes will help establish a transfer function for data sets which include measurements with different ozonesondes and solution strengths. This supports our WMO involvement to establish recommendations for ozonesonde operating procedures.

Another important aspect of the study is observations of polar stratospheric clouds (PSC) in the Antarctic. In this study we will continue to address questions related to the nucleation of nitric acid hydrates, the existence of large particles within Antarctic PSCs, and the index of refraction of PSC particles. Measurements associated with nucleation of nitric acid hydrates within PSCs will include collaboration with the European VORCORE project.

The broader impacts of this work have several aspects. Measurements establishing the first signs of ozone recovery are important reassurances to the world community in support of the commercial sacrifices that have been made to limit the release of chlorine into the atmosphere. Thus, in addition to the scientific interest, there are broad social implications dependent on maintaining ozone measurements through the first decade after maximum chlorine has been reached in the stratosphere. This research also contributes to the training and education of a post-doctoral scholar, engineer, technician, and graduate students. (A-131-M; NSF/OPP 05-38679)

Antarctic Impulsive Transient Antenna.

Peter W. Gorham, University of Hawaii.

The Antarctic Impulsive Transient Antenna (ANITA) is designed to identify high-energy particles created by collisions between cosmic rays and the cosmic microwave photons that pervade the Universe... Carried by a high-altitude balloon to an altitude of approximately 40 kilometers, ANITA will probe both the nature of the sources of these extreme particles, called neutrinos, and the fundamental interactions of high energy physics at extreme scales.

During circumpolar flights, ANITA will monitor radio frequencies of the antarctic ice sheet. Rare radio emissions from electromagnetic cascade interactions of the high-energy neutrinos, also known as Askaryan pulses, transmit through the polar ice.

The ANITA pathfinding mission is a high-energy neutrino astronomy project. Outreach activities of this project include

- enhanced involvement of middle school-aged girls in inquiry-based science via the web-based Antarctic Balloon Observatory Virtual Explorer (ABOVE) program;
- participation by underserved high school and college students in research through the DetectNet Program; and
- mentoring by ANITA scientists in the ANITA Academics program who will assist pre-service teachers at a historically minority campus in research related to the ANITA mission. (A-142; NASA award)

Long-Duration Balloon Program.

William Stepp, Columbia Scientific Balloon Facility.

The Columbia Scientific Balloon Facility (CSBF) provides logistic, engineering, and technical support to scientists working for NASA and for universities from all over the world. CSBF's services include launching large (400 ft. diameter), unmanned, high altitude (120,000+ ft.) research balloons; tracking them during flight; and recovering the payloads. The balloons have a volume of 40 million cubic feet and will ascend at a rate of approximately 900 feet per minute to a float altitude of 125,000 feet. In Antarctica, the long-duration, stratospheric balloons enter the polar vortex to circumnavigate the continent between 70° S and 80° S, carrying scientific payloads to collect data on a variety of astrophysical and geophysical phenomena.

CSBF will launch three stratospheric balloons from the Long-Duration Balloon Facility at Williams Field between December 2006 and January 2007. Once a balloon has completed its mission, project personnel will fly to within line-of-sight of the balloon over the Ross Ice Shelf or Polar Plateau and send a radio command to release the payload and terminate the flight. The payload will descend on a parachute to a predicted impact site, where team members and supported scientists will use air or ground support to recover it. Payload instruments will be returned to the home institutions to be refurbished. (A-145-M; NSF/NASA agreement)

Solar Bolometric Imager.

David M. Rust, Johns Hopkins University.

Solar irradiance variations affect the Earth's climate, but the magnitude of the Sun's intrinsic variation is uncertain. Current observations cannot reject the possibility that intrinsic variations played a major role in the climate changes recorded over the past few millennia. Physical understanding, based on images of the sources of irradiance variation, will clarify the Sun's role in global climate change. From space-borne bolometric radiometers, we know that the total solar irradiance (TSI) during the 11-year sunspot cycle varies in proportion to local magnetic fields.

In this project we will study irradiance at the upcoming sunspot minimum, when the local fields will be weakest. This approach will help detect other possible

sources of TSI variation with the least confusion by the large amplitude signals from local magnetic fields. It is also the best observational approach to physical understanding of the possible long-term TSI variations.

The goal is to operate the Solar Bolometric Imager (SBI 2) above Antarctica, where near-space conditions can be attained. The SBI 2 will operate for 10 to 20 days and provide bolometric (wavelength-integrated light) and color temperature images of the Sun, from which both the irradiance signals and their underlying physical causes may be assessed. Images are necessary to characterize irradiance variations associated with subtle magnetic structures, acoustic oscillations, pole-equator temperature differences, and rotational-convective cells. (A-146; NASA award.)

BLAST: A comprehensive plan for galactic and extragalactic surveys at submillimeter wavelengths from an LDB platform in Antarctica.

Mark Devlin, University of Pennsylvania.

The Balloon-borne Large Aperture Submillimeter Telescope (BLAST) will aid in addressing some of the most important cosmological and galactic questions regarding the formation and evolution of stars, galaxies, and clusters.

The telescope will fly from a high-altitude, long duration balloon (LDB). It will incorporate a 2-meter primary mirror with large-format bolometer arrays operating at wavelengths of 250, 350 and 500 m. This will provide the first sensitive large-area (~0.5 to 40 square degrees) submillimeter surveys at these measurements.

BLAST's primary goals are to

- measure photometric redshifts, rest-frame far-infrared (FIR) luminosities, and star formation rates of high-redshift starburst galaxies, thereby constraining the evolutionary history of those galaxies that produce the FIR/submillimeter background;
- measure cold pre-stellar sources associated with the earliest stages of star and planet formation;
- make high-resolution maps of diffuse galactic emission over a wide range of galactic latitudes; and
- observe solar system objects including planets, large asteroids, and trans-Neptunian objects. (A-147; NASA award)

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

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

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

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

A meteor radar was installed at the South Pole Amundsen-Scott station in January 2001 and has been running continuously since January 2002. Data collected from this meteor radar system in conjunction with medium frequency radar data collected from the Japanese station at Syowa, Australian station at Davis and British station at Rothera will be used for this project. These data will be analyzed simultaneously to determine the structure and evolution of the horizontal circulation pattern in the MLT over the Antarctic continent. Data from a complementary network in the Arctic will also be analyzed for comparative studies in addition to observations from the NASA TIMED spacecraft.

A new sodium nightglow imager will be installed at the South Pole to infer the sodium abundance in the MLT. Observations from this instrument will be combined with the South Pole Fabry-Perot interferometer temperature measurements and the meteor radar wind and meteor flux measurements to improve our understanding of the sodium chemistry and dynamics. These observations will be interpreted using sophisticated numerical models.

Teaching, training, and learning will be advanced by the inclusion of graduate students, especially underrepresented minorities, in this research. All of the students involved in this project will be encouraged to present their results and participate in professional meetings. (A-284-S; NSF/OPP 05- 38672)

Extremely-low-frequency/very-low-frequency (ELF/VLF) observations of lightning discharges, whistler-mode waves, and electron precipitation at Palmer Station, Antarctica.

Umran S. Inan, Stanford University.

Tropospheric lightning results from about 2,000 thunderstorms that are active at any given time and that maintain a global average lightning flash rate of about 100 per second. Our study focuses on the coupling of thunderstorm to the radiation belts, characteristics of lightning flashes that lead to upward electrodynamic coupling, ionospheric variability and parameters, and global lightning and climatology. We will measure the precipitation of radiation belt particles by whistler waves launched by lightning discharges via the associated localized and transient disturbances of the lower ionosphere, which are sensed remotely by means of their effect on the phase and amplitude of very low frequency (VLF) signals propagating in the nearby earth-ionosphere waveguide.

Our project is part of an international collaboration with Stanford observations at Palmer Station being complemented by and coordinated with observations at Rothera Station, Antarctica, by the British Antarctic Survey and at Commandante Ferraz (CF) station on King George Island by Centro de Radio-Astronomia e

Aplicacoes Espaciais of Brazil, and at Vernadsky Station by the National Antarctic Center of Ukraine. The program complements a similar set of measurements that are conducted by Stanford in the northern hemisphere under support from the Atmospheric Sciences Division of NSF and the Office of Naval Research. Coordinated measurements in both hemispheres are needed to study the geomagnetic conjugacy of the phenomena. A new ELF/VLF observations site is proposed to be established in Bermuda, near the geomagnetic conjugate region of Palmer to allow for the simultaneous measurement of the lower ionospheric regions in both hemispheres, especially in association with hurricane systems.

At Palmer Station we will measure broadband ELF/VLF radio atmospherics to determine the characteristic waveforms of the electromagnetic radiation (or sferics) associated with such upward electrodynamic coupling phenomena as sprites and terrestrial gamma-ray flashes. From recent studies, we know that these measurements can be useful as a proxy measure for occurrence of intense upward coupling phenomena on a global scale. The unique location of Palmer Station makes it possible for us to measure sferics originating in lightning discharges over large regions of the globe, including the Americas, Africa and the Atlantic and Pacific oceans. When used with space-borne measurements, the determination of occurrence and arrival bearings of sferics measured at Palmer is a powerful new tool for assessing global lightning activity. This effort to locate geographically lightning discharges will be carried out in collaboration with Vaisala, Inc., which operates the National Lightning Detection Network (NLDN) across the continental United States, as well as several networks in other countries and long-range systems.

As a result of this research we will develop new technologies for lightning detection, at few observation sites and on a global scale. These technologies will benefit agriculture, navigation and other activities where lightning and thunderstorms affect human life.

A new ELF/VLF observation site also will be established on Ascension Island in the southern Atlantic, with support from Vaisala, Inc., Data from Palmer and Ascension Island will provide the capability of long-range (greater than 5,000 km) detection of lightning discharges in South America and Africa.

VLF Observations at Palmer will provide crucial support to the establishment and operation of a VLF Beacon transmitter at South Pole. Reception of the beacon signal at Palmer Station will allow the continuous measurement of relativistic electron precipitation from the outer radiation belts, an important component of worldwide efforts to assess Space Weather. (A-306-P; NSF/OPP 05-38627)

ELF/VLF observations in the Southern Pacific Ocean.

Umran S. Inan, Stanford University.

This project conducts very low frequency (VLF) radio measurements on board the research ship *Nathaniel B. Palmer*. These measurements are intended to support and complement the High Frequency Active Auroral Research Program (HAARP) heating facility in Gakona, Alaska, which investigates extremely low frequency (ELF)/VLF wave-injection and magnetospheric probing.

The primary tasks of the program are to

- construct and install a VLF receiver on the *Nathaniel B. Palmer*,
- study the magnetospheric amplification of ducted ELF/VLF whistler-mode signals,
- examine associated triggering of ELF/VLF emissions by the injected signals,
- investigate induced precipitation of energetic radiation belt electrons pitch angle scattered in cyclotron resonance interactions with the amplified and triggered waves, and
- transfer and analyze the data.

A key component of this research will be observations near the geomagnetic conjugate point of the HAARP HF heater, which lies in the South Pacific Ocean. The *Nathaniel B. Palmer* regularly cruises between Christchurch, New Zealand, and McMurdo Station, passing directly through the HAARP conjugate point and thus providing an outstanding scientific opportunity for measuring ELF/VLF.

The research vessel also provides a unique diagnostic platform for sampling the ELF/VLF environment in the geomag netic conjugate region of the central United States, an area rich in lightning activities and related phenomena. (A-327; NSF/OPP 05-38242)

IceCube.

Francis Halzen, University of Wisconsin-Madison.

We are building the IceCube Observatory, which will be installed at the South Pole. IceCube, a neutrino telescope that will be buried 1.4 to 2.4 kilometers below the surface of the ice, will be constructed during the austral summers over the next 4 years. The detector will consist of 4,800 optical modules deployed on 80 vertical strings. The now-completed Antarctic Muon and Neutrino Detector Array (AMANDA) project served as a prototype for this international collaborative effort. Last season, we shipped the remaining components, began drilling in the ice sheet, and started to assemble and test systems. During this austral summer, field team members will install 12 to 14 detector strings in the IceCube array and 10 IceTop stations (sensors used to detect air showers, study atmospheric muons and calibrate IceCube). In addition, project personnel will prepare for and implement the move from the temporary lab to the permanent IceCube Laboratory.

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

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

Extending the South American Meridional B-field Array (SAMBA) to auroral

latitudes in Antarctica.

Eftyhia Zesta, University of California-Los Angeles.

We intend to install two additional magnetometer stations in Antarctica and thus extend the South American Meridional B-field Array (SAMBA), which now comprises 10 stations, to higher latitudes. The two additional magnetometers will be at Palmer Station, a year-round U.S. research station in the Antarctic Peninsula region, and at Patriot Hills, a more remote, nonpermanent Chilean base. The Patriot Hills installation will be done with the logistical support of the Chilean Antarctic Institute.

We intend to

- extend the SAMBA chain to auroral latitudes and increase the spatial resolution of the effective cusp-to-cusp chain comprising Magnetometer Arrays for Cusp and Cleft Studies (MACCS), Magnetometers Along the Eastern Atlantic Seaboard for Undergraduate Research and Education (MEASURE), SAMBA, the automatic geophysical observatories, and a few other individual stations;
- extend the number of conjugate pairs of stations between MEASURE in the Northern Hemisphere and SAMBA in the Southern Hemisphere, thus increasing the size of the inner magnetospheric region that can be remotely monitored from the two hemispheres;
- establish an auroral latitude station conjugate to the Canadian Poste de la Baleine and study the conjugate differences in substorms and general auroral activity;
- determine, with the addition of other antarctic auroral stations, a Southern Hemisphere auroral electrojet (AE)-type index and compare it with the standard AE index; and
- provide the scientific community with near-real-time data from Southern Hemisphere low- and auroral-latitude stations that can be used to validate models that up to now have been tuned primarily with data from the Northern Hemisphere. (A-357-M/P; NSF/OPP 03-41861)

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

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

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

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

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

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

Science Coordination Office for Astrophysical Research in Antarctica.

John E. Carlstom, University of Chicago.

Antarctica holds tremendous potential for cosmology and astrophysics that can best be realized if the scientists involved understand and participate in the management, planning, and oversight of the shared resources and logistical support. To ensure the highest quality research is conducted at the Admundsen-Scott South Pole Station, a consortium of investigators conducting cosmology and astrophysics projects, called the Science Coordination Office for Astrophysical Research in Antarctica (SCOARA), will be formed.

SCOARA will have a positive impact on the quality and timeliness of the astrophysical research conducted at the South Pole. In addition, it is anticipated all antarctic projects will benefit from SCOARA's extensive open and maintained communication channels as well as its education and outreach activities. The environment provided by SCOARA will also enhance the career development of young investigators. (A-370; NSF/OPP 04-43177)

South Pole observations to test cosmological models.

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

One of the most important discoveries in cosmology is that much, if not most, of the mass in the Universe is apparently 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.) Determining just what fraction of the mass is in the noninteracting, nonbaryonic particles form is of great interest to cosmologists and physicists.

The University of Chicago leads a consortium of six institutions in designing and using a 10-meter off-axis telescope at Amundsen-Scott South Pole Station to survey galaxy clusters. Such a 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 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), 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), can be measured by using radio telescopes. The SZE is important to the study of cosmology and the CMB for two reasons:

- The observed hotspots created by the kinetic effect distort the power spectrum of CMB anisotropies. These need to be separated from primary anisotropies 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)

Measurements of the surface layer turbulence at Dome C.

Tony Travouillon, California Institute of Technology.

Over two austral winters, we will study surface layer turbulence to fill the gaps in knowledge about the total turbulence profile at Dome C. We will use sonic anenometers placed along an existing 30-meter mast to measure the CN2 parameter at four different heights within the first 30 meters of the atmosphere (3, 10, 20, and 30 meters). This parameter describes the strength of the optical turbulence at any given point in the atmosphere. By interpolating and integrating these measurements, we will be able to calculate the surface layer component.

A complete understanding of the spatial and temporal evolution of the turbulence above Dome C is important in comparing this site with other existing or potential observatory sites. This section of the atmosphere is particularly crucial for small and intermediate-size projects that are currently proposed for this site and will be affected by the turbulence.

Other fields, notably geophysics, will be greatly interested in these measurements. Other parameters, such as temperature, wind speed and direction, and surface heat flux, will be derived from them and will help us understand the structure of the airflow on the antarctic continent.

The data we derive will be made available to the international community in semi-real time on a dedicated World Wide Web site. (A-442-E; NSF/OPP 04-40874)

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WHERE DISCOVERIES BEGIN

ORGANISMS AND ECOSYSTEMS

These gentoo penguin chicks are taking a nap after eating a big meal. (*NSF/USAP photo by Zee Evans*)

Overview

Antarctica is a place like no other; as an intriguing habitat, it is a scientist's dream. It is a land where water is scarce—truly a desert—despite having more than two-thirds of the world's freshwater supply trapped in ice. Though it borders the world's major oceans, the Southern Ocean system is unique; it is 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. (One of them, the East Antarctic Ice Sheet, is larger than most countries.)

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 Organisms and Ecosystems 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 ecosystems.** Polar marine environments are characterized by complex interactions among biotic, chemical and physical processes, in areas that include the marginal ice-zone, continental shelves, polynyas, and open-ocean systems. Topics include interactions among trophic levels, factors influencing primary and secondary production, and the ecological role of organisms in biogeochemical cycling. Remote sensing techniques, long-term observations, and modeling are appropriate tools to enhance this area of research.
- **Terrestrial and freshwater ecosystems.** Organisms in ice-free areas, in ephemeral streams, and in perennially ice-covered lakes show remarkable persistence in the face of harsh conditions. Research on adaptive mechanisms, in the context of the present day hydrologic and biogeochemical environment, is encouraged. The McMurdo Dry Valleys of southern Victoria Land are of particular interest due to the large body of data available through ongoing research programs, including the McMurdo Dry Valleys LTER, but other locations can be proposed. Research in support of future field exploration of subglacial lakes is also considered.
- **Population dynamics, physiological ecology, and adaptation.** The extremes of light, temperature, and moisture have resulted in unusual adaptations within organisms at all levels of organization. Research concerning metabolic, physiological, and behavioral adaptations of marine and terrestrial organisms, their population dynamics, and their diversity, is encouraged. Of special interest are processes occurring during the austral winter. Long-term observations are also supported, with the goal of understanding the impact of environmental change on organismic and ecological processes.
- **Genomics.** "Genome-enabled" biology provides a foundation for understanding the genetic basis of organism-environment interactions. The unusual antarctic environment presents a compelling natural laboratory for the study of environmental genomics. A National Research Council report, *Frontiers in Polar Biology in the Genomics Era,* addresses some of these opportunities.

Effects of oxygen and temperature on egg mass function of Southern Ocean marine invertebrates.

Amy Ladd Moran, Clemson University, and H. Arthur Woods, University of Texas at Austin.

This project explores the evolutionary physiology and temperature biology of reproductive structures in antarctic marine organisms, specifically variation in egg mass function as it relates to low temperature, high oxygen conditions found at high latitudes in the Southern Ocean.

Research will include the following:

- using first principles to model the diffusion of oxygen into egg and embryo masses at environmentally relevant temperatures;
- testing model assumptions by measuring the temperature-dependence of embryonic metabolism and oxygen diffusivity through natural and artificial gels;
- testing model predictions by measuring oxygen gradients in both artificial and natural egg masses, as well as measuring developmental rates of embryos at different positions in masses; and
- comparing the structure and function of egg masses from the Southern Ocean those from temperate waters.

This study will provide insight into organismal solutions to the fundamental physiological problem of balancing oxygen supply and demand across different temperatures, which broadly relates to the impact of global climate change. In addition, this study will support further teaching, learning, and research in polar biology and polar ecological physiology via photographs, web-linked video, and experiments for high school and undergraduate students. (B-004; NSF/OPP 05-51969 and NSF/OPP 04-40577)

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

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

The Erebus Bay Weddell seal *(Leptonychotes weddellii)* population study in eastern McMurdo Sound was initiated in 1968 and represents one of the longest intensive field investigations of a long-lived mammal in existence. For over 35 years, a total of 16,809 animals have been tagged, with 161,994 resighting records logged in the database. This study is a valuable resource for understanding the population dynamics not only of Weddell seals, but also of other species of terrestrial and marine mammals. We are pursuing two lines of investigation that combine the long-term database with new field initiatives.

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

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

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

The molecular signals that regulate the ontogeny of aerobic capacity, lipid metabolism, and elevated myoglobin concentrations in the skeletal muscles of Weddell seals.

Shane B. Kanatous, University of Texas.

What are the molecular signals that regulate the changes in skeletal muscle physiology as young Weddell seals *(Leptonychotes weddellii)* develop into elite divers? We will address this broad question during a 3-year study that builds on our previous work, which characterized the enzymatic and structural adaptations for diving that occur in the skeletal muscles of newly weaned, juvenile, and adult Weddell seals and began to define the molecular signals that regulate these ontogenetic changes in skeletal muscles.

We will proceed as follows:

- We will use enzymatic, immunohistochemical, and myoglobin assays to further characterize the ontogenetic changes in muscle aerobic capacity, lipid metabolism, and myoglobin concentration and distribution in newly weaned, subadult, and adult seals.
- We will determine the molecular controls that regulate these changes in aerobic capacity, fiber type distribution, and myoglobin in skeletal muscles during maturation.

Through subtractive hybridization and subsequent analysis, we will determine the differences in mRNA in the swimming muscles of the different age classes of seals. These techniques will allow us to identify the proteins and transcription factors that influence the ontogenetic changes in myoglobin concentration, fiber type distribution, and aerobic capacity. The results will increase our understanding of the ontogeny and molecular mechanisms by which young seals acquire the physiological ability to make deep (up to 700 meters) and long (about 20 minutes) aerobic dives.

This study will advance our knowledge of the molecular regulation of adaptations that enable active skeletal muscle to function under hypoxic conditions; this has broader applications for cardiac and pulmonary disease in humans. The project will involve a postdoctoral fellow and two graduate students and also has a significant outreach component. In addition to interviews, e-mail exchanges with high school and middle school students, public seminars, and presentations at meetings, we will continue to support our World Wide Web site, this year in collaboration with the "Yes I Can Science Program" (http://www.polar06.yesican-projects.ca/), where we supply weekly updates about our research during the field season, answer questions from students and teachers, and supply periodic off-season updates on our results. Our earlier web site, developed in collaboration with the Science Teachers Access to Resources at Southwestern (STARS) Program, is available online at http://www.swmed.edu/stars/02antarcticexpedition/index.htm. (B-018-M; NSF/OPP 04-40713)

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

Much of our recent work has focused on defenses against predators in a variety of sluggish or non-free-moving marine invertebrates, including sponges, echinoderms, and nudibranchs and on defenses against herbivores in macroalgae. Mesoherbivores, specifically amphipods, are a dominant component of the macroalgal community in Antarctica. Despite their high abundance, the functional ecology, particularly the trophic relationships of antarctic amphipods, are poorly understood. Our project will evaluate the importance of mesograzers (small invertebrate predators approximately 1 to 25 mm in body length) in western Antarctic Peninsula marine communities by examining the role of mesoherbivores in structuring macroalgal communities and by explaining the ecological interactions of mesograzers with the marine sponges. Chemical studies also will be conducted to gain a more thorough understanding of the chemical defenses that Antarctic Peninsula sponges direct towards crustacean mesograzers.

We will address three sets of questions concerning the importance of mesograzers, particularly amphipods, in nearshore habitats of the western Antarctic Peninsula. First is the hypothesis that the high abundance of mesoherbivores in western Antarctic Peninsula marine communities has an important influence on algal community structure. Initially, we will document which species of amphipods feed in whole or part on microalgae and macroalgae, the incidence and distribution of filamentous endophytes (plants that grow within another plant) in dominant macroalgae, comparative night time patterns of amphipod abundances on macrophytes, and the role of chemical mediation in these relationships.

Second, we will test the broad hypothesis that mesograzers in general, and amphipods in particular, interact with and prey on sponges to a greater extent than has previously been recognized in antarctic communities. Considering the functional basis of these associations, we will examine whether the sponges are used as prey, and if they are, whether some sponges produce secondary metabolites that are effective against mesograzers like amphipods.

Third, we will test the following two hypotheses:

1. Antarctic algae and invertebrates biosynthesize secondary metabolites that deter feeding by amphipod predators.
2. Pigments found in three antarctic sponges are tryptophan catabolites produced as defenses against crustacean predators that impact molting.

We will evaluate these hypotheses based on isolation and characterization of the specific anti-feeding metabolites, on biosynthetic studies to establish the metabolic origin of the pigments, and on bioassays to establish the chemical defense roles of both groups of compounds.

Various educational activities will be a major component of this project. Opportunities will be made to support graduate and undergraduate research, both through NSF programs as well as home university-based programs, including a number of funded programs that enhance the representation of minorities in the sciences. We will continue to involve a large numbers of teachers, K–12 students, and other members of the community at large in their scientific endeavors in Antarctica and will actively participate in outreach efforts by presenting numerous talks on our research to school and community groups. (B-022-O; NSF/OPP 04-42769 and NSF/OPP 04-42857)

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

David G. Ainley, H.T. Harvey and Associates, and R. Glenn Ford, RGFord Consulting.

In collaboration with scientists from New Zealand, Italy, and France, 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 38 percent of the world's population of this species resides, and is in some way related to ameliorating climate.

We continue to examine

- the relative importance of resources that constrain colony growth;
- aspects of natural history that might be affected by exploitative or interference competition among neighboring colonies;
- climatic factors that influence the latter;
- behavioral mechanisms that influence colony growth; and
- foraging effort, as a function of diving and swimming capabilities and food availability.

We have shown how sea ice affects diet, foraging, and winter survival. In addition, the large colony at Cape Crozier, in concert with minke and killer whales, affects the foraging patterns of penguins at the smaller colonies and, perhaps, their size. Emigration also appears to be constrained by sea ice, with reasonable concentrations of ice favoring the growth of smaller colonies where foraging competition is minimal.

We will use 10 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 the only demographic study for this species that was conducted at Cape Crozier during the 1960s and 1970s when populations were declining. Satellite tags are providing information on local, foraging movements, and geolocation tags are providing information on the winter journeys of southern Ross Sea penguins.

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. Our study will contribute greatly to understanding the effects of climate change on antarctic marine organisms. (Additional information can be found on our World Wide Web site: www.penguinscience.com.) (B-031-M; NSF/OPP 04-40643)

Differential expression of oxygen-binding proteins in Antarctic fishes affects nitric oxide—mediated pathways of angiogenesis and mitochondrial biogenesis.

Bruce D. Sidell, University of Maine, and Kristin O'Brien, University of Alaska, Fairbanks.

Antarctic fish, specifically the channichthyidae icefishes and the red-blooded notothenioid species, are the focus of this study on the physiology and biochemistry of fishes thriving at body temperatures around zero degrees Celsius.

Researchers will study the species' hemoglobin and myoglobin levels (or lack thereof), and the function of nitric oxide in these oxygen-binding proteins. For example, both proteins are normally considered essential for adequate delivery of oxygen to aerobically poised tissues of animals. To compensate for the absence of hemoglobin, icefishes have developed large hearts that rapidly circulate a large volume of blood. Overall characteristics between the two species will be compared physiologically, anatomically, and molecularly.

This study aims to test the hypothesis that loss of hemoprotein expression in icefishes has resulted in an increase in levels of nitric oxide that mediate modification of vascular systems and expansion of mitochondrial populations in oxidative tissues. In addition, the study may aid in understanding tumorogenesis and metabolic pathologies in humans. (B-036; NSF/OPP 04-37887 and NSF/OPP 04-38778)

Studies of Antarctic Fungi: Adaptive strategies for survival and protecting Antarctica's historic structures.

Robert Blanchette, University of Minnesota.

Microorganisms are fundamental to the functioning of antarctic ecosystems, but we know very little about their biology and ecology. Knowledge about their survival mechanisms in polar environments is also very meager. Fungi in antarctic ecosystems, major contributors of biodiversity, have great influence on processes such as biodegradation and nutrient cycling. It is essential for biological surveys as well as genomic and proteomic studies to be completed so a better understanding of these organisms is obtained.

During earlier projects our research team has identified unique fungi associated with historic wooden structures brought to Antarctica by Robert F. Scott and Ernest Shackleton during the Heroic Era of exploration. Many of the species had never been described and belong to a little known genus Cadophora. Investigations have shown that these fungi are some of the most prominent organisms found in wood and soils at the historic hut sites, as well as at diverse sites throughout Antarctica. The objective of our current research is to obtain important new information on the fungi present in the Ross Sea and Antarctic Peninsula regions, to determine their role in decomposition and nutrient recycling, and to elucidate their survival mechanisms and strategies. To assess microbial diversity in antarctic substrates, we will use new tools and methods of investigating fungi in the environment, including denaturing gradient gel electrophoresis (DGGE), real-time PCR, and proteomic profiling to obtain key details of the physiological adaptations these fungi have evolved.

The impacts of the proposed results are broad and far reaching. These studies provide important baseline data on fungal diversity and their function in not only the antarctic environment but for other polar ecosystems as well. Only with this basic understanding can we have greater insight into ecosystem functioning and its response to environmental change. This work, coupled with the training and learning opportunities it provides, will be of value to many fields of study including microbial ecology, polar biology, wood microbiology, environmental science, soil science, geobiochemistry, and mycology as well as fungal phylogenetics, proteomics and genomics.

Besides these fundamental studies of microbial biology, the results of this research will be immediately useful to help preserve and protect Antarctica's historic monuments. In cooperation with the Antarctic Heritage Trust and the University of Waikato in New Zealand, our team has carried out investigations of deterioration at three historic huts in the Ross Sea Region (Discovery hut, Cape Evans hut, and Cape Royds hut) and have shown that unique fungi are decaying wood in contact with the ground and various cellulose degrading fungi are attacking artifacts made of leather, textiles, paper and other organic materials inside the huts. This investigation will continue our work identifying the microbes attacking these historic structures and artifacts and describing their biology and ecology in the polar environment. This austral summer we will work in the Antarctic Peninsula region at East Base, an American historic site on Stonington Island from the Admiral Byrd and Ronne Expeditions of 1939–1948. In March, we will travel to Palmer Station, stopping on the way at Deception Island to study microbial diversity and decomposition processes in wood remain from whaling stations and abandoned bases. Samples of soil and organic material will be collected to provide information about microorganisms and possible ecosystem changes related to the effect of volcanic disturbances on the deterioration processes affecting the historic artifacts. At Palmer Station the team will study sites on Humble Island and near the old Palmer Station and retrieve samples from different sterile substrates previously placed into the ground to act as baits for microflora. (B-038-E/L; NSF/OPP award 05-37143)

Penguins as monitors of the krill-centric Southern Ocean marine ecosystem.

Wayne Z. Trivelpiece, National Oceanic and Atmospheric Administration.

Adélie, gentoo and chinstrap penguins (*Pygoscelis adeliae, P. papua* and *P. antarctica,* respectively), the major predators of krill (*Euphausia superba*) in the Antarctic Peninsula, are key species used to monitor the potential impacts of fishery activities in this area. This project continues our long-term work in testing hypotheses relating penguin breeding biology, foraging ecology, and demography to environmental variability during the breeding season. Additionally, this work will expand recent investigations to address questions on the distribution and trophic interactions among the three species during the winter.

Recent warming in the Antarctic Peninsula region is now well documented, but little is known about the real or potential future impacts of this warming on the antarctic marine ecosystem, particularly the impacts on animals in the higher trophic levels of the Southern Ocean community. A 2002 study highlighted several apparent impacts of warming on Antarctic seabird populations and discussed potential causes for changes in population trajectories in penguin species at some locations. However, the authors concluded that few studies had data with both the continuity and decadal time series needed to test hypotheses of the mechanisms and linkages associated with these changes.

We have been working with Adélie, gentoo and chinstrap penguins at our study site in Admiralty Bay since 1977. Consequently, we have data on all aspects of the breeding biology and foraging ecology of the *Pygoscelis* species at this site and the only long-term demographic data (e.g., adult annual survival, chick cohort survival, age at first breeding, life time reproductive success) for any penguin species at any site in the Antarctic Peninsula region. This region is the site of most krill fishery activity and is where the recent changes in climate (warming) are most dramatic and best documented. Our objective is to describe the functional relationships between penguin predators, their primary prey, antarctic krill and key environmental variables. To thoroughly understand the structure and function of the antarctic marine ecosystem, we must determine the impact of environmental variation on the structure and regulation of upper trophic level

predators such as the *Pygoscelis* penguins. (B-040-E; NSF/OPP 04-43751)

Aging in Weddell seals: Proximate mechanisms of age-related changes in adaptations to breath-hold hunting in an extreme environment.

Markus Horning, Oregon State University, and Jo-Ann E. Mellish, Alaska SeaLife Center.

Our primary objective is to establish diving seals as a model for the study of cardiovascular and muscular physiology in mammal aging. Research on Weddell seals could validate this model and thus develop a foundation for similar research on other species. Evolutionary aging theories predict that elderly diving seals should exhibit senescence. Aging humans, by contrast, exhibit marked reduction in aerobic and physical exercise capacities, as well as circulatory system changes.

The ability of pinnipeds to avoid apparent senescence is remarkable, giving rise to two questions:

- What specific physiological and morphological changes occur with advancing age in pinnipeds?
- What subtle adjustments are made by these animals to cope with such changes?

This investigation will be the first to describe specific, small-scale physiological and behavioral changes relating to dive capability with advancing age in a model pinniped. To answer these questions, data collected from Weddell seals at the peak and near the end of their reproductive age range will be compared. Blood and muscle samples will be collected, and assessments will be made of the seals' ability to do external work (i.e., diving and foraging) as well as internal work (i.e., muscle functionality).

Basic mammalian aging is an area of study that still requires considerable effort. With people living longer than ever, any research into the development of new models for the study of aging has tremendous potential benefits to society at large. If seals prove a viable model system as we anticipate, unusual mechanisms to cope with aging may be revealed. (B-041; NSF/OPP 04-40780 and NSF/OPP 04-40715)

Evolution of morphology and trophic strategies in antarctic agglutinated foraminifera.

Samuel S. Bowser, New York State Department of Health.

We will study, in an interdisciplinary fashion, the evolution and ecological significance of foraminiferan protists, a major but neglected group of marine organisms. For over a decade, we have studied the cell biology, ecophysiology, and evolution of single-chambered foraminifera (allogromiids), focusing on giant (larger than 1 millimeter) high-latitude species.

Our studies have revealed a high degree of diversity in this group. The molecular phylogenetic framework is based on studies of a single gene (ribosomal small subunit or SSU) that, unfortunately, does not clearly indicate the relationship between major groups. Adding to the confusion is the fact that morphological characters traditionally used for species identification are not distributed in any meaningful way on the SSU tree. Therefore, there is no well-determined phylogeny to evaluate ecological and evolutionary hypotheses. Also, morphological identifications in the field do not always reflect the underlying biological reality. Without a better understanding of morphology, genetic identity, and ecologically relevant behavior, studies of this group are less likely to yield meaningful data.

In addition, we will study a taxonomically definitive group of allogromiids to generate a more robust, detailed phylogeny and use this new evolutionary framework as a springboard to test hypotheses in polar marine science. Specifically, we will investigate the biogeography of morphospecies that appear to be distributed in both arctic and antarctic waters. We will also use newly established underwater macroscopy equipment, lipid biomarker analyses, and predator/prey assays to determine the extent of carnivory within the early-evolving lineages. Ultimately, we intend to further develop rapid molecular screening methods for ecological studies and to understand the forces that led to the early diversification of foraminifera, whose origin dates from the Neoproterozoic and spans the dawn of skeletonization in multicellular organisms.

Our interactions with other scientists and international collaborations help transfer state-of-the-art advances in biomedical research to the ocean sciences. We will continue to promote the training of women and underrepresented groups through grassroots efforts and participation in formal regional and national programs. Moreover, we interface original research with K– education and public outreach and will continue to partner with science teacher organizations and educational foundations that emphasize hands-on learning. (B-043-M; NSF/OPP 04-40769)

Former elephant seal colonies in the Antarctic: Implications for Holocene climate change and genetic diversity in the Southern Ocean.

Brenda L. Hall, University of Maine, and Paul Kock, University of California–Santa Cruz.

What drives climate change? Long-term fluctuations may be paced by astronomical cycles, but how these factors and shorter-term variations control climate is poorly understood. The Southern Ocean and Antarctica are crucial for testing hypotheses of global change because their climate may be out of phase with that of the rest of the world. If this is true, it would favor the hypothesis that abrupt climate changes are caused by variations in ocean circulation. We will therefore develop data to address the pattern, timing, and cause of Holocene climate change.

During previous research, we discovered that colonies of southern elephant seals (Mirounga leonina) once existed along the Victoria Land coast. Molted sealskin and hair are found along 300 kilometers of coastline, more than 1,000 kilometers from any extant colony. The colony was apparently abandoned about 1600 A.D., possibly because of cooling and the encroachment of land-fast, perennial sea ice that made access to haul-out sites difficult. The record of seal habitation along the Victoria Land coast may therefore be a proxy for climate change.

We will address several questions:

- Why did elephant seals colonize and then abandon the coast?
- What does the record reveal about Holocene climate change and sea-ice conditions?
- What were the seals' foraging strategies and did they change with the climate?
- What is the genetic structure of the Victoria Land seals versus extant populations?
- How did genetic diversity change?
- What can we learn about population dynamics?
- What was the relationship between elephant seals and the Adélie penguins that occupied the sites at different times?

Carbon and nitrogen isotope analyses will provide information on changes in feeding strategies. We will document past sea-ice conditions by beach morphology and sedimentology and determine genetic structure from skin sample analyses. These data will allow us to develop an integrated history of the Victoria Land colonies.

Data from this study will be compared with existing records and used to develop a proxy for Holocene climate. Our research will allow us to test hypotheses of global climate change, modify graduate and undergraduate courses, and train new researchers. (B-068-M; NSF/OPP 04-39979 and NSF/OPP 04-39906)

Impacts of elevated pCO_2 on a dominant aragonitic pteropod (Thecosomata) and its specialist predator (Gymnosomata) in the Ross Sea.

Victoria Fabry, California State University–San Marcos.

Rising carbon dioxide levels are affecting both oceans and marine organisms via decreased carbonate saturation that affects calcification rates and acid-based metabolic physiology disturbances. We propose to quantify the impact of elevated carbon dioxide on a dominant aragonitic pteropod, *Limacina helicina*, and its specialist predator, the gymnosome *Clione antarctica*, in the Ross Sea. The unusual, co-evolved relationship between the cosomes (a marine calcifying organism that forms shells made of calcium carbonate-based aragonite) and their gymnosome predators provides a unique backdrop against which to assess the physiological and ecological importance of elevated carbon dioxide. Pteropods are functionally important components of the antarctic ecosystem with potential to influence phytoplankton stocks, carbon export, and dimethyl sulfide levels that, in turn, influence global climate through ocean-atmosphere feedback loops.

New evidence suggests that because of rising atmospheric carbon dioxide concentrations and acidity in the ocean, surface waters of the Southern Ocean will become undersaturated with respect to aragonite within the next 50 to 100 years. We will expose animals to a range of pCO_2 values and directly measure pteropod calcification rates and sublethal effects on organismal energetics. These data can be used to evaluate critical processes and determine the carbon dioxide thresholds beyond which these effects may become detrimental.

Data collected in McMurdo Station fieldwork will be disseminated to high school students with the goal of infusing them with the excitement of Antarctica, the thrill of scientific discovery, and an awareness of the rapid environmental change underway in polar regions. (B-069; NSF/OPP 05-38710)

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

Ron Naveen, Oceanites, Inc.

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

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

- breeding population size (number of occupied nests) and
- breeding success (number of chicks per occupied nest).

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

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

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

James T. Hollibaugh, University of Georgia.

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

Our goals are to

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

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

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

Toward an understanding of protein homeostasis in cold-adapted antarctic fish.

Gretchen E. Hofmann, University of California–Santa Barbara.

We will examine protein homeostasis in the cells of antarctic notothenioid fishes. Since previous research has suggested that these proteins may be subject to a great deal of misfolding at the subzero temperatures typical of antarctic coastal waters, we will continue to use a comparative approach highlighting the physiological differences between temperate New Zealand notothenioid fishes and antarctic fishes. Specifically, we will

- use ubiquitin conjugate analysis to measure the levels of damaged proteins tagged and targeted for degradation by the proteasome in the cells of antarctic fishes;
- estimate the efficiency of protein synthesis in cold-adapted antarctic fish cells by using isolated hepatocytes, pulse-chase experiments, and proteasome inhibitors to measure the levels of defective ribosomal products and determine the efficiency of protein biogenesis;
- measure relative 26S proteasome activity in the cells of antarctic fishes by using an established in vitro fluorometric assay to provide insight into whether cells are processing high levels of misfolded or otherwise damaged proteins; and
- assess the nature of cold-adapted gene expression in antarctic fishes compared with their temperate New Zealand relatives by examining the patterns of specific genes by means of real-time polymerase chain reactions.

Further, in collaboration with other researchers, we will use DNA microarray analysis to examine genomic-scale gene expression patterns in antarctic fishes compared with the New Zealand species to provide a more global view and to highlight whether deficient expression or alteration in gene expression is found after evolution at subzero temperatures.

In addition to providing undergraduate and graduate students with research experience, we have an extensive program that includes both K– curriculum development and informal outreach. Our team includes an award-winning middle-school science teacher and a writer/journalist who focuses on environmental issues and has written children's books. These efforts will be coordinated through a program called Oceans Alive! Sponsored by the Marine Science Institute at the University of California-Santa Barbara, this program's primary goal is to increase public understanding of earth and ocean science. This collaboration and participants' significant educational expertise will ensure that our efforts will be communicated to a wider audience. (B-134-M; NSF/OPP 04-40799)

Altitude symptoms at the South Pole.

Bruce Johnson, Mayo Clinic.

The goal of this project is to develop algorithms to better understand the mechanisms of altitude-related illness; to develop demographic, biochemical (serum and plasma), and genetic predictors (or combinations of predictors) of who may be most susceptible to altitude sickness; and to develop protocols to help optimize acclimatization practice. This research is important to the antarctic program because each year a large number of individuals develop mild to moderate altitude-related symptoms as a result of the relatively sudden transition from sea level to the reduced atmospheric pressures associated with the South Pole. It could also benefit the increasing number of people worldwide who visit altitudes similar to that at the South Pole.

Symptoms will be assessed at sea level (McMurdo Station) and six times at altitude to follow the progression to symptom resolution. This project will emphasize the mild to moderate symptoms often experienced with acute exposure to moderate altitude. Researchers anticipate that results from this study will improve current altitude-illness preventive procedures at South Pole as well as help identify personnel who may be at increased risk for developing more severe altitude symptoms (and therefore require more effective preventive measures). Findings will also be applicable to commercial air travel and the space program (long-term space flight at reduced atmospheric pressures) and may provide insight into clinical pathologies that result in low oxygen tensions in the blood or tissues (e. g., lung disease, obstructive sleep apnea, and heart failure).

Researchers will develop a web site with links to local secondary school programs as well as mountaineering and clinical web sites that inform students, climbers, and the general population about altitude-related illness. In addition, with the help of secondary school teachers, a curriculum on altitude adaptation, symptoms, and prevention will be developed. (B-179; NSF/OPP 05-40710)

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

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

We plan to study prokaryotic organisms in the permanently ice-covered lakes of the McMurdo Dry Valleys 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 Valleys 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.

This austral summer the research team will focus on Lakes Bonney, Hoare, and Fryxell but will also visit Don Juan Pond, Bratina Island salt ponds, and Lake Vanda to collect sediment and water samples. One member of the team will study the microbial ecology of Blood Falls at the terminus of the Taylor Glacier.

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)

The aerobic dive limit: Oxygen transport and depletion in emperor penguins.

Paul John Poganis, Scripps Institution of Oceanograpy.

This project studies the diving of emperor penguins at an isolated dive hole on the sea ice of McMurdo Sound to investigate blood and muscle oxygen store depletion in relation to the documented aerobic dive limit (ADL), which is the onset of post-dive blood lactate accumulation.

The ADL is probably the most commonly used, but most rarely measured factor to interpret and model the behavior and foraging ecology of diving animals. This study of the diving of emperor penguins at the isolated dive hole is one of the few in which physiological responses and the ADL have actually been measured.

The project also continues its long-term monitoring of the Ross Sea emperor colonies, which is especially important in light of both fisheries activity and the movement of large icebergs.

Broad impactsof the project include

- technological development of a microprocessor-based near-infrared spectrophotometer backpack, which will be applicable not only to other species, but also other fields such as exercise physiology;
- collaboration with the U.S. Naval Hospital in San Diego to train anesthesia residents in research techniques and the application of those techniques to Antarctic field research; and
- an improved understanding of the ADL concept and its use in the fields of diving behavior and physiology.

In addition, the annual censuses of emperor penguin colonies in the Ross Sea, along with the continued evaluation of previously developed remote monitoring cameras, will form the basis of a new educational web site and an educational outreach program to school children through SeaWorld of San Diego. (B-197; NSF/OPP 05-38594)

Capital expenditure, lactation energetics, and the importance of foraging to Weddell seals and their pups.

Olav Tonnes Oftedal, Smithsonian Institution.

The Weddell seal of Antarctica had been thought to fast during its relatively long lactation period (68 weeks), but evidence from feeding biomarkers, diving behavior, and maternal mass loss suggests that most females feed, at least in late lactation. We will investigate the relationship of capital expenditure, lactation energetics, and food intake in the Weddell seal using a novel multimarker approach to determine the following:

- changes in maternal capital stores (body energy, fat, protein) over the course of lactation;
- maternal energy expenditure (heat production);
- milk production including transfer of energy, fat, water, and protein to pups;
- timing of the onset of feeding in lactating females and pups;
- contribution of food intake to the maternal energy and substrate budget; and
- duration of the lactation period and nature of the weaning process.

From the data collected, we expect to be able to evaluate the relative importance of capital expenditure and food intake, and of energy vs. protein, in the evolution of a mixed capital and income breeding strategy.

A multilevel outreach package for the Smithsonian National Zoological Park program will include development of a dedicated web page about the project; multimedia and interactive presentations and exhibits, demonstrations, and one-on-one interpretive interactions between scientists and zoo visitors; and participation with minority youths from the Columbia Science Workshop, an NSF-funded science program. (B-224; NSF/OPP 05-38592)

Environmental and ecological regulation of differences and interactions between solitary and colonial forms of *Phaeocystis antarctica.*

Kam Wing Tang, College of William and Mary, Virginia Institute of Marine Science.

Phaeocystis antarctica is widely distributed in the Southern Ocean and plays an important role in polar ecology and biogeochemistry. It is a dominant primary producer, a main component of organic matter vertical fluxes, and the principal producer of volatile organic sulfur in the region. Yet *P. antarctica* is also one of the lesser known species, and, moreover, information collected on other *Phaeocystis* species or from different locations may not be applicable to *P. antarctica* in the Ross Sea.

P. antarctica occurs mainly as two morphotypes—solitary cells and mucilaginous colonies; these differ significantly in size, architecture, and chemical composition. Relative dominance between solitary cells and colonies determines not only the size of the population, but also its carbon dynamics, nutrient uptake, and use, and colony formation could effectively alter predator-prey interactions and interspecific competition. However, what regulates the differences between solitary and colonial forms of P. antarctica is not certain. We will therefore address the following questions:

- Do solitary cells and colonies differ in growth, composition, and rates of photosynthesis?
- How do nutrients and grazers affect colony development and size distribution?
- How do nutrients and grazers act synergistically to affect long-term population dynamics?

We will conduct laboratory experiments at McMurdo Station to study size-specific growth and rates of photosynthesis in *P. antarctica,* size-specific grazing mortality from microzooplankton and mesozooplankton, the effects of macronutrients on the relative dominance of solitary cells and colonies, and the effects of iron and grazing-related chemical signals on colony development. We will use mesocosm experiments to study the synergistic effects of nutrients and grazing on the long-term dynamics of solitary cells and colonies.

P. antarctica is of critical importance in the Ross Sea and in the entire Southern Ocean, and our research will provide information on factors that regulate its role in food webs and biogeochemical cycles, as well as advance our understanding of many ecological and biogeochemical processes in the waters it dominates. Results will also allow us to compare *P. antarctica* with the better known *Phaeocystis globosa* and *Phaeocystis pouchetii* and begin to unveil their ecological and evolutionary similarities and differences. (B-230-M; NSF/OPP 04-40478)

Habitat utilization by Southern Ocean seals: Using novel methods of oceanographic data collection to determine the foraging behavior of crabeater and elephant seals.

Daniel P. Costa, University of California–Santa Cruz.

Marine mammals must be capable of accommodating broad variations in food resources over large spatial and temporal scales. Variation in the physical and biological environment is particularly profound in the Southern Ocean. Our current understanding of this spatial and temporal variation and of how animals respond is limited to population studies that cannot provide insight into the strategies individual animals use or their spatial or temporal course.

The key to understanding the processes that lead to high predator abundance is identifying the specific foraging behaviors associated with different features of the water column. We will examine the southern elephant seal (*Mirounga leonina*) and the crabeater seal (*Lobodon carcinophagus*) in the western Antarctic Peninsula. Although these two species are phylogenetically related, they use different but adjacent habitat types. Southern elephant seals are predominantly pelagic, moving throughout the Southern Ocean and venturing occasionally into the seasonal pack-ice, while crabeater seals range throughout the pack-ice and venture occasionally into open water. We will determine how specific foraging behaviors and animal movement patterns are related to oceanographic and bathymetric features, develop and test models of the importance of these features in defining habitat use, and compare how individual animals respond to environmental variability.

Besides supporting some of the planet's most abundant marine resources, the Southern Ocean plays an important role in climate. Significant efforts are being directed at developing mathematical models of oceanographic processes with the goal of better understanding the role that the Southern Ocean plays, predicting the responses of ocean and global processes to climate change, and understanding the links between physical and biological processes. These efforts have been limited by the scarcity of oceanographic data, especially at high latitudes during the winter months. This lack impedes understanding of several key features of the Southern Ocean.

In addition to providing new data on temperature and salinity profiles, our efforts are geared toward understanding the dynamics of the upper water column of the continental shelf off the western Antarctic Peninsula, with an eye toward developing a mechanistic understanding of the column's annual and seasonal heat and salt budgets. (B-232-E; NSF/OPP 04-40687)

Physiological and molecular mechanisms of stress tolerance in a polar insect.

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

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

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

splash. Alternatively, larvae may be subjected to extended periods of desiccation as their microhabitats dry out.

Our research will focus on three areas:

- Microclimatic variability: Our primary objective is to obtain a detailed characterization of microclimatic conditions experienced by *B. antarctica,* especially related to thermal and hydric diversity, both seasonally and among microhabitats near Palmer Station. These data will be critical for establishing the relevant ecological conditions to be used in laboratory experiments.
- Physiological and molecular responses to extreme fluctuations in water availability: We will assess the hypothesis that midge larvae use cryoprotective dehydration for winter survival. It is also anticipated that genes encoding heat shock proteins and other genes are up-regulated in larval responses to dehydration and rehydration.
- Dietary transmission of cryoprotectants: Our experiments are designed to test the hypothesis that midge larvae acquire increased resistance to desiccation and temperature stress by getting cryoprotectants from their host plants.

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

Controls on Ross Sea Algal Community Structure (CORSACS): Interaction of iron, light, and carbon dioxide on phytoplankton community dynamics in the Ross Sea.

Giacomo R. DiTullio, University of Charleston; Robert Dunbar, Stanford University; Peter Sedwick, Bermuda Biological Station for Research; David Hutchins, University of Delaware; Philippe Tortell, University of British Columbia; and Walker O. Smith, College of William and Mary, Virginia Institute of Marine Science.

The Southern Ocean will play a central role in modulating future climatic changes and will, in turn, be greatly affected by them. The ability to predict these changes and to assess their impact on marine systems is hindered by a poor understanding of oceanographic processes and their links to global climate. A critical question concerns controls on the large-scale distribution and production of the two major bloom-forming phytoplankton in the Southern Ocean—diatoms and *Phaeocystis antarctica.* Through their involvement in the biogeochemical cycles for carbon, sulfur, and nutrient elements, these two groups may have played important roles in the climate variations of the late Quaternary and are likely to be key players in future environmental change.

One paradigm posits that irradiance (vertical mixing) and iron availability drive phytoplankton dynamics in the Southern Ocean. Recent work, however, suggests that carbon dioxide may also be important in structuring algal assemblages. The Ross Sea is ideal for investigating the factors that regulate the distribution and production of these two algal groups since it has seasonal blooms that are typically separated by space and time. We will examine the interactive effects of dissolved iron concentration, irradiance, and partial pressure of carbon dioxide on diatom and *Phaeocystis* bloom dynamics in the Ross Sea through

- a field survey and analysis of algal assemblage composition, iron, mixed layer depth, and carbon dioxide levels on two transects in the southern Ross Sea during the spring *Phaeocystis* bloom and the summer postbloom period; and
- shipboard semicontinuous and natural community chemostat culture experiments to examine the response of diatom and *P. antarctica* assemblages to high and low levels of iron, light, and carbon dioxide.

Our project will provide information on the major factors controlling the production and distribution of these phytoplankton and the related biogeochemical cycling of carbon, sulfur, and nutrients. Our results will ultimately enhance the ability to predict how the Southern Ocean will be affected by and could modulate future climatic change. Moreover, we will involve graduate and undergraduate students, postdoctoral fellows, and a student teacher as well as engage in community outreach and educational activities. (B-272-N; NSF/OPP 03-38097, NSF/OPP 03-38350, NSF/OPP 03-38164, NSF/OPP 03-38111, and NSF/OPP 03-38157)

Improving acoustic estimates of antarctic krill populations.

Joseph Warren, State University of New York at Stony Brook.

Antarctic krill are a vital link in the food web of the Southern Ocean. In addition to serving as prey for birds, pinnipeds, and whales, they are also harvested by several nations. To manage this fishery, acoustic surveys are conducted annually. While acoustic methods have several advantages, converting backscatter information to numerical abundance is difficult. In this 3-year program, we seek to improve the accuracy of acoustic surveys by examining three questions:

- Are acoustic surveys underestimating krill by avoiding shallow-water, near-shore areas?
- Is upwelled deep water the cause of the high productivity of the waters around Cape Shirreff, Livingston Island, and, if so, how does this vary?
- Can a new technique improve the conversion of acoustic backscatter data to numerical abundance?

Using a research vessel chartered by the National Oceanographic and Atmospheric Administration's Antarctic Marine Living Resources Program, we will conduct a small-boat survey to collect acoustic, meteorological, hydrographic, and video data. We will sample off- and on-shelf regions, focusing on two submarine canyons flanking Cape Shirreff. We will construct and deploy five spar buoys to collect acoustic backscatter and Acoustic Doppler Current Profiler data. We will use these data, along with the hydrographic information from the small-boat survey, to determine whether Upper Circumpolar Deep Water is traveling up the submarine canyons and increasing productivity. We will determine how this influx varies in order to understand the functions that control the abundance of krill.

We will measure the total target strength of different sizes, ages, and species of live krill during years 1 and 3 and develop algorithms to determine whether broad-bandwidth scattering data can be used to identify types. The results will improve the ability of scientists and fishery managers to use acoustic data to estimate krill abundance and will lead to a better understanding of the importance of near-shore populations and the factors controlling their distribution and abundance.

The instrumentation used in this project will be deployed off Long Island to provide students who will participate in data analysis with access to modern sampling

methods. The buoy data and the course materials we develop will be placed on the Internet. (B-320-E: NSF/OPP 06-33939)

Temporal variability in natural and anthropogenic disturbances at McMurdo Station, Antarctica.

Mahlon Kennicutt, Texas A&M University.

Antarctica represents one of the most carefully tended, strictly monitored habitats on Earth. Protecting the flora, fauna, and atmosphere of this pristine environment is important, but in addition, the extreme southern latitudes provide a virtual barometer of global pollution. A basic precept in understanding human-induced changes in natural systems is that they take place against a backdrop of natural variability that would occur with or without anthropogenic perturbation. The causes of change cannot be unambiguously determined unless natural variability is defined. This requires long-term observations. In this project, we will continue our previous studies at McMurdo Station to establish the extent of temporal variability in terrestrial and marine habitats.

We are collecting observations that should enable scientists to be more aware of any anthropogenic impacts, locating them precisely and tracking them over time. Drawing on our 3-year pilot program, we will create an initial environmental monitoring program that will include point-data sampling grids measuring a series of attributes indicative of change at various spatial scales. Our objectives are to determine

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

We will collect a series of 163 terrestrial samples of hydrocarbons, trace metals, and carbon analyses at fixed-point and random-sample locations. We will also sample three transects of three offshore points for chemical contaminants, sediment properties, and benthic infaunal assemblages and assay them for toxicity. We will then use geographic information system techniques and geostatistical methods to organize these diverse data sets into a coherent, coordinated framework and multivariate statistics to analyze them.

Continuous observations are a critical component of U.S. environmental stewardship in Antarctica. Our monitoring will provide the objective information needed to make timely and informed management decisions on support and science operations. By providing fundamental knowledge of how antarctic systems operate and how human activities alter them, our study will also help fulfill environmental protection regulations under both domestic law and the Antarctic Treaty. (B-518-M; NSF/OPP 03-54573)

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LONG-TERM ECOLOGICAL RESEARCH

The peaks of the Royal Society Range as seen from a bird's-eye view in the Taylor Valley in the McMurdo Dry Valleys. (*NSF/USAP photo by Peter Rejcek*)

Overview

Ecology has taken its place among science's vital, strategic disciplines, thanks to an ever-greater awareness of how the web of life and the Earth's other dynamic processes constitute a closed and coherent system. As part of this evolution, the National Science Foundation's Long-Term Ecological Research (LTER) Program, begun in 1980, has grown into a network of 26 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.

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 Organisms and Ecosystems 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 studies a polar marine biome that focuses on the antarctic pelagic marine ecosystem, including marine sea ice habitats, regional oceanography, and the terrestrial nesting site of seabird predators. It 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 places on Earth 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.

The role of resource legacy on contemporary linkages between biodiversity and ecosystem processes in a cold desert ecosystem: The McMurdo Dry Valley Long-Term Ecological Research Program.

W. Berry Lyons, Ohio State University.

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

The McMurdo LTER project focuses on the aquatic and terrestrial ecosystems in the Dry Valleys landscape as a context to studying biological processes and to exploring material transport and migration. During this 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 in ecosystem structure and function. We will test a series of eight hypotheses in three major focus areas—hydrology, biological activity/diversity, and biogeochemical processes—by continuing our monitoring projects and long-term experiments.

Understanding the structure and function of the McMurdo Dry Valleys ecosystem requires deciphering the hydrological response to climate, both now and in the past. Current patterns of biological activity and diversity reflect past and present distributions of water, nutrients, organic carbon, and biota. Biogeochemical processes responsible for the transport, immobilization, and mineralization of nutrients and other chemicals provide the linkages between the region's biota and the physical environment. The timing, duration, and location of biogeochemical processes in the past and present are controlled by the availability of water. We continue to focus on the integration of the biological processes within and among the lakes, streams, and terrestrial ecosystems that comprise the McMurdo Dry Valleys 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 2006-2007 field season, the following studies will be conducted in the McMurdo Dry Valleys as part of the LTER project:

Chemistry of streams, lakes, and glaciers. (B-420-M; NSF/OPP 04-23595)
W. Berry Lyons, Ohio State University.

Flow, sediment transport, and productivity of glacial melt streams.(B-421-M; NSF/OPP 04-23595)
Diane M. McKnight, University of Colorado-Boulder.

Lake pelagic and benthic productivity: Microbial food webs. (B-422-M; NSF/OPP 04-23595)
John C. Priscu, Montana State University–Bozeman.

The influence of environmental conditions on carbon and nitrogen cycling and on soil biota, the effects of environmental change and food supply availability on soil biota, and the effects of climate change on biota.(B-423-M and B-424-M; NSF/OPP 04-23595)
Ross A. Virginia, Dartmouth College, and Diana H. Wall, Colorado State University.

Glacier mass balance, melt, and energy balance: Climate monitoring in Taylor, Wright, Victoria, and Beacon Valleys.(B-425-M; NSF/OPP 04-23595)
Andrew G. Fountain, Portland State University.

Paleoclimatology, paleoecology, and meteorological data collection. (B-426-M; NSF/OPP 04-23595)
Peter T. Doran, University of Illinois-Chicago.

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

Hugh W. Ducklow, College of William and Mary, Virginia Institute of Marine Science.

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

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

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

By studying extant food webs in both the marine and terrestrial environments, we will continue to investigate ecosystem changes at lower trophic levels; changes

in response to continued, dramatic warming; and shifts in the poleward climatic gradient along the western Antarctic Peninsula.

During the 2006-2007 field season, the following studies will be conducted as part of the PAL LTER project:

Seabird (penguins, giant petrels, and skuas) ecology.(B-013-L/P; NSF/OPP 02-17282)
William R. Fraser, Polar Oceans Research Group.

Primary production and phytoplankton ecology.(B-016-L/P; NSF/OPP 02-17282)
Maria Vernet, University of California-San Diego, Scripps Institution of Oceanography.

Physical oceanography and ocean-climate modeling.(B-021-L; NSF/OPP 02-17282)
Douglas G. Martinson, Columbia University.

Zooplankton and nekton stocks, feeding, and growth.(B-028-L/P; NSF/OPP 02-17282)
Langdon B. Quetin, University of California-Santa Barbara, and Robin M. Ross-Quetin, University of California-Santa Barbara.

Remote sensing and bio-optics. (B-032-L/P; NSF/OPP 02-17282)
Raymond C. Smith, University of California-Santa Barbara.

Microbial ecology and biogeochemistry.(B-045-L/P; NSF/OPP 02-17282)
Hugh W. Ducklow, College of William and Mary, Virginia Institute of Marine Science

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OCEAN AND ATMOSPHERIC SCIENCES

A cable portrudes from the ice wall at Explorer's Cover, New Harbor, McMurdo Sound. The cable is used for the Remotely Operable Micro-Environmental Observatory (ROMEO), an underwater camera. Connected to onshore equipment and linked by radio to the Internet, ROMEO allows scientists to study benthic fauna year-roun. (*NSF/USAP photo by Steve Clabuesch*)

Overview

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

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

The Antarctic Ocean and Atmospheric Sciences Program supports 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 Meteorological Research Center.

Charles R. Stearns, University of Wisconsin–Madison and David B. Reusch, Pennsylvania State University.

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– science education. (O-202-M/P/S; NSF/OPP 01-26262 and NSF/OPP 05-38064)

Changes in atmospheric oxygen (O_2), carbon dioxide (CO_2), and argon (Ar) concentrations in relation to the carbon cycle and climate.

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

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 collections (flask sampling of air) being made at a series of baseline sites around the world. The two antarctic sites are South Pole and Palmer Stations.

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. The project will also involve continued measurements of changes in atmospheric argon concentrations, which provide constraints on the magnitude of air-sea heat exchange and on oceanic influences on atmospheric oxygen.

The data we gather will be of great use in modeling studies of ocean circulation and various carbon-related processes. Technology for making climate-relevant observations will be advanced and made available to the scientific community through publications and student training. This project will help enhance our understanding of the processes that regulate the buildup of carbon dioxide in the atmosphere and of the change processes, especially climate change, that regulate ecological functions on land and sea. (O-204-P/S; NSF/ATM 03-30096)

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

Taro Takahashi, Columbia University, and Colm Sweeney, Princeton University.

The Southern Ocean provides an important component of the global carbon budget. Cold surface temperatures, with consequent low vertical stability, ice formation, and high winds, produce a very active environment in which the atmospheric and oceanic reservoirs readily exchange gaseous carbon. The Drake Passage is the narrowest point through which the Antarctic Circumpolar Current and its associated fronts must pass; this so-called chokepoint provides the most efficient site to measure the latitudinal gradients of gas exchange.

Working from the research ship *Laurence M. Gould*, we will use equipment designed to measure dissolved carbon dioxide gas, occasional total carbon dioxide, nutrients, and carbon-13 in the surface waters during transects of the Drake Passage. Two short cruises (4 to 5 days) will also be dedicated to providing a baseline for surface measurements with water column profiles.

This work extends similar measurements made aboard the research ship *Nathaniel B. Palmer* and complements other data collected on surface temperatures and currents. The objective is to test the hypothesis that the mean annual partial pressure of carbon dioxide (pCO_2) in the surface water of the Drake Passage is determined by the degree of winter mixing. This is of special significance in light of two scenarios that may be affecting the ventilation of deep water in the Southern Ocean now and in the future:

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

If winter mixing determines the mean annual pCO_2 in the Drake Passage, the increasing trend in atmospheric pCO_2 will have little effect on sea surface pCO_2.

The data sets we will gather, supplemented by satellite imagery, will enable scientists to estimate the net production and carbon export by the biological community, as well as the basic targets—a quantitative description of the sources of dissolved carbon dioxide variability and a calculation of carbon dioxide fluxes between the ocean and the atmosphere. These data will also help validate biogeochemical modeling efforts and provide a baseline data set for studies throughout the Southern Ocean. (O-214-L/N; NSF/OPP 03-38248 and NSF/OPP 06-11553)

South Pole monitoring for climatic change—U.S. Department of Commerce NOAA Earth System Research Laboratory, Global Monitoring Division.

David Hofmann, National Oceanic and Atmospheric Administration, Earth System Research laboratory, Global Monitoring Division.

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

- seasonal and temporal variations in greenhouse gases,
- the depletion of stratospheric ozone,
- transantarctic transport and deposition,

- the interplay of trace gases and aerosols with solar and terrestrial radiation fluxes that occur on the polar plateau, and
- the development of polar stratospheric clouds over Antarctica.

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

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

The Drake Passage high-density XBT/XCTD program.

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

At the latitude of the Drake Passage, which is off the tip of South America, there are no continental boundaries to impede the flow of the Antarctic Circumpolar Current. The continual circumpolar flow therefore provides an effective mechanism for water-property exchanges and the transfer of climate anomalies throughout the world's oceans. The region experiences the strongest winds in the world, driving the current and enhancing the large heat and momentum exchanges between the ocean and the atmosphere. Recent studies have shown that large fluctuations can occur from weekly to interannual time scales in response to regional and remote forcing.

The dynamics and heat exchange within the Southern Ocean are further complicated by the prevalence of eddy variability. Eddy heat flux probably plays a strong role in heat balance, with a more uncertain role in providing an effective mechanism for dissipating the energy input of the wind. We will attempt to determine the significance of the eddy fluxes to the heat and momentum balance of the current and their relationship to the forcing fields.

During each crossing of the research ship *Laurence M. Gould*, we intend to launch expendable bathythermographs (XBTs), supplemented by expendable conductivity- temperature-depth (XCTD) probes, to obtain high-density sections from which to study the seasonal variability and long-term change in the upper ocean structure of the Drake Passage. Whenever the distance between Antarctica and neighboring land is narrow, as in the Drake Passage, the Antarctic Circumpolar Current, which drives the waters in the Southern Ocean, is extremely strong.

The information we gather will lead to the establishment of a high-quality database that can be used to study the magnitude and depth of penetration of the seasonal signals, the connections to atmospheric forcing, and the effects of interannual variations such as those associated with the Antarctic Circumpolar Current The sections obtained during these voyages will supplement the approximately 20 sections that we have been gathering and studying since September 1996. Our data analysis will continue to be carried out in cooperation with the Instituto Antártico Argentino in Buenos Aires. (O-260-L; NSF/OPP 03-37998)

Collection of atmospheric air for the U.S. Department of Commerce NOAA Earth System Research Laboratory, Global Monitoring Division, worldwide flask-sampling network.

David Hofmann, National Oceanic and Atmospheric Administration, Earth System Research Laboratory, Global Monitoring Division.

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.

Palmer Station personnel 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)

The Amundsen Continental Shelf and the Antarctic Ice Sheet.

Stanley S. Jacobs

Focusing on the Amundsen Sea and Pine Island Glacier with an experienced team of scientists and engineers aboard the *Nathaniel B. Palmer*, we will use an autonomous underwater vehicle (AUV), sea-floor swath mapping, vertical wate-column profiling, and geochemical sampling to study interactions between the ice shelves and the seawater that floods the deeper parts of the continental shelves in the southeast Pacific sector of Antarctica.

We will also investigate how this water gains access to the continental shelf, transports heat into the ice shelf cavities via deep, glacially scoured troughs, and rises beneath the ice to drive basal melting. This work will be carried out in combination with parallel modeling, remote sensing, and database projects in an

effort to narrow uncertainties about the response of the West Antarctic Ice Sheet to climate change.

Our project will be the first use of a sophisticated long-ranging AUV under warm-regime ice shelves and is likely to become the proof of concept for that methodology.

Using state-of-the-art facilities and instruments, our work will enhance knowledge of water mass production and modification, and understanding of the interactions between ocean circulation, sea floor, and ice shelves. Findings will be reported to publicly accessible archives and submitted for publication in the scientific literature. The information obtained should prove invaluable for the development and validation of general circulation models needed to predict the future role of the Antarctic Ice Sheet in sea level change. (O-274; NSF/OPP 04-40775)

Antarctic automatic weather station program: 2004-2007.

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

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

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

Shipboard acoustic Doppler current profiling on the *Nathaniel B. Palmer* and *Laurence M. Gould.*

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

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

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

Our long-term objectives are to

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

With new dual-frequency ADCP capability gained through the acquisition and installation of 38 kilohertz phased-array Doppler sonars, in addition to the existing 150 kilohertz ADCP capability, the maximum profiling range will increase to about 1,000 meters under good sea and scattering conditions while maintaining higher vertical resolution in the upper 300 meters. New software developments will improve the ability to measure currents while the ships are in ice. The collection, quality control, real-time processing, and dissemination of this high-quality data set allow these observations to be used to support ongoing antarctic science programs and make the data easily accessible for conducting retrospective analyses, planning future observations, and validating numerical models. (O-315-N and O-317-L; NSF/OPP 03-37375 and NSF/OPP 03-38103)

Physics and mechanics of the breakup of warm antarctic sea ice: In-situ experiments and modeling.

John P. Dempsey, Clarkson University.

We will study how the antarctic sea ice cover responds to stresses applied by wind and ocean waves and how the temperature distribution within the sea ice affects these responses. We will investigate the breakup of antarctic sea ice in light of recent findings indicating that the fracture strength of first-year ice is strongly size dependent, that the deformation and fracture on the scale of tens of meters is influenced by microstructural anisotropy, and that the characteristic flaws of sea ice (such as brine drainage features) give rise to length scales relevant to transitions in fracture behavior. Given the importance of warm McMurdo Sound sea ice for research and tourism at McMurdo Station, there is an urgent need to understand its fracture behavior. We will therefore investigate the following topics:

- coupled deformation-diffusion influences (due to fluid transport within the ice matrix),
- the influence of loading rate versus specimen size over a significant size range,
- fractal descriptions of the failure surfaces, and
- a new cyclic loading geometry (independent of the fracture testing).

Our findings will provide insight into the underlying mechanisms of ice breakup and will significantly improve the accuracy and reliability of models.

Each fracture test will have several parts that will allow us to make quantitative comparisons between deformation and fracture energy and the fractal dimension. Few such comparisons are available for any geologic material. We will examine, both theoretically and experimentally, the ability of sea water and brine to be transported within the ice matrix, and we will also make quantitative assessments of permeability. We have timed our work to coincide with significant warming of the sea ice.

Two graduate students will be involved in this project and in the teaching and outreach associated with it, and every effort will be made to recruit them from underrepresented groups. Moreover, a different K– teacher will be invited for each of the three trips we will take. To more broadly disseminate our material, we will produce CDs and maintain a World Wide Web page. (O-316-M; NSF/OPP 03-38226)

Cape Adare long-term mooring.

Bruce Huber

Antarctic Bottom Water (AABW) is the densest of the major water masses filling the deepest parts of the worlds oceans. Because it obtains many of its characteristics during its contact with the sea and glacial ice and with the atmosphere along the continental margins of Antarctica, it is expected that changes in newly formed AABW may represent an effective indicator for abrupt climate change. The two most important source regions for AABW are within the Weddell and the Ross Seas. The latter arguably the second largest source, yet no systematic efforts have been undertaken to make long-term measurements of its outflow.

An array of moorings will be deployed and maintained east of Cape Adare at the northwestern corner of the Ross Sea to observe the properties of AABW exiting the sea.

This study will significantly improve our knowledge of the long-term variability in the outflow of deep and bottom water from the Ross Sea and will provide the beginnings of a long-term monitoring effort that ultimately will allow global climate changes to be detected in the ocean. When joined with similar efforts ongoing in the Weddell Sea, long-term behavior and possible coupling of these two important sources of the ocean's deepest water mass can be examined in detail.

Several aspects of climate research depend on high quality observations made consistently over a long period of time. This has been recognized, and global programs such as the World Climate Research Program have strongly encouraged such observations. Data from the project will be made available to the community in a timely fashion to foster its widespread use for climate research and operational assessments. (O-399; NSF/OPP 05-38148)

National Science Foundation
WHERE DISCOVERIES BEGIN

EARTH SCIENCES

Andrew Podoll and Kelly Gorz, undergraduate students under scientist Allan Ashworth, are working on their own project to map the morphologies and topography of their study area in the McMurdo Dry Valleys using GPS with centimeter accuracy. (*NSF/USAP photo by Peter Rejcek*)

Overview

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. 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.

Geologists have found evidence that there was once a forested supercontinent, which they call Gondwanaland, in the Southern Hemisphere. Before the Earth's 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 rocks 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 meters 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 Earth Sciences Program include the following:

- exploring new horizons in geology with discoveries that range from new dinosaur fossils to meteorites from Mars;
- determining the tectonic evolution of Antarctica, from its central role in the breakup of the Gondwana supercontinent to the active deformation driving present-day volcanism, rifting, and orogenesis;
- observing unique geologic processes, such as the mysterious formation of subglacial lakes or the aeolian sculpting of the Dry Valleys, in action;
- 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
- deciphering paleoenvironmental records, through drilling of the continental margin, to understand Antarctica's role in global climate, ocean circulation, and the evolution of life.

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 Earth Sciences 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 Antarctic 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) 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 Florida State University's Antarctic Marine Geology Research Facility, 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.

ANDRILL.

David M. Harwood, University of Nebraska–Lincoln; Robert M. DeConte, University of Massachusetts; Thomas R. Janecek, Florida State University; Terry J. Wilson, Ohio State University; and Ross D. Powell, Northern Illinois University.

Antarctic Drilling (ANDRILL), an international program representing over 150 scientists from Germany, Italy, New Zealand, the United Kingdom, and the United States, is designed to investigate Antarctica's role in Cenozoic global environmental change. ANDRILL will obtain a record of important Eocene, Neogene, and Holocene stratigraphic intervals in high southern latitudes and will address four themes:

- the history of the antarctic climate and ice sheets,
- the evolution of polar biota,
- antarctic tectonism, and
- Antarctica's role in the Earth's ocean-climate system.

This research will lead to insights into

- the development of the antarctic cryospheric system (ice sheet, ice shelf, and sea ice);
- the magnitude and frequency of cryospheric changes;
- the influence of ice sheets on Eocene to Holocene climate, the modulation of thermohaline ocean circulation, and eustatic change; and
- the evolution and timing of major tectonic episodes and the development of sedimentary basins.

The successful retrieval of cores and excellent depth of penetration from fast-ice, ice-shelf, and land-based platforms is ensured by the improved drilling system. The program will provide new, seismically linked and well-constrained Cenozoic stratigraphic records from locations proximal to the antarctic cryosphere. Empirical data garnered from these records will calibrate numerical models and will allow new constraints to be placed on estimates of ice volume variability, marine and terrestrial temperatures, the timing and nature of major tectonic episodes, and the development of Antarctica's marine, terrestrial, and sea-ice biota.

This research will contribute to the development of strategies to cope with future climate change, provide insight into relationships between ice-sheet fluctuations and volcanic and seismic hazards, and improve models of glacially influenced sedimentary rift basins.

During the 2006-2007 austral summer, we will deploy current meters through the sea ice at the ANDRILL drill site in southern McMurdo Sound. One field party will travel by tracked vehicle to the drill site and establish a field camp. Using a hole melter to create one or more holes in the sea ice, they will deploy an acoustic Doppler current profiler tethered to the sea-ice surface. They will also deploy a string of physical current meters positioned at various depths in the 530-meter water column. These meters, attached to a cable that is anchored to the ocean floor and tethered to the sea-ice surface, will record 6 to 8 weeks of oceanographic current velocity data, are required in advance of drilling operations at the site to model the sea-riser riser behavior under variable tidal current velocities at various water depths. A second field team will recover the instruments in late November.

The project will also contribute to other international science goals, bring together international teams, and provide opportunities to share antarctic earth science with the global community. ANDRILL will foster strong partnerships with established educational programs to develop a broad array of activities designed to educate policymakers, K– teachers, students, and the community at large. (G-049-M; NSF/OPP 03-42484, NSF/OPP 03-42407, NSF/OPP 03-42408, NSF/OPP 03-42436, and NSF/OPP 03-42445)

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

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

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

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

Our research is aimed at the following:

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

During the 2006–2007 austral summer, our group will be divided into two field teams. Working in Beacon Valley, one group will attempt to determine the age, origin, and climate significance of buried ice in the western Dry Valleys region. This team will drill and collect approximately 15 cores from buried ice. The second team will study Dry Valley microclimates At Don Juan Pond to better understand ancient and current climate processes on Mars. This team will document the

range of surface geomorphic processes in at least three discrete microclimate zones (a coastal-thaw zone, and inland-mixed zone, and a stable-upland zone) in the Dry Valleys.

Better understanding of surface processes above buried ice on Earth will permit researchers to gain access to a record of atmospheric and climate change that could well cover intervals that predate Quaternary time. Since the conditions in the Dry Valleys are analogous to those found on Mars, extending the results could bring valuable insight into the potential for life on Mars. (G-054-M; NSF/OPP 03-38291 and NSF/OPP 03-38244)

3-D dynamics of the Ferrar magmatic mush column, McMurdo Dry Valleys, Antarctica.

Bruce D. Marsh, Johns Hopkins University.

A fundamental difficulty in understanding the highly integrated nature of planetary magmatism is that so few of the deeper aspects of the true dynamic nature of an active system can be directly observed. The historic concept of a deep source of magma connected by a simple conduit to a high-level expansive magma chamber is being replaced by the concept of a magmatic mush column a vertically extensive stack of sills or high aspect ratio chambers interconnected by a plexus of pipe-like and/or dike-like conduits stretching over significant depths beneath areas of active volcanism.

The Ferrar dolerites of the McMurdo Dry Valleys system represent *perhaps* the best exposed, most highly integrated, and most petrologically diverse crustal expression of a magmatic mush column on Earth.

The goal of this research is to determine the dynamics of establishment and operation of this system through a series of pivotal studiesby

- building a 3-D image of the entire system based on the detailed and regional geology;
- using the Opx tongue crystals within the 3-D magmatic structure as tracers to gauge the pattern of filling, understand the dynamics of entrainment, transport, and deposition of these phenocrysts, and determine the ultimate provenance or source characteristics of the Opx load itself;
- exploring a process of granite dike production and re-injection associated with sill formation, which is of fundamental importance in chemically contaminating Mush Columns; and
- seeking to numerically simulate the texture, crystal size distributions, and physical properties of basaltic magma during solidification and then to use the lattice-Boltzmann method to study the texture for critical physical properties.

The insights and results of this work are being used to understand the mitigation of magmatic hazards at Yucca Mountain; to understand ore deposition at Sudbury, Ontario, and to design museum exhibits. The work is also being interwoven with undergraduate research and in writing special lectures for the K–students, including students with learning disabilities. (G-056; NSF/OPP 04-40718)

The antarctic search for meteorites (ANSMET).

Ralph P. Harvey, Case Western Reserve University.

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

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

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

During the 2006–2007 austral summer the main ANSMET field team will conduct a full-scale systematic meteorite recovery from icefields at sites near the Grosvenor Mountains in the central Transantarctic Mountains. Three key sites are targeted:

- the Larkman Nunatak icefield, where 80 specimens were recovered in just a few days during the 2004–05 field season;
- the Mt. Block / Mt. Mauger icefields, which have not been previously visited;
- and the Mt. Raymond / Mt. Cecily area, where 164 meteorites were recovered during the 1985 and 1995 field seasons.

At all three locations the field team will establish a base camp and then begin systematic recovery of meteorite specimens through overlapping transect searches of exposed blue ice. (G-057-M and G-058-M; NSF/OPP 99-80452)

Late Cenozoic volcanism and glaciation at Minna Bluff, Antarctica: Implications for antarctic cryosphere history.

Thomas Wilch, Albion College.

To understand and respond to global warming and its accompanying threats of sea level rise and agricultural disruptions, well-dated and characterized reconstructions of the antarctic cryosphere are critical. This study will use volcanic and glacial records at Minna Bluff in the western Ross embayment of

Antarctica to interpret antarctic cryosphere history. Minna Bluff, a 50-kilometer-long peninsula, is a significant topographic barrier that has effectively blocked the Ross Ice Shelf and the former Ross Sea Ice Sheet from flowing southward into McMurdo Sound.

In addition to providing a record of the emergence of the topographic barrier, the Minna Bluff study should yield a discontinuous but reliable record of synvolcanic expansions of the Ross Sea Ice Sheet. The study will include geologic field mapping, sampling, and lithofacies analysis fieldwork. Pilot studies include Argon-40/Argon-39 dating, petrography, and geochemical analyses; stable isotope evaluation of alteration environment of glaciovolcanic deposits; and Chlorine-36 dating of post-volcanic glacial deposits. The research also has direct relevance on the ANDRILL project and provides a complementary terrestrial record to the marine record, and project results and outreach will be coordinated and shared with the ANDRILL community.

The project also features a McMurdo Station series of short geological field trips as an outreach component geared to the non-science McMurdo Station community. Additional outreach efforts include educational programs targeted at public schools and community groups near our home institutions, exhibits for a science museum, and a project website. (G-062; NSF/OPP 05-38342)

Deducing the climate in late Neogene Antarctica from fossil-rich lacustrine sediments in the Dry Valleys.

David R. Marchant, Boston University, and Allan C. Ashworth, North Dakota State University.

Ancient lake sediments deposited alongside former outlet and alpine glaciers in the Dry Valleys are sensitive indicators of past climate and ecological change. We will analyze 17 former lake sites above 1,000 meters on the north wall of central Taylor Valley and in north-facing valleys of the Asgard and Olympus Ranges. Chronological control comes from argon isotope analyses of interbedded volcanic ash. Lake sediments over 13 million years old contain layers of well-preserved pleurocarpous mosses, diatoms, woody stems, and insects; younger sediments lack such fossils. The fossil-rich lacustrine sediments of the Dry Valleys contain the only known in-situ tundra-type flora and fauna in the Transantarctic Mountains outside the Beardmore Glacier region.

Our objectives include

- developing a better characterization of the distribution of ancient lakes and their flora and fauna,
- securing a more refined chronology,
- producing a geochemical signature for glass within ice-marginal lakes, and
- providing a comparison for previously mapped terrestrial vegetation in the central Transantarctic Mountains.

Our results will help place the modern Dry Valleys lakes in a long-term framework and will facilitate dating among deposits across the Transantarctic Mountains. Moreover, our work will improve dating in marine cores from nearby Cape Roberts.

The key questions we will address are as follows:

- When did the polar desert replace the Neogene tundra?
- Was the climate change that caused the biotic turnover unidirectional and permanent, or did short-lived, warmer climatic conditions, supporting tundra, return to the Dry Valleys after the mid-Miocene?
- Were warmer conditions regional or continental?
- What variation is there in species content and richness among Neogene fossil sites in the Transantarctic Mountains?
- Was the extinction of Gondwanaland biota gradual, or were there dispersal episodes during warmer intervals that replenished the biota from South America, New Zealand, and Tasmania, thus delaying extinction until the Pliocene?

This research will introduce students to a unique synthesis of the Dry Valleys; results will be disseminated in scientific journals and in a special volume of the American Geophysical Union's Antarctic Research Series. (G-063-M; NSF/OPP 04-40711 and NSF/OPP 04-40761)

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

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

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

In October 2006 during a 14-day cruise aboard the *Nathaniel B. Palmer*, we will test seismic reflection equipment and host a marine geophysics class for undergraduate and graduate students. Beginning in Lyttleton, New Zealand, the cruise will transit about 2 days to the east-northeast to get out of shipping lanes and into deeper waters. The approximate survey region will be bounded by latitudes 40 °S to 43 °S and longitudes 177 °E to 173 °W, all within New Zealand territorial waters. After the transit, we will conduct 10 days of streamer testing and geophysical surveying, followed by a 2-day transit back to Lyttleton. Our research team will survey magnetics, conduct multi-beam swath bathymetry, and collect echo sounder data whenever possible.

The survey area is on the northeast side of the Chatham Rise, New Zealand. Our primary research objective is to study the boundary between the Hikurangi Plateau and the Chatham Rise. This boundary is believed to be a fossil (Cretaceous) subduction zone in which the edge of the oceanic Hikurangi plateau was forced beneath the continental crust of the Chatham Rise, which was part of West Antarctica. A better understanding of the oceanic basement structure here will help in models of Cretaceous plate tectonics along the antarctic margin. (G-071-N; NSF/OPP 03-38317 and NSF/OPP 03-38346)

Dry Valley Seismic Project.

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

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

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

From Hatherton, they pass along a point-to-point protocol link to the Internet at McMurdo Station and then to the Albuquerque Seismological Laboratory for general distribution to the international seismological community. This data set complements 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)

Mount Erebus Volcano Observatory II (MEVO II): surveillance, models, impacts, and outreach.

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

Mount Erebus, Antarctica's most active volcano, is known for its unique geochemistry and for a persistent convecting lake(s) of anorthclase phonolite magma in its summit crater. It is one of only a handful of volcanoes worldwide that have permanent lava lakes and exhibit readily observable and nearly continuous Strombolian explosive and associated internal activity. The volcano also serves as a natural laboratory to study magma degassing associated with an open convecting magma conduit as well as a test-bed for evaluating instrumentation and power systems in antarctic and volcanic environments.

The primary goal of this study is to develop an understanding of the Mount Erebus eruptive and noneruptive magmatic system using an integrated approach from geophysical, geochemical, and remote sensing observations by

- sustaining year-round surveillance of on-going volcanic activity primarily using geophysical observatories;
- understanding processes within the convecting conduit that feeds the persistent lava lakes; and
- comprehending the impact of Erebus eruptive activity the antarctic environment.

In addition to contributing fundamental knowledge to the understanding of volcanic processes, this research will be included in a special issue of the *Journal of Volcanology and Geothermal Research* devoted to Erebus volcano. We will also work with various media organizations and filmmakers and include graduate and undergraduate students and a science teacher in our laboratory and field studies. (G-081; NSF/OPP 05-38414)

Integrated study of East Antarctic Ice Sheet tills (ISET): Tracers of ice flow and proxies of the ice-covered continental shield.

Kathy J. Licht and R. Jeffrey Swope, Indiana University, Purdue University–Indianapolis; John W. Goodge, University of Minnesota; and G. Lang Farmer, University of Colorado-Boulder.

Our interdisciplinary study of glacial deposits in the Ross embayment will help constrain Antarctica's Late Quaternary glacial history (about 18,000 years ago) and improve our knowledge of the rocks underlying the East Antarctic Ice Sheet. While constraining changes to till during transport, we will use till provenance to evaluate models for the last glacial maximum and to characterize rocks eroded from the East Antarctic Craton.

Although progress has been made in constraining the extent and timing of the last glacial maximum in the Ross Sea, reconstructions vary substantially. For example, some studies have concluded that ice streams derived from the west were dominant features of the Ross Ice Sheet during the last glacial maximum, while others show roughly equal inputs from east and west. Glacial sediments from the Ross embayment can be used to test these models.

Despite limited data, our previous work suggests that:

- the east-to-west variations in the sand composition of Ross Sea till can be linked to eastern and western sources and that the ice sheets contributed equivalent volumes to the Ross Ice Sheet during the last glacial maximum,
- tills from West and East Antarctica are distinguishable and can be related to Ross Sea tills, and
- detritus from specific glaciers in the Transantarctic Mountains can be isotopically fingerprinted.

We will collect till samples from moraines at the heads and mouths of the Amundsen, Beardmore, Byrd, Liv, Nimrod, Reedy, Scott, and Shackleton Glaciers. We will then characterize particle size distribution, clast lithology, sand petrography, isotopic composition and elemental abundance of the silt/clay fraction, and ages of detrital zircons.

We will build predictions of the ice sheet's response to changing climate and rising sea level from models that accurately predict past configurations. Detailed sampling will allow us to characterize changes to till produced by the processes that modify sediment during transport and to determine constraints on the transport distances of eroded bedrock, as well as provide evidence of unmapped, buried rocks.

Also, we will host curriculum development workshops for 30 Indiana earth science educators, thus allowing us to reach over 600 students from diverse backgrounds. (G-084-M; NSF/OPP 04-40885, NSF/OPP 04-40160, and NSF/OPP 04-40177)

Gneiss dome architecture: Form and process in the Fosdick Mountains, Antarctica.

Christine S. Siddoway, Colorado College, and Christian Teyssier, University of Minnesota-Twin Cities.

Gneiss dome formation involves material and heat transfer from middle or deep crustal levels and therefore represents a fundamental orogenic or mountain-forming process. Recent breakthroughs in understanding the role of migmatitic gneiss domes result from the geophysical exploration of contemporary mountain belts that reveal a thick, midcrustal layer of partially molten crust within the orogenic system. As middle crust exposures, gneiss domes offer the means to study structural and metamorphic processes that cannot be observed directly in contemporary orogens and to undertake a detailed analysis of structures beyond the resolution of seismic imaging.

In the Fosdick Mountains of the Ford Ranges of western Marie Byrd Land are excellent three-dimensional exposures of an elongated migmatite dome derived from sedimentary and plutonic protoliths. Preliminary findings suggest that peak metamorphism occurred about 105 million years ago at depths of about 25 kilometers, followed by decompression as the Fosdick Dome was emplaced to 16 to 17 kilometers, or possibly 8.5 kilometers, by 99 million years ago. Near-isothermal conditions, favorable for producing substantial volumes of melt, were maintained during ascent. Because mineral assemblages record decompression and because the ages of argon isotopes indicate rapid cooling, the gneiss dome has been interpreted as a product of extensional exhumation. This is a viable interpretation from the regional standpoint, because the dome was emplaced during the mid-Cretaceous with the rapid onset of divergent tectonics along the proto-Pacific margin of Gondwanaland.

However, the complex internal structures in the Fosdick Mountains have not been integrated into the extensional exhumation model, and alternative models have not been explored. Possible alternatives are upward extrusion within a contractional setting or lateral flow within a transcurrent attachment zone. To address this question, we will use detailed structural analysis, paired with geothermobarometry and geochronology, to determine the flow behavior and structural style that produced the Fosdick Dome. Our study will be relevant to research on the role of gneiss domes for material and heat transfer in orogeny and on mechanisms of gneiss dome formation.

In addition to multidisciplinary research, students will be involved in developing curriculum materials. (G-088-M; NSF/OPP 03-38279 and NSF/OPP 03-37488)

Global seismograph station at Palmer Station and the South Pole.

Rhett G. Butler, Incorporated Research Institutions for Seismology.

Seismology, perhaps as much as any other science, is a global enterprise. Seismic waves resulting from earthquakes and other events can be interpreted only through simultaneous measurements at strategic points all over the planet. The measurement and analysis of these seismic waves are not only fundamental to 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, the Incorporated Research Institutions for Seismology (IRIS)was created in 1985.

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

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

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

At Palmer Station, a science technician will continue to monitor the GSN seismometer installed there. (G-090-P/S; NSF/EAR 00-04370)

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

Lisa Tauxe, Hubert Staudigel, and Catherine Constable, Scripps Institute of Oceanography.

This project's research focuses on the Earth's magnetic field. Paleomagnetic data 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. During a previous study, we sampled 70 sites in the high Southern Latitudes. For this study we will obtain paleomagnetic and geochronological data samples from lava flows in these targeted regions. These samples will be essential to an enhanced understanding of the time-averaged field and its long-term variations.

Outreach activities will include development of web-based middle and high school classroom materials about the Earth's magnetic field and plate tectonics with the goal of expanding these materials for college-level introductory classes. (G-182; NSF/OPP 05-38392)

An integrated and geomagnetic and petrologic study of the Dufek Complex.

Jeffrey S. Gee, Scripps Institution of Oceanography.

The Dufek Complex of Antarctica (including the Dufek Massif and Forrestal Range) provides a unique setting to test hypotheses relating to

- the intensity and directional stability of the Earth's magnetic field in the Jurassic,

- the extent to which secular variations of the geomagnetic field are averaged in slowly cooled intrusive igneous rocks, and
- the magmatic construction and thermal history of this large layered intrusion.

This research features an integrated petrologic and magnetic study, which should provide powerful constraints on the magmatic construction and thermal history of the Dufek Complex and its relationship to the Ferrar diabases and Kirkpatrick basalts.

We plan to integrate our research efforts with graduate and undergraduate education by including students in the data collection and interpretation. The chemical data collected will be made available via the internet and on CD/DVD media and the magnetic data will be archived in the paleomagnetic database (http://www.earthref.org/MAGIC/index.html). This research complements and extends planned German/Chilean International Polar Year activities in the Dufek area. The study's results will be presented at international conferences and in published papers. (G-192; NSF/OPP 05-37609)

UNAVCO global positioning system survey support.

Bjorn Johns, UNAVCO.

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

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

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

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

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

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

Controls on sediment yields from tidewater glaciers from Patagonia to Antarctica.

Bernard Hallet, University of Washington.

Using Patagonia and the Antarctic Peninsula region as an ideal natural laboratory, this project will examine the role of glacier dynamics in determining glacial sediment yields via glaciology and marine geology techniques. Prior studies of the region have noted a significant decrease in glaciomarine sediment accumulation in the fjords along a southward transect, and the fjords constitute accessible and nearly perfect natural sediment traps. We hypothesize that rates of glacial erosion are a function of sliding speed and are therefore expected to diminish sharply as basal temperatures drop below the melting point.

To test this hypothesis, we will measure both sediment accumulation rates in fjords and dynamic characteristics of the glaciers producing the sediments, from fast-moving temperate glaciers in Patagonia to slow-moving polar glaciers on the Antarctic Peninsula. For each of the six tidewater glaciers, we will define an empirical relationship between glacial erosion rates and ice dynamics by

- assessing sediment yields and, by inference, erosion rates by determining sediment accumulation rates within the fjords using seismic profiles and core data, and
- measuring dynamic properties and basin characteristics of the glaciers, all of which have distinctly different ice fluxes and basal thermal regimes.

The results of the project will contribute to a better understanding of the linkages between climate, tectonics, and topography in all high mountain ranges; of the climate record archived in glaciomarine sediments; and of the drastic retreat of the glaciers in Fuego-Patagonia and the Antarctic Peninsula.

Educational outreach activities will encourage participation of underrepresented groups, especially younger women in the sciences and K– educators. The study also will include a cross-disciplinary exchange and collaboration with Chilean glaciologists and marine geologists. (G-411; NSF/OPP 03-38371)

The connection between mid-Cenozoic seafloor spreading and the western Ross Sea embayment.

Steven C. Cande, Scripps Institution of Oceanography, and Joann Stock, California Institute of Technology.

Prior studies indicate 170 kilometers of seafloor spread between East and West Antarctica during the mid-Cenozoic period, between 43 and 26 million years ago. However, the relationship of the seafloor spreading to the continental basins to the south in the Ross Sea embayment area has yet to be established. This study will use a marine geophysical survey to study the structural relationship of the seafloor between the Adare Basin and the northern and central basins of the Ross Sea embayment to determine how this area was accommodated.

This project will acquire magnetic, gravity, swath bathymetry, and multi-channel seismic data from the southern end of the Adare Basin to the northern parts of the northern basin and central trough for testing two hypotheses:

- there is complete structural continuity from the Adare Basin south into the northern basin, and the northern basin of the Ross Sea Embayment also experienced 170 kilometers of extension; or
- there is a structural offset that transferred some of the displacement sideways into the central trough of the Ross embayment.

In addition to furthering an understanding of Ross Sea tectonics, the Adare Basin work will better constrain models of mid-Cenozoic motion between East and West Antarctica; affect study of the global plate circuit linking the plates of the Pacific Ocean to the rest of the world; and contribute to our understanding of rifted margins. The project will support two graduate students, one at University of California, San Diego and one at California Institute of Technology and will have other students as watchstanders. The project will also involve scientists from Australia, New Zealand, and Japan, and, consequently, will foster the broad dissemination of results to the international community. (G-413; NSF/OPP 04-40959 and NSF/OPP 04-40923)

Constraining the petrogenesis and mantle source of Adare Basin seamount lavas.

Paterno R. Castillo, Scripps Institution of Oceanography, and Kurt S. Panter, Bowling Green State University.

The fundamental cause of Cenozoic magmatism associated with the West Antarctic rift system has been explained by a variety of models based primarily on geochemical evidence gathered from igneous rocks from continental West Antarctica. The goal of this project is to collect petrographic, geochronologic, geochemical, and isotopic data to assess these existing, but often conflicting, models on mantle geodynamics and control on magmatism in the region.

To accomplish this goal, we will collect dredged samples from the numerous but relatively small volcanic seamounts in the Adare Basin in the western Ross Sea, northern Victoria Land, which are collectively called Adare Basin seamounts. By establishing that these seamounts are of Cenozoic age and genetically related to other Cenozoic igneous rocks in West Antarctica, researchers should be able to better constrain the "pristine" mantle source composition of West Antarctic magmas and possibly of the whole southwest Pacific.

The project's geochemical database will be available to other researchers addressing similar problems in the Adare Basin region. Outreach activities include fostering faculty and student collaboration and pooling multidisciplinary resources among Scripps Institution of Oceanography, Bowling Green State University, and the New Mexico Institute of Mining and Technology to ensure these multi-user facilities continue to be valuable sites for advanced technological mentoring of science students. (G-430; NSF/OPP 05-38266 and NSF/OPP 05-38374)

Controls on sediment yields from tidewater glaciers from Patagonia to Antarctica.

John B. Anderson and Julia S. Wellner, Rice University, and Bernard Hallet, University of Washington.

Glacial erosion is a principal issue in contemporary research on landscape evolution and high-latitude climate change. In the Himalayas, for example, the spatial pattern and rapid rates of tectonic rock uplift correspond closely to patterns and rates of erosion by ice and water. On a global scale, the onset of widespread glacial erosion is often viewed as responsible for the increase in sedimentation that coincided with a change to a cooler, more variable climate at the onset of late Cenozoic glaciation (about 2 to 4 million years ago). At high latitudes, this increase in sedimentation created clastic wedges up to 5 kilometers thick on continental margins; these sediments contain a rich history of climate change recorded in proxy climate data (ice-rafted debris, foraminifera) and sediment accumulation rates that reflect the production of glacial sediment.

Our aim is to define an empirical relationship between glacial erosion rates and ice dynamics. We will use glaciologic and marine geologic techniques to examine the role of glacier dynamics in determining glacial sediment yields. We hypothesize that glacial erosion rates are a function of sliding speed and will therefore diminish sharply as basal temperatures drop below the melting point. To test this hypothesis, we will study six tidewater glaciers ranging from fast-moving temperate glaciers in Patagonia to slow-moving polar glaciers on the Antarctic Peninsula. For each system, we will

- use seismic profiles and core data to assess yields and, by inference, erosion rates by determining sediment accumulation rates in the fjords, and
- measure the dynamic properties and basin characteristics of each of the glaciers, which have different ice fluxes and basal thermal regimes.

We will base our work in Patagonia and the Antarctic Peninsula because

- the large latitudinal range provides for a wide range of precipitation and glacier thermal regimes over relatively homogeneous lithologies and tectonic settings,
- earlier studies have noted a significant decrease in the accumulation of glaciomarine sediment in the fjords along a southward transect, and
- the fjords constitute accessible and nearly perfect natural sediment traps. (G-435-N; NSF/OPP 03-38137 and NSF/OPP 03-38371)

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WHERE DISCOVERIES BEGIN

GLACIOLOGY

An ice core drill lies on a table revealing the scoop cutters and collet (the metal ring just inside the drill). Both features are new to ice core drilling and were tested at WAIS in 2006–2007. For more information on this research, read the January 7, 2007, issue of *The Antarctic Sun* at: http://antarcticsun.usap.gov. (*NSF/USAP photo by Steven Profaizer*)

Overview

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 thick, that is larger than most countries, that rises over 2,000 meters 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 meters. Actually, the continent has two distinctly different sheets: the much larger East Antarctic Ice Sheet, which covers the bedrock core of the continent, and the smaller, marine-based West Antarctic Ice Sheet, which is beyond the Transantarctic Mountains and overlays a group of islands and waters.

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

- correlating antarctic climatic fluctuations (from ice-core analysis) with data from arctic and lower-latitude ice cores;
- integrating the ice record with terrestrial and marine records;

- documenting the geographic extent of climatic events noted in paleoclimatic records and the extension of the ice core time series to provide information on the astronomical forcing of climate;
- establishing more precise dating methodologies for deep ice cores;
- determining the Cenozoic history of antarctic ice sheets and their interaction with global climate and uplift of the Transantarctic Mountains and the response of the antarctic ice sheets to the Pliocene warming;
- investigating the physics of fast glacier flow with emphasis on processes at glacier beds;
- investigating ice-shelf stability; and
- identifying and quantifying the feedback between ice dynamics and climate change.

Ice cores from Antarctica are important for determining whether the rapid climate changes recorded in Northern Hemisphere ice cores, such as those obtained from Summit, Greenland, in the Greenland Ice Sheet Project II (GISP2), are global in extent. Efforts have begun to drill a deep ice core at a site that has both thick ice and high annual accumulation and is located on the ice divide in West Antarctica. This is the only antarctic site where scientists can obtain an ice core capable of providing a long, annual resolution history of Southern Hemisphere climate in which compressed snow layers are thick enough to allow absolute dating. This ice core will provide a Southern Hemisphere equivalent to the GISP2, GRIP (the European Greenland Ice Core Project), and North GRIP ice cores and will allow a detailed comparison of environmental conditions between the Northern and Southern Hemispheres. The ice cores will also complement those already under study from Byrd Station and Siple Dome in West Antarctica and Taylor Dome and Vostok Station in East Antarctica. Ice cores are unique in that they contain continuous, or nearly continuous, records of annual precipitation, atmospheric temperature, and components of the atmosphere, including gases as well as soluble and insoluble aerosol particles from a variety of sources (biogenic, terrestrial, solar, marine, volcanic, anthropogenic).

Ice cores collected under the Antarctic Glaciology Program are stored at the National Ice Core Laboratory (NICL), a government-owned facility for storing, curating, and studying cores recovered from the ice-covered regions of the world. NICL is supported through an Interagency Cooperative Agreement with the U. S. Geological Survey (USGS) and provides researchers funded by the National Science Foundation and the USGS with the capability to examine and measure ice cores while preserving the integrity of these cores in a protected environment.

Fluctuations of the West Antarctic Ice Sheet in relation to lake history in Taylor Valley, Antarctica, since the last glacial maximum.

Michael L. Prentice, Plymouth State University; Ronald S. Sletten, University of Washington; and Steven A. Arcone, U.S. Army Cold Regions Research & Engineering Laboratory.

This study examines the stratigraphy of near-surface sediments in Taylor Valley, Antarctica. Two contrasting hypotheses proposed for surface sediments in this region have important and different implications for how the West Antarctic Ice Sheet (WAIS) responded to the sea-level rise of the last deglaciation and Holocene environmental changes. One hypothesis holds that the sediments directly reflect more than 10,000 Carbon-14-years of WAIS shrinkage in the Ross Sea during and perhaps driven by deglacial sea-level rise. The other hypothesis holds that the Taylor sediments have little significance for WAIS change during the deglaciation because this sediment was deposited in a large glacial lake, the surface level of which was not necessarily influenced by the WAIS.

These two hypotheses reflect fundamentally different interpretations of the sediment record. To test these two hypotheses, we will use glacial geology, geochemistry, ground-penetrating radar (GPR) and portable sediment coring. We will also study the geomorphology and stratigraphy of valley-floor sediment sequences and collect GPR profiles and 30 meters of sediment core in two separate locations that feature excellent conditions to test both models of sediment formation. The coring is vital to calibrating interpretation of the GPR results.

Understanding the glacial and lake history in the McMurdo Sound region has important implications for the role that the WAIS will play in future sea-level and global climate change. Moreover, the history of Taylor Valley has significance for the ecosystem studies currently being conducted by the Antarctica Long Term Ecological Research Project. Two graduate and undergraduate students will participate in the studies, and research will also feature prominently in our teaching. (I-133; NSF/OPP 05-40073, NSF/OPP 05-41054, and NSF/OPP 05-39983)

A Science Management Office for the U.S. Component of the International Trans Antarctic Expedition (US ITASE SMO): A collaborative program of research from Taylor Dome to the South Pole.

Paul Andrew Mayewski, University of Maine.

Changes in the antarctic environment have the potential to exert significant controls on the global climate system. The International Trans Antarctic Scientific Expedition (ITASE) is a long-term, multinational, multidisciplinary field research program with the broad aim of understanding the recent 200-year environmental history of Antarctica. The U.S. component of the project is focused on ice core investigation and data collection from the Taylor Dome to the South Pole region in East Antarctica.

The sum of the traverses in this region will provide environmental data on temperature change and atmospheric circulation, ice accumulation rates, ice thickness, and internal radio-echo horizons for ice entering the Ross Sea embayment from the south and west through a series of large outlet glaciers, including Beardmore, Nimrod, Byrd, Mulock, and Shackleton glaciers.

This project and US ITASE activities thus far will provide important focus to determine the significance of environmental change in both West and East Antarctica. The overall program has integrated the disciplines of meteorology, remote sensing, geophysics, dynamical glaciology, ice core glaciology, and atmospheric chemistry.

Outreach activities planned include annual workshops to discuss logistics and science; maintenance and expansion of a public website; a virtual exhibit at the Museum of Science in Boston; and numerous lectures for K– students, the public, and professionals. (I-153; NSF/OPP 04-40679)

Grounding line forensics: The history of grounding line retreat in the Kamb Ice Stream outlet region.

Ginny Catania, University of Texas, Austin; and Christina Hulbe, Portland State University.

Understanding ice streams' unique geologic setting and associated dynamics is a long-standing objective of West Antarctic glaciology. Comprehending such processes has important influence over our ability to accurately predict mass balance changes in this region. Currently, Kamb Ice Stream is quiescent and Whillians Ice Stream is slowing in its downstream reaches. The Kamb shutdown appears to have begun at its downstream end but beyond that simple observation, it is not yet possible to draw meaningful comparisons between these two adjacent streams. We do not know whether current events on Whillians Ice Stream are similar to what transpired during the Kamb shut-down. Using radio-echo sounding and global positioning, this study will to bridge that gap by exploring past grounding line migration and the relationship between that process and ice stream shutdown.

This study will contribute to the hotly debated possibility that the West Antarctic ice streams might be grinding to an interglacial halt. We intend it to also have a broader impact of training the next generation of scientists and engineers and encouraging women to pursue scientific or engineering careers. (I-159; NSF/OPP 05-38120 and NSF/OPP 05-38015)

Using polarimetric radar methods to detect crystal orientation fabrics near the Ross/Amundsen Sea ice-flow divide and at the Siple Dome ice core site.

Charles F. Raymond and Kenichi Matsuoka, University of Washington.

The alignment of ice crystals, called crystal-orientation fabrics (fabrics), has an important effect on ice deformation. As ice deforms, anisotropic fabrics are produced; these in turn influence further deformation. Consequently, fabric variation measurement can reveal how the ice was deformed and indicate how it will deform in the future. Ice cores can determine a vertical fabric profile, but not horizontal variation. Examining variation over large areas requires remote sensing with ice-penetrating radar. We will therefore use ground-based radar measurements to investigate fabrics near the Ross/Amundsen Sea ice-flow divide, where a deep core will be drilled.

When fabric is not rotationally symmetrical around a vertical axis, vertically propagating radio waves are affected by bulk birefringence related to the fabric's axis. Polarimetric methods can detect the degree of horizontal anisotropy and the orientation of fabrics, even when they are nearly vertical.

At McMurdo Station, we will calibrate and test our ice-penetrating radar system. When these tests are complete, we will travel by LC-130 aircraft to the WAIS Divide field camp in West Antarctica. Using snowmobiles, we will take detailed radar measurements of the ice at 21 sites within a 60 kilometer by 150 kilometer area. We will also measure the strain grids that were installed at these sites last season. We will use the global positioning (GPS) data, together with depth variation of radar-detected isochrones, to derive modern strain rate configuration and to simulate fabrics for shallow depths (about 1,000 meters). Using the simulated fabrics as a reference, we will examine mismatches between simulated and measured fabric azimuths and strengths, and their horizontal variation, to infer divide migration in the past.

Our work will help evaluate the impact of the West Antarctic Ice Sheet on the rise in global sea level and support collaboration between the United States and Japan. Moreover, our measurements may lead to new designs for polarimetric radio-wave sensors for ice on Earth and Mars. (I-163-M; NSF/OPP 04-40847)

Spatial variability in firn properties from borehole optical stratigraphy at the inland WAIS core site.

Edwin D. Waddington, University of Washington.

Ice core records provide details about the climate, atmospheric chemistry, and accumu-lation that are essential to our understanding of the Earth's history. Yet ice cores measure the snow from only a tiny piece of the ice sheet present millennia ago and cannot account for spatial variations in accumulation or in snow-metamorphic processes that can change ice core chemistry. Thus ice core records may contain spurious apparent climatic variations brought about when spatial patterns of accumulation change over decades. It is particularly critical to understand variations of this type near the proposed inland West Antarctic Ice Sheet (WAIS) core, because this core site is thought to have good resolution of decadal climate variations.

Using Borehole Optical Stratigraphy (BOS), we will study the patterns of accumulation variation and microstructural properties near the WAIS core site in a 2.5-kilometer array of 20-meter boreholes. The BOS detects layers in firn that result from changes in firm microstructure, giving annual-scale records of how accumulation varied across the array over the past 40 to 50 years.

Statistical analysis of the layer data will let us predict the following:

- the expected level of variability in layer thickness due to interannual accumulation vari-ability
- the expected level of variability in layer thickness at decadal scales due to changing spatial patterns in accumulation and
- the expected level of variability in microstructure-driven metamorphism due to changing spatial patterns of microstructure.

With these statistics in hand, a scientist measuring climatic shifts found in the inland WAIS core will be able to determine the fraction by which signals they measure exceed the signal due to background accumulation variations.

The results of this field experience will be incorporated into an undergraduate seminar as well as a middle school science and math class. (I-171; NSF/OPP 05-38639)

Ice dynamics and surface glaciology along U.S. ITASE traverse routes in East Antarctica.

Gordon S. Hamilton, University of Maine.

Global sea level rise is accelerating and poses a substantial threat to society. Complete melting of the West Antarctic Ice Sheet would raise sea level by approximately 5 meters. The much larger East Antarctic Ice Sheet contains the sea level equivalent of 65 meters of water. Small ongoing changes in these ice sheets might account for some of the unexplained contribution to observed sea level rise, but there are too few direct measurements of the ice sheets to test this hypothesis. A better understanding of ice sheet changes is therefore necessary to assess their current contribution to global sea level and to model future contributions.

This work will be conducted along the traverse route from Taylor Dome to South Pole. Its objectives are to take advantage of the overland traverse logistics framework provided by the U.S. component of the International TransAntarctic Scientific Expedition (US ITASE) and to collaborate with other US ITASE investigators to:

- calculate rates of ice sheet thickness change (mass balance) on domes, along elevation contours, and along flow lines in East Antarctica using precise global positioning system methods;
- assess variability in snow accumulation rates using shallow ice cores and ground-penetrating radar profiling, and provide a way to deduce true past climate variation in accumulation rates from 200-year-long ice core records by measuring ice motion and upglacier gradients in accumulation rate; and
- study patterns and causes of the onset of streaming flow in the catchments of selected large outlet glaciers draining through the Transantarctic Mountains.

The results of this project will lead to an improved understanding of the Earth system and provide a basis for sound planning and policy decisions. (I-178; NSF/OPP 04-40792)

Center for Remote Sensing of Ice Sheets (CreSIS)

S. Prasad Gogineni, University of Kansas–Lawrence; Richard B. Alley, Pennsylvania State University; David Braaten, University of Kansas; Kenneth C. Jezek, Ohio State University; and Glenn E. Prescott, University of Kansas.

CreSIS will study the present and future contributions of the polar ice sheets to sea-level change. The problems of determining ice-sheet mass balance and creating predictive models of ice-sheet dynamics are scientifically and technologically complex, gauged by the intricacy of the ice sheet processes themselves. Ice accumulation and loss rates are affected by seasonal and interannual variations in snowfall, snow drift, radiation, temperature, and other weather and climate variables. Ice sheets contain ice streams, ice shelves, and glaciers whose dynamics and interaction with the ocean and atmosphere are imperfectly understood. A multidisciplinary team of scientists and engineers will address these issues through technical innovation, data collection, and data analysis over a span of years.

To determine the mass balance of polar ice sheets, data will be gathered from satellite and airborne platforms and in situ observations. To gather more comprehensive data over areas undergoing significant changes, technologically innovative sensors, platforms, and cyberinfrastructure are necessary. Furthermore, new analytical models and algorithms to interpret the data must be developed to predict long-term ice-sheet behavior from measurements such as ice flow rates, current ice thickness, and average seasonal temperatures for the ice sheet.

Sea-level rise is a serious issue that requires long-term, multidisciplinary collaborations that can be accomplished effectively through a science and technology center where university scientists and engineers work collaboratively with counterparts in industry. The Center for Polar Research and Remote Sensing will serve as a headquarters for current work and a forum for planning future work in an environment where scientists and engineers routinely meet to discuss problems and share solutions in the areas of ice-sheet dynamics and remote sensing, and where they have access to the newest technology and data. Investigations in this area will be more productive by ensuring that ideas, information, and data are readily exploited, technology is effectively developed in response to emerging needs, and contradictions in the data are quickly resolved. (I-189, NSF/OPP 04-24589)

Earth's largest icebergs.

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

Icebergs released by the antarctic ice sheet represent the largest movements of fresh water within the natural environment. Several of these icebergs (e.g., 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 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.

Furthermore, 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 World Wide Web site (http://amrc.ssec.wisc.edu/iceberg.html) that scientists and the general public can access.

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

Characterizing Lake Amundsen-Scott, South Pole: A ground geophysical program.

Sridhar Anandakrishnan, Pennsylvania State University.

This project is a study of Lake Amundsen-Scott using seismic and radar methods. Radar imaging and satellite altimetry work have been used to identify a catalog of over 100 subglacial lakes in Antarctica, which have the potential to harbor novel life forms. Lake Amundsen-Scott is typical of many of the subglacial lakes in its radar signature and subglacial morphology. However, temperature modeling and radar reflection strength modeling have cast doubts on the presence of free water at the base of the ice sheet near the South Pole. Reconciling these contradictory results is crucial to establishing the validity of the subglacial lake catalog.

This study will foster a cross-disciplinary pollination of ideas, techniques, and tools between the seismic and marine acoustics communities. In addition to traditional seismic techniques, new methods of data analysis that have been developed by acousticians will be applied to this problem as an independent measure of lake properties. (I-205; NSF/OPP 05-28097)

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

Helen A. Fricker, University of California-San Diego, Scripps Institution of Oceanography.

Iceberg calving from the front of fringing ice shelves is the primary mechanism by which the antarctic ice sheets lose mass. A single large iceberg can remove a large fraction of the mass gained through years of accumulation and thus can be a significant component in the overall mass balance. This mass contributes to the freshwater flux of the Southern Ocean but does not lead to a change in sea level, since the ice was already floating. However, the presence of ice shelves can influence the discharge of inland ice via the ice streams that feed the shelves; in particular, a reduction in the extent of the ice shelf could increase the rate of discharge. Further, any changes in mass caused by calving could be an indicator of the regional effects of climate change and could modify freshwater mass production rates, which could have global consequences. Therefore, it is important not only to monitor the frequency of iceberg calving, but also to understand the mechanisms that govern it.

Icebergs calve when "rifts," crevasses that penetrate from the surface of the ice shelf to its base, propagate far enough that part of the ice shelf becomes detached. The mechanics are not well understood. We will therefore examine an active rift system—a combination of two longitudinal-to-flow rifts and two transverse-to-flow rifts—that formed at the tip of the western longitudinal rift on the Amery Ice Shelf about 7 years ago. We will use instruments to study the latter two rifts. Their propagation is not independent, and the longer of them is propagating at around 8 meters per day. When this rift meets the eastern longitudinal rift, an iceberg (roughly 30 kilometers by 30 kilometers) will calve. Once calving has occurred, we will examine its effects on the dynamics of the ice shelf and previously inactive rifts.

Calving sparks a great deal of media and public interest. We will report our results widely at conferences and in the scientific literature, and we will use the Visualization Center at the Scripps Institution of Oceanography to display our results. (I-277-E; NSF/OPP 03-37838)

Major chemical composition of the West Antarctic Ice Sheet Divide ice core.

Jihong Cole-Dai, South Dakota State University.

This project will contribute to the U.S. West Antarctica Ice Sheet Ice Divide ice core (WAIS Divide) project by determining the concentrations of the major ions present in all ice cores. To measure the chemical concentrations, we will use a melter-based, continuous-flow, multi-ion-chromatograph technique and newly developed instrumentation (CFA-IC). The fast analysis speed of the CFA-IC system, at approximately 10 meters per day, will permit the high-resolution analysis of the entire core (about 3,300 meters) to be completed within one year of the completion of the deep core drilling.

Annual layer counting using the CFA-IC and other high-resolution measurements will contribute significantly to the project's goal of producing precisely dated climate records for the past 40,000 years. In addition, longer (more than 100,000 years) records of ice core chemistry will be produced, as well as the longest volcanic record from antarctic ice cores. The volcanism-climate connection will also be studied.

The complete continuous, high-resolution chronological records of snow chemistry will be available to the research community to investigate the dynamic history of atmospheric chemistry and its relationship with climate variations, the biogeochemical cycles of important elements, and anthropogenic impact on atmospheric chemical composition. (I-355; NSF/OPP 05-38553)

Using a deep ice core from the West Antarctic Ice Sheet ice divide to investigate climate, ice dynamics, and biology.

Kendrick C. Taylor, University of Nevada Desert Research Institute.

The U.S. ice core research community will collect a deep (3,400 meters) ice core from the West Antarctic Ice Sheet ice-flow divide and integrate approximately 15 separate projects to develop, analyze, and interpret a series of interrelated climate, ice dynamics, and biological records in order to understand the interactions among global systems.

The most significant characteristic of this program will be the development of climate records with an absolute annual-layer-counted chronology for the past 40,000 years (approximately). Lower temporal resolution records will extend to roughly 100,000 years ago. These records will enable us to compare environmental conditions in the Northern and Southern Hemispheres and to study greenhouse gas concentrations in the paleoatmosphere in more detail. The themes of the program are as follows:

- Climate forcing by greenhouse gases: This research will provide a record of greenhouse gases with unprecedented time resolution during the rapid climate changes that occurred at the end of the last glacial period. The relative timing of changes in greenhouse gases and other environmental parameters will be determined.
- The role of Antarctica in abrupt climate change: We will develop high-time-resolution records that can be used to infer the interaction of the southern oceans and atmosphere with each other and with their northern counterparts. This will allow a precise investigation into the role of the Antarctic in abrupt climate changes.
- The relationship among northern, tropical, and southern climates: Small differences in the age of the ice versus the age of the gas in the ice will allow us to investigate the relative timing of Northern Hemisphere Dansgaard-Oeschger events and corresponding Southern Hemisphere climate excursions.
- The stability of the West Antarctic Ice Sheet: We will determine how the West Antarctic Ice Sheet responded to previous climate changes, thereby improving predictions of how the ice sheet and sea level will respond now and in the future.
- Biological signals in deep ice cores: This research will yield information about biogeochemical processes that control and are controlled by climate, as well as lead to new insights about life on Earth.

This season, the project has two phases. First, one field team member will fly aboard an LC-130 airplane to the WAIS Divide field camp and will work with an Ice Core Drilling Services team to drill and extract a 130-meter ice core as close as possible to the main borehole location. Afterward, the crew will drill and extract a 100-meter core from the main borehole. The ice cores will be shipped to the University of Nevada Desert Research Institute for analysis. Second, one field team member from the National Ice Core Laboratory (NICL) will travel later in the season to the WAIS Divide field camp to conduct a site review of the WAIS Divide facility, particularly the core storage and processing areas within the arch. (I-477-M; NSF/OPP 04-40817)

National Science Foundation
WHERE DISCOVERIES BEGIN

ARTISTS AND WRITERS

An ice cave near Palmer Station, Anvers Island, Antarctica. (*NSF/USAP photo by Zee Evans*)

Overview

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

The Antarctic Artists and Writers Program contributes to NSF's goal of advancing discovery while disseminating results broadly to enhance scientific and technological understanding. The program helps record the Nation's antarctic heritage, responding to White House direction that the U.S. Antarctic Program support the range of U.S. interests in the region. Application procedures are available on the NSF Web site at www.nsf.gov/funding/pgm_summ.jsp?pims_id=12783&org=ANT&from=home and a list of past participants can be found at www.nsf.gov/od/opp/aawr.jsp.

The selection process for the Antarctic Artists and Writers Program is comparable to the one for science projects in that a peer-review panel meets at NSF annually to evaluate the applications; this panel's advice heavily influences the selections. The applicants who are chosen receive field support (including air travel from the United States), but no direct NSF funding. The program, while intended mainly for U.S. citizens, considers requests from artists and writers who live in other Antarctic Treaty nations but whose applications demonstrate that their works will reach a significant U.S. audience. The next application deadline for participation will be June 2008.

ANTARCTICArt.

Xavier Cortada

Miami artist Xavier Cortada will travel to Antarctica to develop three art projects that will raise awareness about the continent, its activities and their relationship to our world. In depicting this, the artist seeks to demonstrate how interconnected we as people are to each other and to our planet.

One mural, the Antarctic Message Mural, will be createdin collaboration with scientists and researchers in the Antarctic. A second, the Longitudinal Message Mural, will be a South Pole installation of replicas of other message murals the artist has created around the globe. For the third project, entitled "The 150,000 Year Journey,"the artist will plant an artistic replica of a mangrove seed (made from a yet-to-be-determined noninvasive element) on a 3-kilometer-thick glacial ice sheet at point of the Earth's exact geographic center. Embedded in the moving glacier, the mangrove seed will begin sliding downhill (9.9 meters every year) in the direction of the Weddell Sea, 1,400 kilometers away. The seed will thus begin its 150,000-year journey toward the sea. The project exploits the terrain of the South Pole to address a sociological concern of the artist: the travails of an immigrant's journey—the displacement, the solitude, the struggle to simply integrate into society. In a more universal way, the journey explores humankind as it evolves through time. (W-217-M; NSF/OPP 05-38105)

Works and days: An antarctic chronicle.

Anne Aghion

No one gets to the antarctic by accident: there has to be a real motivation. What makes people choose the physical and emotional exile of this area? Anne Aghion's film, *Works and Days: An Antarctic Chronicle* will explore the human experience of being a scientist today in the extreme environment of Antarctica by looking more closely and more slowly. Spanning a whole season in Antarctica, the stories of three teams of scientists will focus on living in the same conditions at McMurdo Station, Dry Valleys, and in a remote camp and their relationships to their work, to the extraordinary environment that surrounds them, to each other, and to themselves.

By focusing on the relationship of scientists in the Antarctic to their surroundings, both real and imaginary, Ms. Aghion will make the continent a full-fledged character in the film. At the same time, the film will enable the audience to truly experience the atmosphere of the place by allowing them to identify with the protagonists living in an environment that is so extreme that it is difficult to imagine.

All the narrative tension of the film, both in the larger arc, and in the smaller stories that will emerge, will revolve around transmission of knowledge and lore: from old to young, from experienced Antarctican to neophyte, from scientist to layperson, from winter-over to everyone else. With stunning images and sound, the film will be at once compelling, instructive, moving, poetic, and cinematic. Intended for a wide general audience, it will be ready for release in late 2007 to coincide with the International Polar Year (2007–2008). (W-218-M; NSF/OPP 05-37954)

Antarctica: The inner landscape.

Werner Herzog

Popular art film director Werner Herzog will make for The Discovery Channel the first poetic, feature-length film on Antarctica, antarctic science, and scientists, featuring up-to-date science and images that have not been captured on film before.

Going beyond the cute penguins that figure prominently in almost all the films on Antarctica, Mr. Herzog will spend two austral summers filming the crater of Mount Erebus and the activities in and around McMurdo Sound. The film will capture the continent's inner landscape (climate, volcanic activity, geological history, evolution, and survival of life forms) and the less-documented strange forms of life and the scientists who study them. As in all his films, Herzog will attempt to reach a deeper stratum of truth, an "ecstatic" truth.

Because Mr. Herzog will be allowed more creative control and freedom than is usually allowed network TV filmmakers, better and more sophisticated science will be featured in the film, as well as more unusual and unexpected imagery. The film will be useful in classrooms and other educational forums and will generate a tremendous amount of print, radio, and television press coverage. (W-219-M; NSF/OPP 05-38072)

Antarctic Ice: Sculpture in cast glass.

David G. Ruth

David G. Ruth's casting glass work is inspired by the dramatic geologic formations of Antarctica, particularly the ice formations. After seeing a picture of blue ice floating in an arctic cove, he realized that naturally formed ice could extend the dialog his work has had with water over the past 7 years. Mr. Ruth will continue his interest in the textures of natural objects and how they could translate to cast glass.

In this project, he will study the geology of the continent with the hope of seeing some dramatic ice forms in the glaciers and flows, the sea ice, as well as rock and ice together. The ultimate goal is to translate these observations into a body of work consisting of a series of large-scale molded glass sculptures for exhibition in galleries or museums in the United States. (W-220, NSF/OPP 05-55502)

Stellar Axis: Antarctica.

Lita Albuquerque

South Pole Stellar Axis: Antarctica, an installation built on the McMurdo-area sea ice, involves mapping stars on the ice directly to the skies above. Blue reflective disks of various sizes will be used to create the star map. The size of the disk will correspond with the brightness of the stars, and the shadows will demonstrate the motion of the sun. This two-part project includes a similar installation created at the North Pole. The project will offer the public a glimpse of the realities of time and space on a human scale, will develop a visual language that brings the stars to Earth, and will celebrate our connection to the cosmos. The artist will spend 2 weeks in the McMurdo area creating and recording the installation with her crew. This installation will "symbolically link the terrestrial with the celestial" by creating a large-scale "earthworks" installation.

The artist, an arts educator, teaches graduate and high school students and designs and teaches courses that integrate science into art. When the antarctic project is completed, the artist will develop a course about Antarctica and science for the Art Center College of Design (Pasadena, California) that will allow students to assess their impressions of Antarctica by translating scientific concepts through art. She will also exhibit photographs taken during and after the construction of the project to be shown in galleries and discussed via public lectures. A website detailing the creation of the project will also be made available to the public. Accordingly, many high visibility institutions and media outlets have expressed an interest in supporting and publicizing the project. For more information about the artist and her work, visit: www.litaalbuquerque.com/home.html. W-221, NSF/OPP 05-37948)