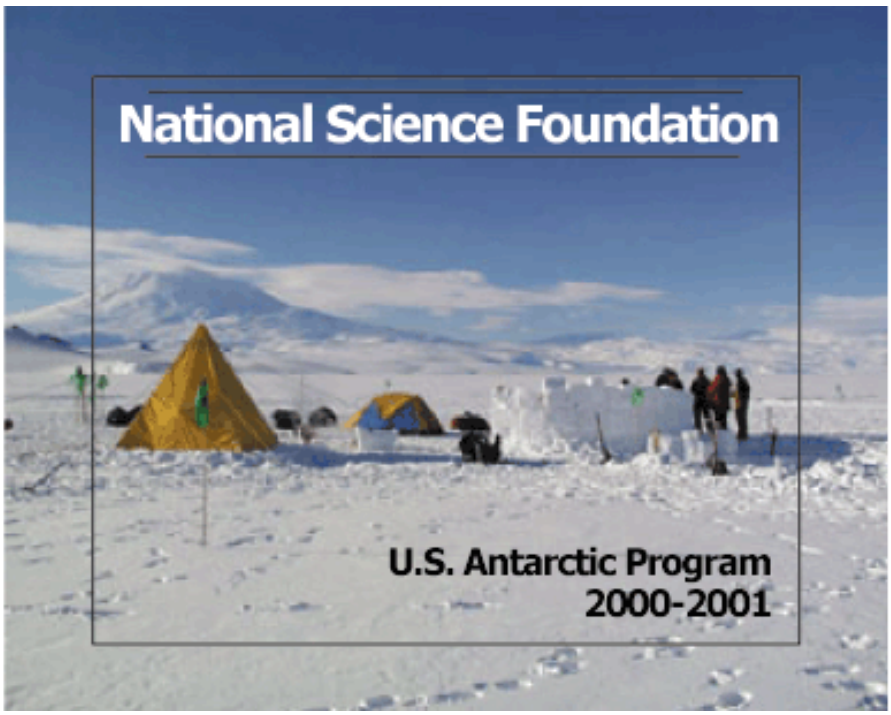

National Science Foundation
U.S. Antarctic Program, 2000-2001

CONTENTS

National Science Foundation
U.S. Antarctic Program, 2000-2001

U.S. ANTARCTIC PROGRAM, 2000-2001

During the 2000-2001 austral summer and the 2001 austral winter, the U.S. Antarctic Program supported more than 800 researchers and other participants in the U.S. Antarctic Program at three year-round stations (McMurdo, Amundsen-Scott South Pole, and Palmer), aboard two research ships (*Laurence M. Gould* and *Nathaniel B. Palmer*) in the Ross Sea and in the Antarctic Peninsula region, at remote field camps, and in cooperation with the national antarctic programs of the other Antarctic Treaty nations. 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 also supports research that can be best or only performed in Antarctica.

The scientists, conducting the projects, come primarily from U.S. universities and have won NSF support in response to the Antarctic Research Program Announcement and Proposal Guide (NSF 01-81; http://www.nsf.gov/cgi-bin/getpub?nsf0181). Operational resources in Antarctica also are used to support scientists from other Federal agencies.

Highlights of the 2000-2001 austral summer research include:

• **Lake Vostok aerial survey.** The Support Office for Aerogeophysical Research, an NSF-funded project at the University of Texas at Austin's Institute for Geophysics, is using a specially equipped Twin Otter airplane to map a 205-by 102-mile grid over subglacial Lake Vostok. The lake, the size of Lake Ontario in North America, has been thousands of meters beneath the East Antarctic Ice Sheet for millions of years and may contain microbes different from known species. The radar survey is a necessary precursor to any international effort to explore the lake. A clean drilling technology would be required to prevent contamination. For additional information about the Lake Vostok project, visit the Lamont-Doherty Earth Observatory site at http://www.ldeo.columbia.edu/./vostok/index.html.

• **Degree Angular Scale Interferometer (DASI).** An interferometric array of 13 microwave antennas is measuring cosmic background radiation temperature variations in a fairly large area of the sky above South Pole. The results appear to have produced some of the most sensitive measurements ever made to help unravel mysteries of the early universe and the nature of the dark matter and energy that many scientists believe constitute most of the universe. For more information about the project, visit either the DASI site on the Center for Astrophysical Research in Antarctica web site at http://astro.uchicago.edu/cara/research/cmbr/dasi.html and the home site for the DASI project at http://astro.uchicago.edu/cara/research/cmbr/dasi.html.

• **Southern Ocean Global Ocean Ecosystems Dynamics (SO/GLOBEC).** Seventeen science teams are using NSF's icebreaking Nathaniel B. Palmer and ice-strengthened Laurence M. Gould research ships to study how marine animals respond to natural and human-caused climate change. During the 2001 austral winter, the ships are working in Marguerite Bay area near the Antarctic Peninsula from March to August. The study is quantifying processes controlling the flux of carbon and other biogenic elements and predicting the response of marine biochemistry to climate change. The Southern Ocean appears to have an extremely large role in this flux. Information about the Southern Ocean GLOBEC program can be at http://www.ccpo.odu.edu:80/Research/globec_menu.html

• **Iceberg B-15 investigations.** An expedition to iceberg B-15, twice the size of the state of Delaware when it calved from the Ross Ice Shelf in 2000, affixed sensors on the berg to study movement of ice in the Southern Ocean. NSF press releases about the project can be found at http://www.nsf.gov/od/lpa/news/media/2000/ma0019.htm and http://www.nsf.gov/od/lpa/news/media/01/ma0104.htm.

• **International Trans-Antarctic Scientific Expedition (ITASE).** Researchers conducted an overland crossing to study the massive West Antarctic Ice Sheet. The traverse is the U.S. part of an International Trans-Antarctic Scientific Expedition (ITASE), a multi-year project seeking to understand changes in the mass and the climate of the West Antarctic Ice Sheet and the climatic events recorded in the ice. Additional information about the project can be found at the University of Maine at http://www.ume.maine.edu/USITASE.

During the 2000-2001 austral summer, seven teachers from U.S. elementary, middle, and high schools joined

researchers on eight projects this austral summer as part of NSF's Teachers Experiencing Antarctica (TEA) project. TEA immerses teachers in research as part of their professional development and to create a polar learning community of teachers, students, school districts, and researchers. U.S. Antarctic Program investigators volunteer to include TEA participants in their field parties; NSF selects the teachers competitively.

The Antarctic Artists and Writers Program provides opportunities for painters, photographers, writers, and others to use serious writing and the arts to increase understanding of the Antarctic and America's heritage there. The 2000-2001 austral summer participants included two painters, an underwater photographer, and a nautralist writing an dillustrating a book on birdes in Chile and the adjacent Antarctic.

Logistics to support these projects includes heavy-lift, ski-equipped C-130 airplanes operated by the New York Air National Guard, ski-equipped Twin Otter airplanes chartered from a Canadian firm, and C-141 and C-5 air-planes provided by the U.S. Air Force between New Zealand and McMurdo Station. Contract helicopters are headquartered at McMurdo to provide operational and close science support. Ground vehicles operated and maintained by an NSF contractor, provide specialized science support and other services. Annually, a U.S. Coast Guard icebreaker opens a channel to McMurdo and provides science support. A tanker and a cargo ship, operated by the Military Sealift Command, bring fuel, cargo, and equipment each January.

Modernization and improvement of the 25-year-old Amundsen-Scott South Pole Station continued. In the last 3 years a new fuel storage facility and a new garage and shop have been erected. During the 2000-2001 austral, a new electric power plant became operational. Modernization of the core station has begun with construction of a tower up from the subsurface new power plant, garage/shop, and fuel facilities. Steel construction of housing and food-service wings of the new elevated station started this summer. The wings will be completed in the austral winter. The project will be completed in 2005. The South Pole Safety and Environmental Project (a $25-million undertaking) and the South Pole Station Modernization Project (a $128-million initiative) will replace the existing station by 2005.

This document is arranged by scientific discipline, except for sections focused on multi-investigator, multi-disciplinary research projects. The order reflects the organization of the Antarctic Sciences Section of NSF's Office of Polar Programs, which funds projects in biology, medical research, ocean sciences, climate studies, geology and geophysics, glaciology, aeronomy, astronomy, and astrophysics.

Related information products that are produced or funded by NSF include:

• Press releases issued by the Foundation's Public Affairs Office to describe specific research progress. See the NSF World Wide Web page at http://www.nsf.gov or call 703-292-8070.

• The Antarctic Sun, which Raytheon Polar Services staff produce in Antarctica during the austral summer for USAP participants. It is funded by NSF and distributed outside of Antarctica from RPSC's web site at http://www.polar.org/AntSun/index.htm. Copies from past season are also available.

U.S. Antarctic Program, 2000-2001
Sites of major activities

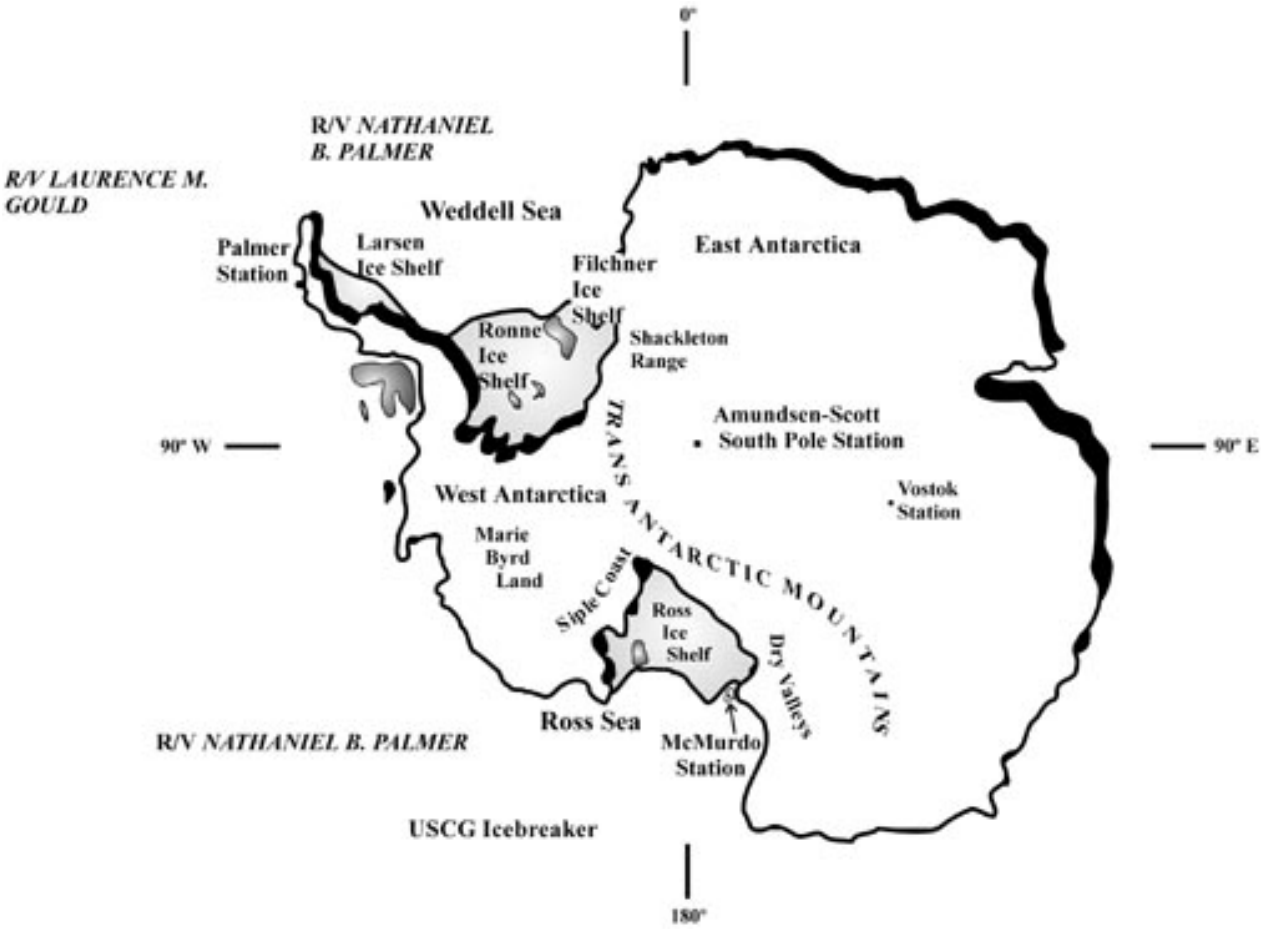

Table of Contents | next section

AERONOMY AND ASTROPHYSICS

The polar regions have been called Earth's window to outer space. Originally, this term applied to aurora and other dynamic events staged as incoming solar plasmas encountered the Earth's geomagnetic fields. Because of its unique properties, the polar upper atmosphere becomes a virtual screen on which the results of such interactions can be viewed (and through which evidence of other processes can pass). More recently, this concept has been 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" in certain seasons.

For astronomers and astrophysicists, the South Pole presents unique opportunities. Thanks to the relative lack of environmental pollution and anthropogenic "noise," the unique pattern of light and darkness, and the geomagnetic force field properties, scientists staging their instruments here can probe the structure of the sun and the universe with unprecedented precision. Studies supported by the Aeronomy and Astrophysics program probe three regions:

• 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 universe beyond, for astronomical and astrophysical studies: Many scientific questions extend outside the magnetosphere, including a particular interest in the sun and cosmic rays. Astrophysical studies are primarily conducted at Amundsen-Scott South Pole Station or on long-duration balloon flights launched from McMurdo.

All research projects sponsored by this program benefit from (indeed most require)
the unique physical conditions found only in the high latitudes, yet their ramifications extend far beyond Antarctica. High-latitude astrophysical research contributes to the understanding of Antarctica's role in global environmental change, promotes interdisciplinary study of geosphere/biosphere interactions in the middle and upper atmosphere, and improves understanding of the critical processes of solar energy in these regions. Life exists on earth in a balance – not only because of the critical distance from the sun – but also because of numerous chemical and atmospheric phenomena peculiar to our atmosphere. The 20th century expansion of traditional astronomy to the science of astrophysics, coupled with the emerging discipline of atmospheric science (See also the Ocean and Climate Systems program), is nowhere better exemplified than in Antarctica.

(AA-130-O)
AMANDA - Antarctic Muon and Neutrino Detector Array.
Robert Morse, University of Wisconsin.

Neutrinos are elementary particles. They are believed to have very little or no mass, no electrical charge, and can take any of three forms. Coursing through the universe, they interact only rarely with other particles. AMANDA's primary objective is to discover the sources - both within our galaxy and beyond - of the shower of very-high-energy neutrinos descending on (and usually passing through) the Earth.

AMANDA uses an array of photomultiplier tubes (embedded between 1 and 2 kilometers into the ice) near the South Pole to create a Cherenkov detector out of the natural ice. Originally, 20 strings were installed in the ice, and last season 6 more strings known as the AMANDA-2 detector were added. This system detects high-energy neutrinos originating off the planet that have passed through Earth. Such sources of origin could be diffuse, made up of contributions from many active galactic nuclei (AGNI); or they could be point sources of neutrinos -

coming from supernova remnants (SNRs), rapidly rotating pulsars, neutron stars, individual blazars, or other extragalactic point sources.

Recently, new sources of high-energy gamma rays have been discovered, such as the source Mrk-421, discovered by NASA's Compton Gamma-Ray Observatory (CGRO) and Mt. Hopkins Observatory. AMANDA is designed to study just such objects, which are believed to emit high-energy neutrinos copiously. To date, neutrino astronomy has been limited to the detection of solar neutrinos, plus one brief, spectacular burst from the supernova that appeared in the Large Magellanic Cloud in February 1987 (SN-1987a). Only now is it becoming technically feasible to build large neutrino telescopes. As one of the first-generation detectors, AMANDA promises to make seminal contributions to this new branch of neutrino astronomy. (AA-130-O)

(AB-145-O)
Long-duration balloon project.
Steven Peterzen, NASA/National Scientific Balloon Facility.

Free-flying balloons possess many advantages as a means of high-altitude exploration; compared to satellites they remain much longer in a specific location, and cost a fraction to launch. The National Scientific Balloon Facility's (NSBF) effort in Antarctica, known as the Long-Duration Balloon (LDB) program, launches high-altitude balloons carrying scientific payloads into the stratosphere.

This season during a launch window from 15 December to 10 January, the LDB program will support two stratospheric flights from its facility at Williams Field (the Top Hat and ATIC projects). The balloons have a volume of 792.756 cubic meters (28.42 million cubic feet) and will ascend at a rate of approximately 275 meters per minute (900 feet per minute) to a float altitude between 3-4 mb (approximately 125kft). The launches will reach float altitude, circumnavigate the continent between 77°S and 80°S latitude (average) and are anticipated to terminate on the Ross Ice Shelf or polar plateau. In advance of these two major launches, up to five "pathfinder" balloons equipped with GPS transponders will be sent up to help determine the stratospheric conditions.

TopHat: This experiment (AO-147-O) will help researchers estimate the mass of the Universe (to at least the 10-percent level) by measuring variations in the cosmic microwave background radiation (CMBR). Instrument data will also provide a high precision map of the sky in the far-IR range for use in galactic studies.

Advance Thin Ionization Calorimeter (ATIC): This project (AO-149-O) involves a series of balloon flights from Antarctica (each from 10-14 days duration) to investigate the composition and energy spectra of galactic cosmic rays (GCR) at the highest energies accessible from balloon platforms. (AB-145-O)

(AB-147-O)
Long-duration balloon program: TopHat 2000-2001 antarctic campaign.
Stephan S. Meyer, University of Chicago, Enrico Fermi Institute.

The CMBR (cosmic microwave background radiation) is the name given to a class of radiation first detected in 1965, which, according to the big bang theory, provides evidence of the Universe's origin. About 15 x 109 years ago, the entire Universe is believed to have consisted only of dense, glowing, hot matter; thus, with no empty space, the seminal explosion was of "space" itself. As the echo of this event, the CMBR proves that the Universe is expanding along with the volume of matter and radiation within it.

This project will conduct a program of complementary balloon-borne experiments to measure the anisotropy on certain angular scales. Such measurements have become increasingly important for providing information on the initial conditions from which the large-scale structure of the Universe has evolved. Measurements detected by COBE on large angular scales (and the results of our FIRS experiment) help to define the outer boundaries for CMBR anisotropy studies. We now enter a detailed measurement phase, which promises quantitative answers to some of the fundamental questions about how the structure of the Universe evolved.

To take advantage of new opportunities for long-duration circumpolar ballooning (LDB), we have developed TopHat. A novel instrument concept designed to provide reliable, quantitative measurements of the CMBR anisotropy, the TopHat instruments are optimized to reject both systematic and foreground spurious signals. By placing the telescope on top of the balloon, we can use an observing environment unequaled in any sub-orbital

CMBR experiment performed to date; The entire sky above the instrument will be free from supporting structures that could scatter radiation into the sidelobes of the optics, which has been a critical source of systematic uncertainty for anisotropy measurements at the 10-6 level of sensitivity. We expect to achieve unprecedented spectral coverage of a significant portion of the sky. Not only does this yield an excellent check of systematic errors which can plague any experiment of this sensitivity, it also will enable us to understand as never before the nature of the far-infrared foreground spectrum in high-galactic latitudes. (AB-147-O)

(AB-149-O)
Long-duration balloon program: Advance thin ionization calorimeter (ATIC) science balloon payload.
John P. Wefel, Louisiana State University.

Galactic cosmic rays (GCR) - electrons and the nuclei of hydrogen and some other atoms - provide the only direct sample of matter from outside the solar system, as they reach the Earth's atmosphere traveling nearly the speed of light. Since they have electric charge, they are deflected by any magnetic fields they encounter on their journey from beyond the solar system. These events, as well as collisions with the nuclei of the atoms making up the tenuous gas throughout the Universe, build valuable scientific information into the GCRs, which scientists on Earth are eager to extract.

Previous, pioneering experiments have indicated differences in the spectra of hydrogen, helium, and the heavier nuclei, based on the energy they posess. Also, when you look at the total overall spectrum and composition of the full ("all-particle") GCR spectrum, you will find changes in the energy regime approaching the well-known spectral "knee" at 1015-1016 electronvolts (eV).

The ATIC Balloon Experiment will use NASA's Long Duration Ballooning program for a series of balloon flights from Antarctica in December 2000 (each lasting 10-14 days) to investigate the composition and energy spectra of galactic cosmic rays (GCR) at the highest energies accessible from a balloon platform, the region up to ~1014 eV. Our goal is to apply new experimental techniques to the study of these very high-energy particles and to verify some previous reports. We also undertake the search for GCR behavior that might be expected if (as is widely believed) supernovae remnants are the "cosmic accelerators" for the GCR. (AB-149-O)

(AO-101-O)
Magnetometer data acquisition at McMurdo and Amundsen-Scott South Pole Stations.
Louis Lanzerotti, University of Alaska Geophysical Institute, and Alan Wolfe, New York City Technical College.

The magnetosphere is that region of space surrounding a celestial object (such as the Earth or the sun) where the object's magnetic field is strong enough to trap charged particles. Magnetometers have been installed at selected sites in both polar regions to measure changes in the magnitude and direction of Earth's magnetic field. The unique climatic conditions in Antarctica also permit scientists to view the atmosphere optically (see project AO-104-O) and to correlate such hydromagnetic-wave phenomena with particle-precipitation measurements.

In this project we are measuring such variations with magnetometers installed at conjugate sites in both hemispheres; at McMurdo Station and Amundsen-Scott South Pole Station, Antarctica, and at Iqaluit, in the Northwest Territories in Canada. The antarctic systems gather unique data related to the coupling of the interplanetary medium into the dayside magnetosphere, including the magnetospheric cusp region. The data also shed light on the causes and propagation of low-frequency hydromagnetic waves throughout the magnetosphere.

The antarctic magnetometers continue to measure the magnitude and direction of variations in Earth's magnetic field in the frequency range from 0 to about 0.1 hertz, with resolution of about one nanoTesla. These data are being analyzed in the context of other concurrent data acquired by the six automatic geophysical observatories (AGOs) that are a part of the Polar Experiment for Geophysical Upper Atmosphere Investigations (PENGUIn) program (project AO-112-0); and the data will also be ranged against data obtained from magnetometers operated by Bell Laboratories in the continental United States. (AO-101-O)

(AO-102-O)
High-latitude magnetic pulsations.
Mark Engebretson, Augsburg College, and Roger Arnoldy, University of New Hampshire.

The Earth's magnetic field arises from its mass and motion around the polar axis, but it creates a powerful phenomena 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 plasmas emanating from the Sun encounter 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 are fluctuations in Earth's magnetic field, called "micropulsations," which can be measured on time scales between 0.1 second and 1,000 seconds. It is known that magnetic variations can significantly affect power grids and pipelines. We plan to use magnetometers (distributed at high latitudes in both the antarctic and arctic) to learn more about how variations in the solar wind can affect the Earth and manmade systems.

We will study these solar-wind-driven variations and patterns at a variety of locations, and over periods of time 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 its manmade systems behavior, it will also involve space weather prediction. (AO-102-O)

(AO-104-O)
Antarctic auroral imaging.
Stephen Mende, Lockheed Palo Alto Research Laboratory.

Scientists are only beginning to essay quantitative studies on the dynamic behavior of the magnetosphere. In the past, detail-oriented explorations with space satellites have enabled them to map the average distribution of magnetospheric energetic particle plasma content. But the dynamics of auroral phenomena - when particles from the magnetosphere precipitate into the atmosphere, producing fluorescence - have been hard to quantify through optical means. Amundsen-Scott South Pole Station is uniquely situated to observe aurora because the darkness of polar winter permits continuous optical monitoring; at most other sites, the sky becomes too bright near local mid-day.

The aurora can actually be regarded as a two-dimensional projection of the three-dimensional magnetosphere, because particles tend to travel along the magnetic field line. By observing the dynamics and the morphology of the aurora, scientists get a reliable glimpse into the dynamics of the region of the three-dimensional magnetosphere associated directly with it. This method relies on knowledge relating the type of aurora to both specific energies of precipitation as well as to specific regions of the magnetosphere.

We are deploying an intensified optical, all-sky imager (operating in two parallel wavelength channels, 4,278 and 6,300 Angstroms) to record digital and video images of auroras in the winter darkness. These wavelength bands allow us to discriminate between more- and less-energetic electron auroras and other precipitation. The South Pole Station observations of the polar cap and cleft regions entail measuring auroral-precipitation patterns and then interpreting the results in terms of the coordinated observations of (magnetic) radio-wave absorption images as well as (high-frequency) coherent-scatter radar measurements.

We expect this work to provide insight into the sources and energization mechanisms of auroral particles in the magnetosphere, as well as other forms of energy inputs into the high-latitude atmosphere. (AO-104-O)

(AO-106-P)
Global thunderstorm activity and its effects on the radiation belts and the lower ionosphere.
Umran Inan, Stanford University.

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

The VLF receivers measure changes in the amplitude and phase of signals received from several distant VLF transmitters. These changes follow lightning strokes because radio (whistler) waves from the lightning can cause very energetic electrons from the Van Allen radiation belts to precipitate into the upper atmosphere. This

particle precipitation then increases ionization in the ionosphere, through which the propagating VLF radio waves must travel. Because the orientations to the VLF transmitters are known, it is possible to triangulate the lightning sources that caused the changes. Once the direction of the lightning source is known, it can be subjected to waveform analysis and used to track - remotely - the path of the thunderstorms. The data will also be correlated with data from the antarctic Automatic Geophysical Observatory network, and will be used by scientists engaged in magnetospheric and ionospheric research. (AO-106-P)

(AO-106-S)
Extremely-low-frequency/very-low-frequency waves at the South Pole.
Umran Inan, Stanford University.

Atmospheric scientists orient their studies around different strata, or regions, and the boundaries and interactions between these regions are of particular interest. How are the upper atmosphere regions coupled electrodynamically? What can we learn by measuring the energy that is being transported between the magnetosphere and the ionosphere? These are but two of the questions the U.S. Antarctic Program's automatic geophysical observatory (AGO) program is designed to explore.

Plasmas occur in the magnetosphere and the ionosphere, and they can be transported and accelerated by a variety of different wave-particle interactions. One important dynamic in this system is particle precipitation that is driven by extra-low-frequency/very-low-frequency (ELF/VLF) waves. Thus, measuring ELF/VLF waves from the multiple sites of the AGO network provides a powerful tool for remote observations of magnetosphere processes.

This project maintains a system at Amundsen-Scott South Pole Station to measure magnetospheric ELF/VLF phenomena, and to correlate the data with measurements made by the AGO system. This season provides an acid test for the reliability of the new digital recording system (compared to the reel-to-reel analog system), which provides higher quality data. (AO-106-S)

(AO-107-O)
Study of polar stratospheric clouds by lidar.
Alberto Adriani, Instituto De Fisica Dell'Atmosfere, Rome, Italy.

The appearance each spring of the stratospheric ozone hole above Antarctica is driven by chlorine compounds interacting on the surfaces of clouds that formed the previous polar winter, known as polar stratospheric clouds (PSCs). This is one explanation for why ozone depletion is much more severe in polar regions than elsewhere.

This project uses light detection and range finding (lidar or a "light detection and rangefinding" instrument) to study the PSCs, stratospheric aerosol, and the thermal behavior and dynamics of the atmosphere above McMurdo Station. Continuous lidar observations provide insight on the formation, evolution, and other peculiar characteristics of these PSCs. These data provide a complement to the information gained from balloon-borne instruments in project AO-131-O, and thus collaborative activities are being coordinated with the University of Wyoming. (AO-107-O)

(AO-109-O)
South Pole Air Shower Experiment-2.
Thomas Gaisser, University of Delaware.

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

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

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

Second, to use the coincident events as a tagged beam. This construction permits us to investigate and calibrate certain aspects of the AMANDA response. This project cooperates with the University of Leeds in the United Kingdom. (AO-109-O)

(AO-110-O)
High-latitude Antarctic neutral mesospheric and thermospheric dynamics and thermodynamics.
Gonzalo Hernandez, University of Washington.

South Pole is a unique and interesting spot from which to observe the dynamical motion of the atmosphere. The fact that it is on the axis of Earth's rotation strongly restricts the types of wave motion that can occur there, as compared to lower latitude sites. Antarctica attracts atmospheric scientists for many reasons; a primary draw is that neutral winds perforce can only blow across the Earth's rotational axis. This simple condition has a profound influence on the large-scale dynamics of the atmosphere at high latitude, as only zonal wave-number one mode horizontal motions are possible.

The resulting simplifications may help in understanding the behavior of the global atmosphere. For example, how do scientists measure the wind speed of the atmosphere? One direct method is by determining the Doppler shift of naturally occurring emissions in the upper atmosphere as they flow along at predictable heights. Hydroxyl radicals (OH), for example, are confined to a fairly narrow band near 90 kilometers altitude.

This study uses a high-resolution Fabry-Perot interferometer (located at Amundsen-Scott South Pole Station) to make simultaneous azimuthal observations of the individual line spectra of several upper atmospheric trace species, most importantly the hydroxyl radical (OH) and atomic oxygen. The observed Doppler shift of the emission lines provides a direct measure of the line-of-sight wind speed, while the wind field structure can also be derived from these multi-azimuth measurements. The simultaneously observed line widths also provide a direct measurement of kinetic temperature. (AO-110-O)

(AO-111-O)
Riometry in Antarctica and conjugate regions.
Theodore J. Rosenberg and Allan T. Weatherwax, University of Maryland at College Park.

The University of Maryland continues to conduct research into upper atmospheric processes; using photometry to take auroral luminosity measurements and riometry to make high-frequency cosmic noise absorption measurements. A primary focus of our analysis activities over the next several years will include coordinated ground- and satellite-based studies and Sun/Earth comparisons.

The latest work also involves extensive collaboration with other investigators using complementary data sets. Continuing science activities in the 1998-2001 time frame - as we enter the next solar maximum period - will enable us to participate in, and contribute to, several major science initiatives, including the GEM, CEDAR, ISTP/GGS, and National Space Weather programs

Riometers measure the relative opacity of the ionosphere. This work employs a new imaging riometer system called IRIS (imaging riometer for ionospheric studies). The first two IRISs were installed at Amundsen-Scott South Pole Station and Sondre Stromfjord, Greenland. A third IRIS has been installed at Iqaluit, Northwest Territories, Canada - the magnetic conjugate to South Pole. Broadbeam riometers also operate at several frequencies at South Pole, McMurdo, and Iqaluit; auroral photometers operate at South Pole and McMurdo. This array of instruments constitutes a unique network for the simultaneous study of auroral effects in both magnetic hemispheres.

The focus of all of this work is to enhance understanding of the relevant physical processes and forces that drive the observed phenomena; this includes both internal (such as magnetospheric/ionospheric instabilities) and external forces, such as solar wind/IMF variations. From such knowledge may emerge an enhanced capability to forecast; many atmospheric events can have negative technological or societal impact, and accurate forecasting could ameliorate these impacts. (AO-111-O)

(AO-112-O)
Polar experiment network for geophysical upper-atmosphere investigations (PENGUIN).
Theodore Rosenberg, University of Maryland at College Park.

The data obtained from automatic geophysical observatories (AGO) help researchers understand the Sun's influence on the structure and dynamics of the Earth's upper atmosphere. The ultimate objective of this research into how the solar wind couples with the Earth's magnetosphere, ionosphere, and thermosphere is to be able to predict solar/terrestrial interactions that can interfere with long-distance phone lines, power grids, and satellite communications.

A consortium of U.S. and Japanese scientists are working with a network of six AGOs, established on the east antarctic polar plateau and equipped with suites of instruments to measure magnetic, auroral, and radiowave phenomena. The AGOs are totally autonomous, operate year-round, and require only annual austral summer service visits.

When combined with measurements made at select manned stations, these arrays facilitate studies on the energetics and dynamics of the high-latitude magnetosphere, on both large and small scales. The research will be carried out along with in situ observations of the geospace environment by spacecraft, in close cooperation with other nations working in Antarctica and in conjunction with conjugate studies performed in the Northern Hemisphere. PENGUIn AGO data will be sent to Augsburg College in Minnesota, and there processed and distributed to PENGUIn investigators. (AO-112-O)

(AO-117-O)
Auroral dynamics by the all-sky-imager at Amundsen-Scott South Pole Station.
Masaki Ejiri, National Institute of Polar Research, Japan.

The South Pole is a unique platform for observing aurora during austral winter season; as a point on the earth's rotational axis, the pole provides a unique vantage to observe the airglow and to discern the characteristics of acoustic gravity waves in the polar region, as they vary in altitude/wavelength.

We can observe aurora continuously throughout the 24 hours in a day, which allows us to collect data on -

• the dayside polar cusp/cleft aurora (due to the direct entry of the solar wind);

• afternoon aurora that are closely associated with the night side magnetospheric storm/substorm activities; and

• on the polar cap aurora, which is dependent on the polarity of the interplanetary magnetic field. Research has shown that these auroras come from the precipitation of low-energy particles entering the magnetosphere in the solar wind.

Since 1965, data have been acquired at the South Pole using a film-based, all-sky-camera system. With the advance of technology, we are now able to obtain digital images and process large amounts of information automatically. The current technology is known as the all-sky-imager (ASI), a digital CCD imager monitored and controlled by the Japanese NIPR (National Institute of Polar Research) using a satellite internet system and modern telescience techniques. ASI is equipped with interference filters for auroral emissions of 427.8 nm, I 557.7 nm and I 630.0nm; an OH (hydo-oxide 730 nm) filter is also available, while a panchromatic image can be obtained without the filter.

These international collaborations should enhance knowledge of the magnetosphere, the ionosphere and of upper/middle atmosphere physics. The HF (high frequency) radars at Halley Bay, Sanae and Syowa Station yield the vector velocity of ionospheric plasma over the South Pole. These studies should provide further insight into the physics of the magnetosphere, the convection of plasma in the polar cap, and solar wind effects; specifically dayside auroral structure, nightside substorm effects, and polar-cap arcs. (AO-117-O)

(AO-120-O)
Solar and heliosphere studies with antarctic cosmic-ray observations.
John Bieber, University of Delaware.

Cosmic rays - penetrating atomic nuclei and electrons from outer space that move at nearly the speed of light - continuously bombard the Earth. Colliding with air nuclei in the upper atmosphere, they create a cascade of secondary particles that shower down through the atmosphere. Neutron monitors deployed in Antarctica 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 occurring over the 11-year sunspot cycle, the 22-year Hale cycle, and even longer time scales.

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

(AO-126-O)
Antarctic miniature lidar/automatic weather station lidar.
Jonathan Rall, NASA Goddard Space Flight Center.

As radar is to electromagnetic energy, lidar (light detection and rangefinding device) is to light. After sending an intense pulse of light (usually from a laser) through the particles and molecules suspended in the air along the propagation line, lidar system detectors are able to analyze the density, structure, and composition of target atmospheric regions based on how the light is scattered and reflected.

One vital object of study for this new technology are the Type 1a (nitric acid trihydrate) polar stratospheric clouds (PSCs) implicated in the annual austral springtime destruction of stratospheric ozone over Antarctica. These clouds play a crucial role in the atmospheric degradation of ozone by freeing up of the chlorine radical from the stable reservoir compounds. Scientists are trying to detect, profile and monitor these PSCs in hopes of better understanding their origin (natural vs. anthropogenic) and evolution (spatial as well as temporal). Ultimately, the goal is an enhanced ability to predict the magnitude of future ozone holes.

The first fully autonomous lidar was deployed to automated geophysical observatory (AGO) P1 on the polar plateau in January of 1999. This instrument operated continuously until the AGO platform failed in July 1999. This instrument will be removed from AGO P1, refurbished at Goddard Space Flight Center and redeployed to an automatic weather station in the 2000-2001 season. Given the limited number of AGO platforms and their fixed locations, we decided to collocate the lidar instruments with established automatic weather stations (AWS). The AWS project (see OO-283-M) has nearly 50 stations at various locations on and around the continent.

This project, meanwhile, is developing and testing a robust, low-power consumption, atmospheric lidar instrument that can operate autonomously yet still establish a long-term data record of the temporal and spatial evolution of polar stratospheric clouds (PSC). The other primary science objective is to continuously monitor the long-term atmospheric optical thickness from the surface to an altitude of 30 kilometers. This data will be compiled into a database that will provide statistics on atmospheric conditions that can be used by future space altimetry missions such as ICEsat. (AO-126-O)

(AO-127-O)
Rayleigh and sodium lidar studies of the troposphere, stratosphere, and mesosphere at the Amundsen-Scott South Pole Station.
George Papen, University of Illinois.

The Earth's atmosphere is described by several stratified layers, each with distinctive structure, dynamics and characteristics. The stratosphere begins about 11 kilometers (km) above the surface; the mesosphere runs from about 50 km to its upper boundary, the menopause, where atmospheric temperature reaches its lowest point (about -80°C), before beginning to rise as altitude increases through the outer layer, the thermosphere, which

runs from 80 km to outer space.

This research deploys a sodium-resonance lidar at the South Pole to study the atmosphere's vertical structure and dynamics, from the lower stratosphere up to the menopause. As the project enters its fourth year, scientists will be able to better study the mesopheric temperature using an iron-resonance lidar (added last year), which extends our ability to measure the air dynamics and temperature structure even higher, to about 100 km. An airglow imaging camera aids in studies of the horizontal structure.

This final complement of instrumentation, used in conjunction with the normal balloon-borne radiosondes flown regularly from South Pole, will provide extensive data on:

• the temperature structure from the surface to 100 km altitude;

• the nature of the polar stratospheric clouds (PSCs), which are important to ozone chemistry;

• the variability and frequency of metallic layers in the mesosphere, which play roles in communications as well as atmospheric chemistry;

• gravity waves in the troposphere, lower stratosphere and menopause regions; and

• many other phenomena, some of which are unique to the South Pole. (AO-127-O)

(AO-128-O)

High-latitude electromagnetic wave studies using antarctic automatic geophysical observatories.
James LaBelle, Dartmouth College.

Aurora are light shows (streamers and arches of light) created when electrons, accelerated along Earth's magnetic field lines, excite atoms in the atmosphere. Many people are familiar with pictures of the aurora's optical effects, but it turns out that the aurora also generates radio signals, invisible to the human eye, but easily detectable with radio receivers tuned to frequencies between 0.05 and 5.0 megahertz (MHz).

Scientists understand the phenomenon of auroral hiss that causes broadband noise at frequencies below 1 MHz. But two other radio phenomena attributable to auroras remain unexplained - narrowband emissions near 2.8 and 4.2 MHz and broadband noise bursts in the frequency range of 1.4 to 4.0 MHz. Although these radio emissions constitute a small fraction of the total energy of the aurora, they may provide important clues to the more energetic processes; this possibility would mirror the use of radio emissions from the Sun to infer processes taking place in the solar corona.

Taking advantage of radio-quiet antarctic conditions, this project uses low-frequency/ middle-frequency/high-frequency receivers in hopes of developing insights about these emissions from antarctic auroral zone and polar cap sites. The receivers have been installed at Amundsen-Scott South Pole Station, in five U.S. automatic geophysical observatories, and in two British automatic geophysical observatories. (AO-128-O)

(AO-129-O)

Spectroscopic and interferometric studies of airglow and auroral processes in the antarctic upper atmosphere over the South Pole Station.
Gulamabas Sivjee, Embry-Riddle Aeronautical University.

While the aurora tend to dominate the optical sky and researchers' interest, other, weaker emissions know as airglow (like aurora) provide indications of solar scattering by various species, and also reveal other phenomena. At Amundsen-Scott South Pole Station, we study the dynamics and chemistry of the upper atmosphere - airglow occurs above 60 kilometers) with an infrared spectrophotometer, an eight-channel photon-counting photometer, and an infrared Michelson interferometer.

By measuring the variations in the brightness and temperature of airglow band emissions, researchers can detect planetary, gravity, and tidal waves. The horizontal wave structures can be elucidated by looking in several directions while making these measurements at several wavelengths (which vary at different heights in the atmosphere) and will also provide information on the vertical extent of the wave activity. Also, viewing the different altitude auroral emissions with the spectrophotometer provides insight into the nature of the sources of

the auroral precipitating electrons, and how these different sources vary over time. (AO-129-O)

(AO-131-O)

Measurements of polar stratospheric clouds, condensation nuclei, and ozone during the austral winter and spring.

Terry Deshler, University of Wyoming.

Ozone depletion in the antarctic stratosphere, in a general sense, is quite well understood; however, questions remain concerning the character of particles in polar stratospheric clouds (PSCs) and which observations may provide the first indications of ozone recovery. This project will contribute to our understanding of these phenomena by continuing balloon-borne measurements based at McMurdo Station, Antarctica.

There are still many uncertainties about PSCs; it is clear, however, that the heterogeneous chemistry - which activates chlorine to destroy ozone - occurs on the surface of these particles. We will continue our PSC-size distribution measurements during the early- and mid-winter period (when PSC activity is greatest), and during late winter, when ozone loss begins.

Mid-winter measurements will be completed by science technicians from the civilian support contractor. We will make 15 aerosol flights between June and September, measuring the concentration of condensation nuclei and particles between 0.15 and 10.0 _m radius. The fundamental measurements from these instruments provide estimates of the size of the particles that form in PSCs. From these measurements the surface areas and volumes within PSCs can be estimated. The particle size estimates help scientists calculate denitrification/dehydration rates, the surface area necessary to quantify chlorine activation models, and volume parameters to estimate particle composition. Further estimates of particle composition will involve methods to infer particle index of refraction, which is a function of composition. That effort involves our continuing collaboration with Alberto Adriani, Instituto di Fisica Dell'Atmosfera, Rome (AO-107-O), where researchers compare optical scattering by measuring aerosol size distributions, either by ground-based lidar or in situ by a balloon-borne laser backscattersonde.

In addition to the aerosol measurements, we will maintain annual late winter/spring measurements of ozone, taken about every 3 days. These measurements have been approved for inclusion in the data base of the Network for the Detection of Stratospheric Change. At a minimum, this will continue to provide a measurement base to detect the first signs of ozone recovery. Stratospheric chlorine levels are now peaking, following which the lessening of ozone depletion is expected to be altitude-dependent. Measurements like these, of vertical ozone profiles, provide one of the crucial tools needed to observe the first signs of recovery following the decline in stratospheric chlorine. (AO-131-O)

(AO-138-O)

Trace gas measurements over the South Pole using millimeter-wave spectroscopy.

Robert L. de Zafra, State University of New York at Stony Brook.

Many atmospheric gases radiate millimeter-length radio waves, but each species has its own unique spectrum. These fingerprints not only identify the gas, but also provide information on its temperature and pressure. These properties enable scientists to use the millimeter-wave spectrum of the atmosphere to determine how abundantly and at what altitudes a number of trace species can be found.

This research (over the course of a full year) monitors the atmosphere above South Pole, Antarctica, with a millimeter spectroscope for ozone, carbon monoxide, nitrous oxide, nitric acid, water vapor, and nitrogen dioxide. Several of these gases have important roles in the formation of the annual antarctic ozone hole. Others - particularly water vapor and carbon monoxide - can provide information about the vertical transport and other dynamics of the upper stratosphere and the mesosphere. (AO-138-O)

(AO-284-O)

Dynamics of the mesophere and lower thermosphere using ground-based radar and TIMED instruments.

Susan K. Avery, University of Colorado, Boulder.

We will study the dynamics of the mesosphere and lower thermosphere over Antarctica using measurements from instruments on NASA's TIMED satellite and a meteor radar to be installed at Amundsen-Scott South Pole station. Specific science objectives include the space-time decomposition of wave motions; delineation of the spatial climatology over Antarctica with emphasis on the structure of the polar vortex; dynamical response to

energetic events; and interannual variability.

The proposed meteor radar is a VHF system that will be able to measure the spatial structure and temporal evolution of the horizontal wind field over the South Pole. We will also use the existing ground-based radars at Davis Station, Syowa Station, Rothera Station, and Scott Base to determine spatial climatology. Wind and temperature measurements to be made by NASA's TIMED satellite during orbits over the South Pole will provide opportunities for combined ground-based, space-based experiments and validation activities. (AO-284-O)

previous section | Table of Contents | next section

CENTER FOR ASTROPHYSICS IN ANTARCTICA

Center for Astrophysical Research in Antarctica (CARA)

John Carlstrom, University of Chicago.

Astronomers probe the infrared (IR) spectrum at submillimeter scales in search of data that could suggest answers to some of the seminal questions about the formation of the Universe; such as:
• How do stars form from interstellar gas?
• How did the planets form?
• What was the nature of primeval galaxies?
• How were matter and energy distributed in the early Universe?

Antarctica is an ideal spot for such research. The cold temperatures and lack of water vapor in the atmosphere above the polar plateau make the infrared spectrum of sky in that region consistently clearer and darker than anywhere else on Earth. These conditions enable scientists to collect measurements that would be extremely difficult or impossible from other sites. To capitalize on these advantages, the University of Chicago and several other collaborating institutions in 1991 established the Center for Astrophysical Research in Antarctica (CARA), one of 17 Science and Technology Centers funded by the National Science Foundation. CARA's scientific mission is to investigate the conditions for astronomy at the South Pole and other sites on the polar plateau, and to establish an observatory at the South Pole. Currently, CARA supports research using three major telescope facilities:

• The Astronomical Submillimeter Telescope/Remote Observatory (AST/RO) project uses a 1.7-meter (m) diameter telescope to survey interstellar gas in the galactic plane, the galactic center, and the Magellanic Clouds.

• The South Pole Infrared Explorer (SPIREX) project uses a 0.6-m diameter telescope to observe distant galaxies, cool stars, and heavily obscured star-forming regions.

• The Cosmic Background Radiation Anisotropy (COBRA) project helps researchers test current theories of the origin of the Universe.

In addition to projects using these three telescopes, CARA's Advanced Telescopes Project collects data on the quality of polar plateau sites for astronomical observations, and configures plans for future telescopes and facilities. The following projects and principal investigators are currently part of CARA: (AC-370-O)

Antarctic Submillimeter Telescope and Remote Observatory (AST/RO):
This austral summer, we will install a new array receiver called PoleSTAR, which will permit high frequency (809 GHz) spectral line observations in four spatial channels simultaneously. We will use PoleSTAR to map emissions from excited carbon atoms and carbon-monoxide molecules in interstellar clouds. To characterize the properties of the polar atmosphere at far-infrared and submillimeter wavelengths, we also will install a broadband Fourier Transform Spectrometer in the AST/RO building. Antony Stark, Smithsonian Institution. (AC-371-O)

Automated Astrophysical Site Testing Observatory (AASTO):
Our objective is to categorize those conditions on the antartic plateau, from the ultraviolet to the sub-millimeter, that are relevant to a future large telescope. This season we will extend our sky monitors to the mid-infrared and sub-millimeter ranges, and continue our measurements of the atmospheric turbulence and the sky emission in the near-infrared. John Storey, University of New South Wales, Australia. (AC-372-O)

Degree Angular Scale Interferometer (DASI):
DASI is a 13-element interferometer designed to measure anisotropies in the Cosmic Microwave Background

Radiation (CMBR), and to determine its angular power spectrum. The unique imaging capabilities of DASI and its angular coverage (140 < l < 910), complement the Viper telescope, especially its future millimeter and submillimeter capabilities (to be provided by ACBAR), as well as the MAP satellite and other CMBR experiments. John Carlstrom, University of Chicago. (AC-373-O)

South Pole Infrared Explorer (SPIREX):
The SPIREX telescope (60 centimeters in diameter) was built to exploit the unique observing conditions at the South Pole, and to develop and demonstrate the technology needed to operate IR telescopes during the antarctic winter. This austral summer, it will be dismantled and removed. Bob Lowenstein, University of Chicago. (AC-374-O)

Viper telescope:
Viper, a 2-meter class telescope, extends our observations to structures in the cosmic microwave background having smaller angular scales. Our primary goal is to determine the power spectrum of the CMBR anisotropy, over the range of angular scales where cosmological models differ most in their predictions. This austral summer we are refurbishing the telescope to allow for new cables and hoses for the ACBAR, Corona, and SPARO instruments. Also, we will raise the elevation of the telescope by about 4 centimeters, and install a new cable wrap, a new azimuth rind and new control wiring. Jeffrey Peterson, Carnegie-Mellon University. (AC-375-O)

Submillimeter Polarimeter for Antarctic Remote Observing (SPARO):
SPARO, which was deployed to the South Pole in 1999, operates on the Viper 2-meter telescope. A 9-pixel, 450-micron polarimetric imager, it requires only infrequent cryogen refills, thus simplifying maintenance during the winterover. The South Pole offers superb conditions for SPARO observations, extending submillimeter polarimetry (measurement of the polarization of thermal emission from magnetically aligned dust grains) to regions of low-column density that cannot be studied from other sites. SPARO resembles polarimeters in the University of Chicago array designed for other telescopes, but those instruments (for example, at the Caltech Submillimeter Observatory and the Owens Valley Radio Observatory) provide much better angular resolution. SPARO's geographic location, however, yields a much enhanced submillimeter sensitivity to extended emission. Giles Novak, Northwestern University. (AC-376-O)

Arcminute Cosmology Bolometer Array Receiver (ACBAR) Instrument:
We plan to install the ACBAR receiver on the Viper telescope, and get it ready for winter observations. ACBAR, a 16-element, 300 mK bolometer array, will be used to map the CMBR with high-angular resolution. We will try to characterize how the structure may have formed and evolved by searching for clusters of galaxies, and also will study nearby clusters with targeted observations. Preliminary observations and calibration will be done in the 2000-2001 summer season; the majority of the science data will be gathered during the 2001 winter. John Ruhl, University of California, Santa Barbara. (AC-378-O)

previous section | Table of Contents | next section

BIOLOGY AND MEDICINE

The Biology and Medicine program funds research to improve understanding of antarctic life forms and ecosystems – their physiology, behavior, adaptations, and relationships. Projects range across all organizational levels – from the molecule, cell and organism to relationships within communities and ecosystems, to the level of global processes. This is another area of inquiry where scientific goals extend far beyond learning (in this field, about flora and fauna) in the high latitudes.

Antarctica is a place like no other: as an intriguing habitat, a scientist's dream; a land where water is scarce – truly a desert – despite containing more than two-thirds of the world's freshwater supply trapped in the ice. Though it borders the world's major oceans, the Southern Ocean system is unique in the world, a sea where average temperatures don't reach 2ºC in summer, where even the water itself is so unique that it can be identified thousands of miles away in currents that originated here. As the Earth makes its elliptical journey around the sun each year – tilted on its rotational axis – the sun "sets" in April, not to be seen again until September. And the ice – unimaginable, incomparable vastness of ice – in a dozen different varieties, at times and in places several thousand meters thick, two major ice sheets (the East larger than most countries), changing dynamically all the time.

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. Support is focused on the following areas:

• Marine ecosystem dynamics: Among the research topics are understanding the natural variability of marine ecosystems; correlating the structure and function of the marginal ice-zone ecosystem with oceanic and atmospheric processes; exploring the sources of nutrition and their influence on prey and on primary production; and the role of marine phytoplankton in carbon dioxide cycling.

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

• Population biology and physiological ecology: At the next level, looking at relationships among organisms, studies have focused on the variability and dynamics of populations of krill and other zooplankton; ecological relationships among and between fish species, marine mammals, and birds have also been the object of much research, with many issues still to be further explored. As organized programs of antarctic science enter their fifth decade (some even longer), data sets and ongoing observations are elucidating manmade as well as natural changes.

• Adaptation: Antarctic extremes present a fundamental research opportunity; topics include low-temperature photosynthesis and respiration, enzymatic adaptations and adaptive physiology such as the development in fish of antifreeze compounds and modifications to the circulatory system in seals; also continuing interest in the response of (and impacts upon) organisms to increased UV-B radiation from the ozone hole.

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

(BO-005-M)
Antifreeze protein antarctic fishes: Ecological and organismal physiology, structure-function, genetics,

and evolution.
Arthur DeVries, University of Illinois.

Despite temperatures that can dip below 0 °C, antarctic waters provide a life sustaining environment for a number of fish species. How are they able to take the most frigid waters on earth through their gills without themselves freezing? A primary reason are the so-called antifreeze proteins, an adaptation found in a number of polar and subpolar species. These biological molecules have a similar effect to antifreeze in a mechanical engine. The Southern Ocean provides the ideal laboratory and molecular biology the ideal probe to study this phenomenon. As the world's coldest marine environment, the near-shore waters of Antarctica, replete with ice crystals, hover just above seawater's freezing point. We are studying the physiology of fish and larvae from these waters to see how ice wants to grow in biological tissues - a crystallization process called nucleation - and how antifreeze glycoproteins (AFGP) inhibit it.

Their evolution of the antifreeze function has enabled the antarctic notothenioids to colonize their frigid habitats very successfully. We are mounting comprehensive multidisciplinary analyses of this adaptation at the level of the gene as well as the protein. Specifically, we will -

• examine the structure of antifreeze proteins;

• refine the molecular model of how these proteins adsorb ice and inhibit ice crystal growth;

• study the physiological parameters governing the natural growth of ice crystals;

• pinpoint the chromosomal locus of the gene family and its protease progenitor gene;

• sketch its evolutionary history by calibrating the rate of notothenioid nuclear protein coding sequences; and

• focus on when these AFGPs develop during embryogenesis and early larval stages. (BO-005-M)

(BO-009-O)
Use of a long-term database and molecular genetic techniques to examine the behavioral ecology and dynamics of Weddell seal (Leptonychotes weddellii) population.
Donald B. Siniff, University of Minnesota-Twin Cities.

The Weddell seal (Leptonychotes weddellii) is found in regions of pack ice or fast ice close to the antarctic continent. These seals are relatively long-lived, and the waters of McMurdo Sound have provided a continuous environment in which to study their survival and aquatic reproductive patterns. A series of long-term population studies, ongoing since the mid-1960s, have generated a rare and valuable set of data.

Recently developed molecular biology techniques, however, permit scientists to examine the DNA of individual seals as well as groups, and to gain insight into their genetic histories, breeding systems and reproductive fitness. Breeding males behave characteristically; looking at this behavioral ecology and their mating systems through the lens of their DNA permits scientists to project backwards in time and correlate the seals' reproductive success with the effective size of their populations. Using and building on the long-term data set, our study will also examine how hypotheses can be tested and parameters can be estimated, in producing models and studies of population demographics. We will also explore the population dynamics of the Weddell seal though the lens of immigration and emigration into and out of the group. Several collaborative efforts will occur this season. In one, blood, scat and diet samples will be collected for researchers studying Weddell seal blood chemistry, health parameters, blood parasites and diet. In another, some of the seals will be mounted with small video cameras to provide data for Japanese scientists studying diving and other underwater behaviors of free-ranging seals. And a remote camera surveillance will be set up to observe the spacing patterns of adult females on the ice surface and underwater.

As the southernmost breeding mammal in the world, the Weddell seal exemplifies the ability to adapt to environmental extremes. Understanding the mating strategies these seals employ should contribute to a deeper understanding of the evolution and population dynamics of the Pinnipedia (a suborder of aquatic, carnivorous mammals, including all the seals and walruses) in particular, as well as how marine mammals more generally, compete. (BO-009-O)

(BO-024-O)

Studies on the impact of sewage-associated microorganisms on indigenous seal and bacterial populations and drinking water quality at McMurdo Station. *John Lisle, Montana State University.*

Human impacts on the environment are typically complex and often reverberate through a wide ecological spectrum. While a comparatively pristine environment, Antarctica is still a populated continent, with all of the inherent issues and challenges of environmental protection. For years, human sewage has been released into the seawater at McMurdo Station, untreated except for the process of maceration (which dilutes or softens a material by steeping it in liquid). What are the impacts on the marine ecosystem? This project focuses on bacteria known to thrive in the sewage deposits, tracing their progress into the drinking-water intake at Intake Jetty, and also into other organisms and indigenous species, such as Weddell seals. One of the bacteria previously associated with this problem is clostridium perfringens, which researchers have suspected were colonizing Weddell seals in the area of the sewage. These and other deposit-feeding invertebrates appear to assimilate the nutrients associated with the sewage and to increase body mass and organ sizes. These earlier results are driving this work, which will use more advanced genetic molecular biology and more sensitive culture-based techniques to determine a number of issues. Are the sewage-associated bacteria and viruses the specific ones that are colonizing Weddell seals? Are these microorganisms exchanging their DNA with indigenous species, thus potentially altering the procaryotic gene pool of this ecosystem? Are they entering the drinking water system at McMurdo Station? The microbiological quality of marine and drinking waters at McMurdo Station is currently monitored, but are we underestimating the risks to the marine environment and to human health?

The results from this study should help to evaluate current monitoring systems and to design remediation efforts. A sewage treatment plant is currently planned for McMurdo Station, and these data will provide a baseline for efforts and studies of ecosystem recovery. The data will shed light not only on the coastal waters off of McMurdo Station, but also on other coastal waters around Antarctica that may be similarly affected by the discharge of untreated human sewage. (BO-024-O)

(BO-025-O)
The biogeochemistry of dimethylsulfide (DMS) and related compounds in a chemically stratified antarctic lake.
John C Priscu, Montana State University, and Giacomo R. DiTullio, Grice Marine Laboratory, University of Charleston.

The earth's atmospheric cycle involves continuous transport of basic elements, one of which is sulfur. Dimethylsulfide (DMS) is the dominant volatile sulfur compound emitted from the ocean and may represent up to 90 percent of the sea-to-air biogenic sulfur flux. When these volatile sulfur molecules oxidize in the atmosphere, condensation nuclei can be released which, scientists hypothesize, may directly counteract the warming effects of anthropogenically produced CO2. Aquatic systems - in particular the waters of the south polar regions - thus play a crucial role in one of the planet's basic transactions. Yet both the sources and the sinks of DMS and associated sulfonium compounds have yet to be fully identified and understood.

This research will examine the biogeochemistry of water column and sedimentary DMS/DMSP (dimethylsulfoniopropionate), and the role of associated compounds (e.g.,dimethylsulfoxide, dimethylated polysulfides) in Lake Bonney. This relatively simple aquatic system provides a highly tractable environment for investigating the microbially mediated cycling of biogenic sulfur because it contains no grazers, no turbulence and little atmospheric exchange.

Preliminary data suggest that maximum levels of DMS precursors may be found in the deep-chlorophyll layer of the lake, a zone dominated by cryptophyte algae. In addition, DMS concentrations deep in the lake, where there is very little light (i.e., in the aphotic waters), are among the highest recorded in any natural aquatic system. These observations indicate that precursors produced by trophogenic zone phytoplankton sink to the aphotic waters and sediments, where microbes decompose them to DMS and other sulfur compounds. The proposed research will define the sources and sinks of DMS and associated compounds, and establish how they function in the overall ecosystem. We hope to develop a model describing the biogeochemical transformations of organo-sulfur compounds in Lake Bonney. (BO-025-O)

(BO-030-O)
Temperature compensation in antarctic pteropods: An integrative approach.
Robert Dudley, University of Texas at Austin.

Life in frigid polar waters reveals many adaptations; creatures have developed physiologic specializations so as to function and react more effectively in the cold. The long-standing hypothesis holds that animal taxa indigenous to these climates evolved the ability to regulate basal and active metabolic rates better than their temperate-zone counterparts; but this theory remains contentious and - in any event - has been applied only to fish and benthic invertebrates. Polar pteropods, small gastropod molluscs commonly found in antarctic zooplankton, are abundant, metabolically active, and provide a different species (another taxon) in which to probe thermal compensation mechanisms that may serve the physiological processes underlying locomotion.

To explore these phenomena, we will use two different sister pteropod species, one from the polar and one from a temperate zone. Experiments will focus on basal and metabolic rates and mitochondrial energetics; also on biomechanical and on neural responses to different water temperatures and viscosities - all in the context of locomotor performance. The neurons that underlie the swim-system will be evaluated at different temperatures, with particular reference to resting potentials, firing thresholds, action potential durations and ion-channel kinetics. A central question is the extent to which all three aspects (metabolic, biomechanical and neural) may contribute to a coordinated ability to compensate for thermal conditions and extremes in polar pteropods.

Not only should this investigation provide fundamental physiological and behavioral information for this taxon, but we hope to systematically evaluate the hypothesis of cold adaptation across organizational levels in pteropods. We may also be able to shed light more generally on the nature of thermal and locomotor constraints for the many invertebrate taxa living and moving within polar waters. (BO-030-O)

(BO-031-O)
Factors regulating population size and colony distribution of Adélie penguins in the Ross Sea.
David G. Ainley, H.T. Harvey and Associates, California.

Over the past few decades, the Adélie penguin (Pygoscelis adeliae) colonies in the Ross Sea region have grown dramatically in size. What demographic mechanisms might account for this change? This collaborative project will investigate one such possible effect, documented changes in the region's climate. We will look at the birds' nesting habitat as a function of access to food, and hope to distinguish the relative importance of the key resources that constrain the growth of colonies. A number of behavioral and demographic mechanisms may influence a colony's growth, relative to its initial size and distribution pattern. One, for example, is a phenomenon known as philopatry: how breeding effort and success may relate to the balance achieved by immigration/emigration.

As the first empirical study to consider the geographic structuring of a seabird population, we expect our results to increase understanding of how populations regulate themselves, and the patterns they follow when they disperse. We also hope to elucidate the effects of climate change (as indicated by changes in the extent of sea-ice cover) on penguin populations. The results should also provide a context in which to interpret conflicting data on penguin population trends from existing programs; in particular, fluctuations in Adélie penguins have been analyzed as an indicator of such anthropogenic impacts on antarctic resources as fishery catches and disturbances created by tourism. But it is problematic trying to distinguish changes due to man from those caused by nature, without the regional perspective on penguin life history this project is undertaking to develop.

Our 6 years of research include intensive field study of various Ross Island penguin colonies - This season colonies at Cape Royds (4,000 breeding pairs), Cape Bird (35,000), Beaufort Island (35,000) and Cape Crozier (170,000). We quantify reproductive effort and success, food availability (access to food), diet quality, habitat use, and immigration/emigration relative to colony size and environmental conditions (i.e., pack-ice cover).

Landcare Research New Zealand (LCRNZ) has conducted two preliminary field seasons, including the testing of new equipment. This project will build on their results, and they will collaborate with us throughout the lifetime of the project. The LCRNZ work is independently funded. Researchers from the University of California-Santa Cruz, the University of Wisconsin, Point Reyes Bird Observatory, and Beigel Technology, will collaborate with those from H.T. Harvey and Associates and LCRNZ to accomplish the project's goals. (BO-031-O)

(BO-034-O)
Investigations of abandoned penguin colonies in Antarctica.
Steven Emslie, University of North Carolina.

Climate change is assumed to be a pivotal factor in the success of many species. This project will investigate the history of Adélie penguins in late Holocene Antarctica. By locating and examining the fossil remains of former colonies, scientists hope to develop a model of when they thrived and when colonies were abandoned - and thus their success - relative to climate change. This model could inform current science on the relationship between climate and population dynamics.

Our study will integrate data from the ecological, geological and paleobiological records with satellite-imagery analyses. The climate factor will be inferred by data contemporaneous with the fossil evidence, in particular the extent of the sea-ice and marine productivity. The population factor will be developed through field and laboratory investigations of abandoned colonies along coastal Antarctica.

Researchers will first collect surface and subsurface bones, feathers, and eggshell fragments preserved at these sites; later, in the lab, scientists can reconstruct the occupation history of each abandoned colony, through standard and radiocarbon analyses. Sediments from each site will be sifted to recover organic remains (such as squid beaks and fish otoliths) believed to be staples of the penguin diet. Statistical analysis of such indicators can trace the changing size of the colony at specific prehistoric times, and thus prey consumption becomes a proxy for population success. This timeline can then be matched to past episodes of climate change, which are well documented for the late Pleistocene and Holocene in ice-core and marine sediment records.

We expect these ancient responses by penguins to climate change, as indicated by the paleoecological record, to parallel those observed in Antarctica today, where regional warming has been documented over the past 20 to 50 years. Ultimately we will be able to test the hypothesis that Adélie penguins - for decades and centuries - have been responding to climate change in a predictable manner, and that those responses can be anticipated, relative to fluctuations in sea-ice extent and marine productivity. (BO-034-O)

(BO-036-O)
Proteins of oxygen-binding and energy metabolism in muscles of antarctic fishes: Evolutionary adjustments to life at cold temperatures.
Bruce Sidell, University of Maine.

Evolution in the frigid extremes of the antarctic environment has fashioned some useful biological adaptations, at both the physiologic and biochemical level. In some instances, constraints on biological function that might be expected from the cold have been overcome. Also, mutations in antarctic fishes that would probably have been lethal elsewhere are not selected against in the frigid, oxygen-rich Southern Ocean environment. These and other adaptations can be seen in the family of Nototheniidae, which over the last 14 million years has become the dominant fish group in Antarctica - with the most species and the largest biomass of any animal in the ecosystem.

This project explores the role of key intracellular proteins that metabolize energy, as well as other biological mechanisms that enable these fish to function normally at the cellular level - while enduring average body temperature about 0 °C. Experiments will target the physiology and molecular biology of several species of notothenioid fish (who are red-blooded) and the channichthyid icefish, who have no hemoglobin. One line of inquiry pursues why the myoglobin-encoding gene is not expressed. Another analyzes the various different isoforms of creatine phosphokinase that serve the locomotor muscle system. A third explores the basis of the substrate specificity of the enzyme fatty acyl-CoA synthetase (which is involved in the catabolism of fatty acids).

We expect results from this study to further elucidate the evolutionary biology of the antarctic notothenioid fishes, and perhaps also to invoke important general principles applicable to widely different taxa beyond the antarctic. (BO-036-O)

(BO-037-O)
Structure, function, and expression of cold-adapted tubulins and microtubule-dependent motors from antarctic fishes.
H. William Detrich, III, Northeastern University.

Microtubules (subcellular "pipelike" filaments composed of the protein tubulin) and their associated motors, dynein and kinesin, participate in many fundamental cellular processes; such as cell division, nerve growth and regeneration, cell motility, and the organization and transport of organelles within cells. In these processes, the elongated microtubules serve as rigid "railroad tracks" for the movement of motors and their cargoes (think of

them as "trains"), and the motors themselves have the effect of efficient, high-velocity, regulative "locomotives." The microtubules and microtubule motors of cold-adapted antarctic fishes are unique in their capacity to assemble and function at body temperatures (-2¦°C to +2 °C) well below those of warm-blooded and temperate organisms. The long-range goal of our project is to determine functional adaptations (at the molecular level) that serve antarctic fishes in this extreme thermal regime; specifically the assembly of microtubules, the expression of tubulin genes, and the activity of microtubule motors. Our objectives are -

• to determine the structural features (e.g., changes in their amino acid sequences) that enable the tubulins of antarctic fishes to polymerize efficiently at low temperatures;

• to characterize the structure, organization, and expression of an alpha-tubulin gene cluster from an antarctic rockcod (Notothenia coriiceps); and

• to examine the biochemical adaptations required for efficient function of antarctic fishflagellar dynein motors at low temperatures. This season we will also collect some additional species and expand the experimentation to include the expression of genes involved in blood formation. In the broadest sense, this research should advance the molecular understanding of the cold-adapted mode of life. (BO-037-O)

(BO-038-O)
Investigations on deterioration in the historic huts of the Ross Sea region of Antarctica.
Robert A. Blanchette, University of Minnesota.

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

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

We plan to: Identify the biological and non-biological agents responsible for causing the deterioration, study the mechanisms and progressive sequence of events taking place during decay processes, test methods to be used to control future deterioration, determine the extent of environmental pollutants in soils at the historic sites, and evaluate chemical spills within the huts.

The goal is to provide the scientific data required by conservators to help protect these important historic sites for future generations. But the project should also shed scientific light on these unique deterioration processes, as well as augment scientific understanding of the biology of antarctic microorganisms and the biodiversity of microbes present in this unusual environment. (BO-038-O)

(BO-040-O)
Penguin-krill-ice interactions: The impact of environmental variability on penguin demography.
Wayne Trivelpiece, NOAA Southwest Fisheries Science Center.

How well organisms thrive in their environment often reveals itself in basic ecological relationships. For two decades at Admiralty Bay on King George Island in the Antarctic Peninsula region, data have been collected on several species of penguins, including the Adélie, gentoo and chinstrap. Looking at some of the basic aspects of the lives of these predators - such as survival and recruitment, population size and breeding success, and diets and foraging ecology - scientists have been able to develop and test key hypotheses about variability in the antarctic marine ecosystem.

This project focuses on one of these relationships. As the extent of sea-ice cover changes with the season and year-by-year, krill (in the Southern Ocean a key food web species that accounts for nearly 100 percent of the

prey eaten by dominant predators such as baleen whales, seals, and penguins) are more or less abundant, directly affecting the population biology of the penguins. Years with heavy winter and extensive sea ice paradoxically favor krill recruitment, because larval krill find refuge and food in the sea-ice habitat. The long-term seabird research indicates that in those same, heavy sea-ice years, Adélie but not chinstrap penguins are also favored.

To explore these relationships, we will capture adult and juvenile penguins periodically to band, measure, and weigh them, and to collect blood and diet samples for genetic and physiologic studies. During the breeding season, the penguins and the sea-ice will be observed by satellite. Another aspect of the population biology of penguins relates to the possible impact of commercial fishing, so this study will provide useful information to the Convention for the Conservation of Antarctic Marine Living Resources, which is the part of the Antarctic Treaty System that focuses on fisheries management.
(BO-040-O)

(BO-041-O)
Microbial mediation of trace metal cycling in four stratified antarctic lakes
William Green, Miami University at Oxford, Ohio.

Aquatic environments often stratify; that is, boundaries at different depths indicate changes in the composition of the water. One of the basic processes in nature is reduction by oxidation(redox); redox boundaries can be found at specific water depths where microbes are implicated in the cycle and fate of a large suite of chemical elements. Thus biogeochemical analyses support limnology - the study of life and the conditions for life in lakes, ponds and streams.

We have been examining the role of microbial influences on metal cycling in four stratified lakes in the McMurdo Dry Valleys: Lakes Fryxell, Hoare, Joyce and Miers, and will focus this season on the latter two. All of these lakes are characterized by unusually stable redox transition zones, and are also especially amenable to a finely spaced sampling regime. Collectively, they represent a broad range of water chemistries. We are testing two hypotheses:

• In stratified water columns there should be a clear spatial difference between the onset of manganese reduction and the onset of iron reduction. Heavy metals and rare-earth elements will be seen to undergo co-cycling with manganese rather than with iron.

• Manganese reduction will be associated with the presence of carnobacteria or other manganese-reducing organisms.

Dissolved and particulate metal profiles will be examined relative to depth - from the ice-water interface at the top all the way down to the sediments. Profiles will be correlated with microbial manganese-reduction assays, and with the presence of manganese reducers; these can be detected by screening with Mn-oxide overlay agar plates and nucleic acid hybridizations that function as probes for known manganese reducers. The research will include significant involvement of undergraduates. (BO-041-O)

(BO-050-O)
Influence of seasonal ice cover on pelagic and benthic communities: Long time-series studies. *Kenneth L. Smith, Scripps Institution of Oceanography.*

The annual expansion and contraction of ice cover in the Southern Ocean - the largest seasonal process in the world ocean - causes primary biomass production to fluctuate extensively, and has a strong impact on both pelagic (open, upper sea) and benthic (deeper, at the bottom) communities of fauna.

This study at Port Foster, Deception Island, will take advantage of a region that has seasonal ice cover and supports a pelagic and benthic fauna that are representative of the antarctic coastal zone. The study of the water column and seafloor will be structured as a long time-series, employing long-term, autonomous monitoring and sampling systems that were developed especially for use in the antarctic. We will deploy a bottom-moored, upward-looking acoustic instrument on the seafloor for 12 months to monitor the vertical distribution, abundance, and biomass of acoustically detectable macrozooplankton and micronekton in the water column. Collections will be made over this period using newly developed, vertically profiling pump sampling. Simultaneously, a time-lapse camera system will be moored on the seafloor to monitor the spatial distribution, sizes, and

movements of the epibenthic megafauna component of the benthic community.

This deployment of instruments will allow us to focus on the effect of the seasonal sea-ice cycle on the distribution, abundance, and biomass of the macrozooplankton and micronekton in the water column. Similar questions about the deeper-dwelling epibenthic megafauna will focus on distribution, size, abundance, and movements. Results from this study should provide a useful foundation database to evaluate the pelagic and benthic community responses to seasonal variability in the Southern Ocean. (BO-050-O)

(BO-197-O)
Diving biology of emperor penguins.
Paul J Ponganis, Scripps Institution of Oceanography.

Because the emperor penguin (Aptenoidytes forsteri) lives within the pack ice zone of the antarctic, its advanced ability to dive has been the subject of interest for many years. Emperor penguins routinely hunt for food for between 2 and 10 minutes, at depths ranging from 50 to 500 meters. These birds have reached a measured depth of nearly 550 meters. The longest dives are not the deepest, however; the recorded longest of twenty-two minutes was nowhere near that record depth. They provide an excellent model to investigate the physiology and behavior of diving birds and mammals; in this study specifically, thermoregulation, underwater behavior and the homoeostatic regulation of myoglobin.

Working with emperors (captured from McMurdo Sound) in a man-made corral with dive holes, we hope to elucidate both the physiological and behavioral mechanisms underlying the breath-holding capacity of these diving birds. To probe how these physiological limits may affect the natural diving behavior and ecology of the penguins, we will focus on the role of decreased body temperature in extending the duration of aerobic metabolism during diving; also we will explore how organs and tissue tolerate oxygen deprivation. Mounting a small camera on some birds will permit us to examine their behavior during their dives, and to correlate changes in body core and muscle temperature with which prey they ingest as well as with their wing stroke frequency.

Another phase of the work involves establishing a second sea-ice camp dedicated to observing the growth and development of young emperor chicks. At the molecular biology level, we will examine transcriptional control of the myoglobin gene to probe the high myoglobin concentration of emperors and the large increases in myoglobin concentration during chick development. All animals will be released at the ice edge at the end of the study. (BO-197-O)

(BO-267-O)
The role of oceanographic features and prey distribution on foraging energetics and reproductive success.
Daniel Costa, University of California at Santa Cruz.

The Southern Ocean enjoys a high seasonal productivity, in both coastal and pelagic environments. But observations over the last several decades show that behind this general productivity lies much variation - during the year and from year to year. Thus, the prey available to vertebrate predators can vary significantly over time and from place to place.

Since the late 1980s, scientists have recorded this spatial and temporal variability for the northern South Shetland Islands region of the Antarctic Peninsula. The antarctic fur seal [Arctocephalus gazella], a subpolar migratory otariid with a short lactation period, is an increasingly dominant marine predator in this region. Its life-history shows a series of foraging trips alternating with short visits to provide for a single offspring; this pattern allows scientists to use the same temporal and spatial scales to measure both maternal investment and the distribution/abundance of prey.

We are trying to quantify the foraging costs and maternal investment associated with different strategies observed in populations of South Shetland antarctic fur seals. Using state-of-the-art techniques (attached to some seals are satellite-trackable transmitters and to others time-depth recorders), we will determine the costs and benefits of different foraging patterns correlated to: Energy expenditure, food intake, dive depth, dive duration, time of day, dive frequency, swim speed, and foraging location. These measurements will coincide with small- and large-scale oceanographic surveys to be conducted by the National Oceanic and Atmospheric Administration's Antarctic Marine Living Resources program, which also contributes to the support of this project.

The research should provide scientists a clearer picture of the life of a free-ranging marine vertebrate predator. We hope to validate patterns linking the biological characteristics of the prey (composition, distribution, and abundance) and the physical characteristics of the foraging environment with foraging success, maternal investment, and reproductive success. (BO-267-O)

(BO-282-O)

Natural product drugs from cold-water marine organisms.

Gregg Dietzman, White Point Systems, Inc.

As with rain forests and jungles the world over, now Antarctica holds the promise of providing natural substances for medicinal uses. Five specific organisms found in antarctic benthos waters have emerged as active leads for developing compounds that might prove toxic to human tumors. In a project co-funded by the National Cancer Institute of the National Institutes of Health, scientists will collect samples (between 1 and 20 kilograms) of these sponges and anemones and bring them back to study their chemistry and biology.

Samples were previously collected in the Antarctic Peninsula region during the 1994- 1995 austral summer. This austral summer, new collection sites north and west of the Palmer Peninsula between King George Island and Palmer Station on Anvers Island will be dredged. (BO-282-O)

(BO-301-O)

McMurdo Station biology course: A training program in integrative biology and adaptation of antarctic marine organisms.

Donal Manahan, University of Southern California.

This international, advanced-level, graduate training course will be organized and taught in Antarctica for one month during the austral summer of 2000-2001. The course introduces students to the diversity of biological organisms in the Antarctic and allows them to study unique aspects of biology that permit life in such extreme environments.

Long-standing questions in evolution and ecology about the biology of antarctic organisms (such as cold adaptation and food limitation) are examined through physiological experiments with organisms, studies of isolated cells and tissues, experiments on protein structure and function, and molecular analysis of genetics systems. Lectures from ten instructors emphasize physiological, biochemical, and molecular biological approaches to understanding the ecology and biological adaptations of antarctic organisms, with exposure to field collection techniques. Specific themes for the 2001 course include biodiversity and molecular phylogeny; energy metabolism; macromolecular synthesis; membrane physiology; temperature adaptation; and UV-photobiology.

Student research projects follow these interwoven themes. The students should gain a rigorous understanding of the power - as well as the limitations - of the physiological, biochemical, and molecular biological methods that are currently being used to answer research questions in environmental science and the biology of adaptation. The course will be held in the Crary Science and Engineering Center at McMurdo Station, Antarctica. This modern research facility provides state-of-the-art laboratory facilities a short distance from the marine and freshwater environments where biological observations are made and material is collected.

By attracting an extremely competitive group of two dozen young scientists, students, and postdoctoral researchers, this course introduces new researchers to Antarctica and teaches students the modern research methods currently being deployed to study mechanisms that are unique to biology in Antarctica. (BO-301-O)

(BO-303-O)

Bentho-pelagic coupling on the west Antarctic Peninsula shelf: The impact and fate of bloom material at the seafloor.

Craig R Smith, University of Hawaii Manoa, and David DeMaster, North Carolina State University.

Primary production in antarctic coastal waters is highly seasonal; each spring/summer, an intense pulse of biogenic particles is delivered to the floor of the continental shelf. This seasonal pulse may have major ramifications for carbon cycling, benthic (seafloor) ecology and the nature of material buried on the west Antarctic Peninsula (WAP) shelf. This project brings several disciplines together in an effort to evaluate the bloom material - its fate, accumulation on the seafloor, and impact on the benthic community.

We will work along a transect of three stations crossing the antarctic shelf in the Palmer Long Term Ecological Research (LTER) study area. We plan to complete a series of five cruises during the 2000-2001 research season, and continue to test the following hypotheses:

• A substantial proportion of spring/summer export production is deposited on the WAP shelf as phytodetritus or fecal pellets.

• The deposited bloom production is a source of labile particulate organic carbon (POC) for bottom-dwelling organisms (benthos) for a time period of months.

• Large amounts of labile bloom POC are rapidly subducted into the sediment column by the deposit-feeding and caching activities of benthos.

• Macrobenthic detritivores undergo rapid increase in numbers and biomass following the spring/summer POC pulse.

To test these hypotheses, we will evaluate seabed deposition and POC lability, patterns of POC mixing into sediments, seasonal variations in macrofaunal and megafaunal abundance, biomass and reproductive condition, and rates of POC and silica mineralization and accumulation in the seabed. We will contrast the fluxes of biogenic materials and radionuclides (into midwater particle traps) with seabed deposition and burial rates (observed through time-lapse photography); this data should permit us to establish water-column and seabed preservation efficiencies for these materials.

A better understanding of the spring/summer production pulse on the WAP shelf should enhance our understanding of carbon cycling in Antarctic coastal systems, as well as the impact of such fluctuations on the seafloor communities.(BO-303-O)

(BO-310-O)
Control of denitrification in a permanently ice covered antarctic lake: Potential for regulation by bioactive metals.
Bess B. Ward, Princeton University.

Denitrification driven by bacteria is the process by which nitrogen is lost from ecosystems. As such, the rate and regulation of denitrification may directly affect both primary biological production and carbon cycling, over both short and long time scales. This research investigates a natural experimental system to be found in the permanently ice-covered Lake Bonney in the Taylor Valley of East Antarctica to ask: What is the role of bioactive metals in regulating denitrification?

Lake Bonney has two distinct lobes, but in only one does denitrification occur. Previous study has ruled out most of the obvious biological and chemical variables - which usually influence denitrification - that might account for the difference between the two lobes. Denitrifiying bacteria are present in both lobes of the lake, where tests of both temperature and salinity reveal conditions they can thrive in. Thus, a paradox: Despite apparently favorable conditions, what is inhibiting denitrification in one lobe and not the other?

Our study entails a combination of culture experiments and field work to examine this paradox. Specifically, we will be:

• experimenting with the denitrifying isolates to determine metal tolerances and requirements for growth;

• measuring metal concentrations and metal speciation in surface transects and depth profiles; and

• probing how denitrifying bacteria respond to alterations in the availability of certain metals.

By elucidating the relationship between microbial activity and metal distributions in Lake Bonney, we hope to add to scientific knowledge about the cycling of elements in other aquatic systems. We also expect to develop insights useful for evaluating the proposed use of paleo-denitrification indicators for past-climate reconstructions. Finally this research may shed light on the potential significance of the ratio of global marine denitrification/nitrogen fixation to atmospheric carbon-dioxide levels. (BO-310-O)

LONG-TERM ECOLOGICAL RESEARCH

Ecology has taken its place among science's vital, strategic disciplines, thanks to ever-greater awareness of how the web of life and Earth's other dynamic processes constitute a coherent system. As part of this evolution, NSF's Long-Term Ecological Research Program (LTER), begun in 1980, has grown into a network of 21 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, 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 Biology and Medicine Program supports two of these LTER project sites – to facilitate research on unique aspects of antarctic ecology – one in the Palmer Station area of the Antarctic Peninsula and the other in the McMurdo Dry Valleys.

The **Palmer Station/Antarctic Peninsula LTER** program is ideally sited to probe a fundamental issue: As the pack ice varies (seasonally and year-to-year), what happens to the antarctic marine community; that is, how do ecological processes influence organisms at different trophic levels? The Palmer Station LTER research 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 to that collected from other coastal systems in the Antarctic Peninsula.

The **McMurdo Dry Valleys LTER** project is more wide-ranging – also due to its unique site – and stages 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 as unearthly as any; NASA scientists wondering what conditions on Mars might be like came here – an island of rock in a sea of ice, the largest ice-free area in Antarctica – where winds howl, what little water there is 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 non-existent. 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 are dependent upon liquid water, and are shaped to varying degrees by climate and material transport; but nowhere is this more apparent than in the McMurdo Dry Valleys. In very few of Earth's environments do minor changes in solar radiation and temperature so dramatically affect the capabilities of organisms to grow and reproduce as happens in the dry valleys. Thus, 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 respond almost immediately. Thus, it is there that the first effects of climate change in Antarctica should be observed.

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 (for example, microbial utilization and re-mineralization of nutrients) these dry valley ecosystems lack many of the confounding variables (diverse and fecund biota and many levels of plants and higher animals) indigenous to other ecosystem research.

Long-term ecological research on the antarctic marine ecosystem, an ice dominated environment: The Palmer LTER program.

Raymond Smith, University of California at Santa Barbara.

The Palmer Long-Term Ecological Research (LTER) project is focused on one major ecological issue: To what extent does the advance and retreat of sea ice each year physically determine spatial and temporal changes in the structure and function of the antarctic marine ecosystem?

Evidence shows this dynamic variability of sea ice to have an important (perhaps determinant) impact on all levels of the food web, from total annual primary production to breeding success in top predators. For example, variability in sea ice may affect prey and predators directly by controlling access to open water or preferred habitats; or indirectly, as changes in the sea-ice cover affect other species that serve as food. Four hypotheses driving our research are that sea ice is a major factor regulating for:

• the timing and magnitude of seasonal primary production;

• the dynamics of the microbial loop and particle sedimentation;

• krill abundance, distribution, and recruitment; and

• survivorship and reproductive success of top predators.

These factors probably differ for different key species, as the magnitude and timing of sea ice changes can have very specific local impacts. What remains unclear are the ramifications for the whole antarctic ecosystem. As one of the basic examples: Greater sea-ice areal coverage promotes more available antarctic krill (a primary food), which enhances the survivorship and reproductive success of Adélie penguins. Overall objectives of the Palmer LTER project are to:

• document not only the interannual variability of annual sea ice and the corresponding physics, chemistry, optics, and primary production within the study area; but also the life-history parameters of secondary producers and top predators;

• quantify the processes that cause variation in physical forcing and the subsequent biological response among the representative trophic levels;

• construct models that will link ecosystem processes to environmental variables, and which will also simulate spatial/temporal ecosystem relationships; and then

• employ such models to predict and validate ice/ecosystem dynamics.

A key challenge for the Palmer LTER project is to characterize and understand the many cross-linkages that have developed in the antarctic ecosystem: Environmental phenomena vary, over time and across areas, having both physical and biological consequences; these changes in turn can develop other loops and linkages that influence each other. The participants for the 2000-2001 field season will be:

• William Fraser, Montana State University (BP-013-O);

• Maria Vernet, Scripps Institution of Oceanography (BP-016-O);

• Douglas Martinson, Columbia University (BP-021-O);

• Langdon Quetin and Robin Ross, University of California at Santa Barbara (BP-028-O);

• Raymond Smith, University of California at Santa Barbara (BP-032-O); and

• David Karl, University of Hawaii (BP-046-O).

The role of natural legacy on ecosystem structure and function in a Polar Desert: The McMurdo Dry Valley LTER program.
W. Berry Lyons, University of Alabama at Tuscaloosa.

The largest ice-free area in Antarctica can be found in the McMurdo Dry Valleys, located on the western shore

of McMurdo Sound. Among the most extreme deserts in the world, the Dry Valleys are the coldest and driest of all LTER sites. Consequently, the 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 are 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.

In 1993, this region was selected as a study site for the National Science Foundation's Long-Term Ecological Research (LTER) program. During the first 6 years of this project, investigators studied the perennially ice-covered lakes, ephemeral streams, and extensive areas of soils to assess the role of physical constraints on the structure and function of the ecosystem. Clearly, the production of liquid water in both terrestrial and aquatic portions of this environment is a primary driver in ecosystem dynamics. Thus, the role of present-day climate variation is extremely important. However, one of the most significant discoveries was that past climatic legacies strongly overprint the present ecological conditions in the McMurdo Dry Valleys.

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

Understanding the structure and function of the McMurdo Dry Valleys ecosystem requires understanding hydrological response to climate - both now and in the past. Current patterns of biological activity and diversity reflect both 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 water availability. We continue to focus on the integration of the biological processes within and among the lakes, streams and terrestrial ecosystems that comprise the McMurdo 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 2000-2001 field season, the following studies will be conducted in the McMurdo Dry Valleys as part of the LTER project:

• glacier mass balance, melt, and energy balance; climate monitoring in Taylor, Wright, Victoria, and Beacon valleys; establishment of a snow fence to mimic the effects of increased precipitation in Beacon Valley. (BM-042-F)
(Andrew Fountain, Portland State University)

• chemistry of streams, lakes, and glaciers. (BM-042-L)
(W. Berry Lyons, Ohio State University)

• flow, sediment transport, and productivity of streams; water quality of Lake Fryxell; water loss from the streams to the atmosphere by sampling water-content changes. (BM-042-M)
(Diane McKnight, University of Colorado)

• lake pelagic and benthic productivity; microbial food webs. (BM-042-P)
(John Priscu, Montana State University at Bozeman)

• the influence of environmental conditions on carbon and nitorgen 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.
(Diana Wall, Colorado State University (BM-042-W) Ross A. Virginia, Dartmouth College; (BM-042-V)

• paleoclimatology, paleoecology and meteorological data collection. (BM-042-D)
(Peter T. Doran, University of Illinois at Chicago)

SOUTHERN OCEAN GLOBAL OCEAN ECOSYSTEMS DYNAMICS (SO GLOBEC)

The goal of the U.S. Global Ocean Ecosystems Dynamics (U.S. GLOBEC) program is to understand and ultimately predict how populations of marine animal species respond to natural and anthropogenic changes in climate. Research in the Southern Ocean indicates a strong coupling between climatic processes - via the annual formation and destruction of sea ice - and ecosystem dynamics. As participants in the Southern Ocean GLOBEC program (SO GLOBEC), we will investigate the dynamic relationship between physical processes and ecosystem responses by identifying critical parameters that affect the distribution, abundance, and population dynamics of target species. Overall, we hope to elucidate shelf-circulation processes and their effect on sea-ice formation and antarctic krill (Euphausia superba) distribution, and to examine the factors that govern how krill survive and become available to higher trophic levels (including penguins, seals, and whales). To accomplish this we use moored-instrument investigations; broad physical, biological, and chemical oceanographic surveys; process-oriented investigations; and modeling studies focused on austral winter processes in the western Antarctic Peninsula region.

We have chosen Marguerite Bay in the central western Antarctic Peninsula continental shelf, which is characterized by unusually high krill production. We hypothesize that these high production levels result from a unique combination of factors, both physical and biological, that enhance krill growth, reproduction, recruitment, and survivorship throughout the year.

Water masses on the continental shelf off Marguerite Bay consist of inflowing Upper Circumpolar Deep Water, which is relatively warm, salty, oxygen-poor, and nutrient-rich. In winter, atmospheric processes cool and freshen this water and recharge it with oxygen to produce Antarctic Surface Water. This austral winter environment also provides particularly favorable conditions for larval and adult krill survival, including

• a shelf circulation that keeps the krill population in a favorable environment for extended periods;

• a persistent winter ice cover that provides dependable food and protection for larval krill to grow and survive over the winter; and

• on-shelf intrusions of Upper Circumpolar Deep Water, supplying heat, salt, and nutrients that affect ice properties and enhance biological production.

Making use of U.S. Antarctic Program's two research ships - the icebreaking research ship Nathaniel B. Palmer and the ice-strengthened research ship Laurence M. Gould - we will begin our 2-year study in mid-March 2001 (the late austral fall). Working in the Antarctic Peninsula region until mid August 2001, we will conduct five cruises aboard the two ships in and around Marguerite Bay. The results of the integrated SO GLOBEC program will improve our power to predict living marine resources, especially with respect to local and global climatic shifts.

Southern Ocean GLOBEC: Circulation and water property evolution.
Robert Beardsley and Richard Limeburner, Woods Hole Oceanographic Institution.

As part of the Southern Ocean GLOBEC program, we will develop and deploy on the continental shelf off Marguerite Bay a series of moorings, which will include current meters, sensors to measure salinity, temperature and zooplankton concentration, upward-looking acoustic sounders to track ice motion, and acoustic Doppler current profilers. Our proposed mooring design will quantify and characterize the inflowing and outflowing water masses, and provide the physical component for the integrated modeling effort. Instrumented drifters will supplement the mooring data. These data should quantify the spatial and temporal variability of the (presumed) clockwise flow of water masses through the bay, and define the tidal and transient flows driven by storms and

southward meanders of the Antarctic Circumpolar Current.

Southern Ocean GLOBEC: Mesoscale circulation, tides and mixing.
Lawrence Padman, Earth and Space Research.

Our project has three major components:

• to collect, analyze, and archive Acoustic Doppler Current Profiler (ADCP) and Conductivity-Temperature-Depth (CTD) data in order to be able to characterize mesoscale circulation features and the regional hydrography;

• to develop an accurate model of tidal currents in Marguerite Bay; and

• to provide a data set of small-scale processes (such as shear instabilities, tidal stirring, mesoscale eddies, and double diffusion) that are required to establish effective parameters for the vertical movement of heat, salt, and nutrients.

The results of our project will provide a unified data base, linking water-column and sea-ice processes with the biology of krill and its predators.

Southern Ocean GLOBEC: Water column microstructure.
Thomas Powell, University of California, Berkeley.

Our objective is to make a quantitative assessment of the small-scale temperature and salinity structure of the oceanic surface layer to study the effect of stratification and turbulence on the biochemical and biological processes under the winter sea ice. These modification processes work through mixing associated with shear instabilities of the internal wave field, double diffusion of salt and heat, and mixing driven by surface stress and convection. We will use two microstructure profilers capable of resolving the small but crucial vertical variations that drive these processes.

Southern Ocean GLOBEC: Hydrography and biological and physical modeling.
Eileen Hofmann, John Klinck and Ricardo Locarnini, Old Dominion University.

We have two objectives - to characterize the regional hydrography, and to develop a hierarchy of models to organize and integrate physical and biological observations. We will define the water masses in the Marguerite Bay region with repeated regional surveys for temperature, salinity, nutrients, and oxygen and will supplement these with data from both a moored current-meter and temperature array and, also, from acoustic surveys of the upper ocean current structure. Modeling will provide a mechanism to link water-column and sea-ice processes with the biology of krill and its predators. To synthesize physical and biological models over the continental shelf, we will use three types of models to order the various observations - time-dependent biological models, depth-time models of physical and biological characteristics, and three-dimensional and time-dependent models.

Southern Ocean GLOBEC: Sea ice physics.
Douglas Martinson, Lamont-Doherty Earth Observatory; Raymond Smith, University of California, Santa Barbara; Donald Perovich, U.S. Army's Cold Regions Research and Engineering Laboratory.

The optical properties of snow and sea ice evolve through the winter and vary greatly, both spectrally and spatially. These properties, important elements of the physical environment, strongly influence the distribution of, and the resources available to, antarctic krill. The intensity and distribution of incident radiant energy within the snow, ice, and water column - and the linked physical, optical, chemical, and biological processes that modulate its distribution - are known but poorly quantified. These properties also influence snow and ice algae, water-column productivity and visibility, for both predator and prey; they are also essential in satellite observations as proxy indicators of geophysical sea-ice parameters. To create improved quantitative models with which to follow the temporal and spatial evolution of this snow and ice marine ecosystem, we will deploy an array of instrumented ice beacons, augmented by periodic, ship-based and satellite observations, along with theoretical studies.

Southern Ocean GLOBEC: Dissolved nutrients and oxygen measurements.
Kent Fanning, University of South Florida.

Our project focuses on providing high quality measurements of water-column silica, phosphate, nitrite and nitrate concentrations, as well as dissolved oxygen. These measurements will be examined in conjunction with

the marine biological and physical oceanography components.

Southern Ocean GLOBEC: Primary production in the water column.
Maria Vernet, Scripps Institution of Oceanography, University of California, San Diego.

Focusing on primary production in the water-column, we will use direct experimental estimates, modeling results from a fast-repetition-rate fluorometer, and modeling of primary production from optical as well as biophysical models. This research will be coordinated with components focused on sea-ice production and sea-ice habitats.

Southern Ocean GLOBEC: Sea-ice microbial communities.
Christian Fritsen, Desert Research Institute; University of Nevada.

Focusing on the distribution and activities of sea-ice microbial communities, we will use an integrated combination of sampling (vertical profiles, horizontal surveys, and under-ice surveys) and observational protocols. Experiments will be designed to estimate microbial activity within the sea ice and at the ice/seawater interface. We will coordinate our research with components studying the water-column productivity and the sea-ice habitat.

Southern Ocean GLOBEC: Water column krill distribution and abundance in winter.
Meng Zhou, University of Minnesota.

We will use acoustic techniques to acquire data on the distribution of juvenile and adult krill and mesozooplankton prey. We will also study krill shrinkage and mortality rates, and krill aggregation behavior. The results will be analyzed in coordination with components involved in physical and biological models.

Southern Ocean GLOBEC: Zooplankton distribution and abundance.
Peter Wiebe, Carin Ashjian, Cabell Davis, and Scott Gallager; Woods Hole Oceanographic Institution.

This project will focus on juvenile and adult krill and mesozooplankton prey-distribution and abundance, using a sophisticated instrument package. Known as BIOMAPPER II, the instruments in the package include an acoustic backscatter sonar system, a video plankton recorder and an environmental sensor system. Additionally, a remotely-operative vehicle will be used to map the distribution and behavior of krill under ice.

Southern Ocean GLOBEC: Winter ecology of larval krill.
Robin Ross and Langdon Quetin, University of California, Santa Barbara.

Focusing on the under-ice distribution and abundance of larval and juvenile krill, we will assess the physiological condition of krill associated with areas of sea ice providing food of differing quality and quantity. In an effort to understand the overall age-specific dynamics of krill in winter, we will coordinate with krill study components focusing on adults in the water column.

Southern Ocean GLOBEC: Krill physiology, distribution, predation and fish ecology.
Jose Torres, University of South Florida; Thomas Hallam, University of Tennessee.

This project will focus on krill physiology, using measures of respiration, excretion, and proximate analysis. Feeding experiments will be conducted using various measurement techniques. Under-ice surveys and sample collection will provide information on krill abundance and distribution. Additionally, the distribution and abundance of fishes and squid - krill predators - will be investigated using acoustic and net-tow methods.

Southern Ocean GLOBEC: Biochemical determination of age and dietary history in the krill.
H. Rodger Harvey, Center for Environmental Sciences, University of Maryland.

To determine the population/age structure of krill in field populations (over seasonal and interannual time scales), and to establish markers for dietary history, we will apply new biochemical approaches based on lipids that are specific to different food resources. This research will be coordinated with components studying krill feeding and growth.

Southern Ocean GLOBEC: Seabird distribution and abundance in winter.
Christine Ribic, University of Wisconsin; William Fraser, Montana State University.

Our project focuses on large-scale distribution, abundance, and habitats of seabirds, as well as on seabird diet-composition and small-scale foraging behavior. To accomplish this, we will use strip-transect surveys and examine large-scale data with spatial analysis software and models. Additionally, satellite transmitters will be

used to correlated foraging behavior with diet studies.

Southern Ocean GLOBEC: Foraging ecology of crabeater seals.
Daniel Costa and Daniel Crocker, University of California, Santa Cruz; Jennifer Burns, University of Alaska, Anchorage.

Using a combination of satellite-linked tracking, specialized diver-recorders, and stable isotopic tracers, we will focus on the distribution and foraging behavior of adult female crabeater seals. These data will be coordinated with other study components focused on prey (krill) distribution and the physical environment. The results will be analyzed using an optimality model.

Southern Ocean GLOBEC: Mysticete whale acoustic census in the GLOBEC west antarctic project area.
John Hildebrand, Scripps Institution of Oceanography, University of California, San Diego.

We will determine minimum population estimates, distribution, and seasonality for mysticete whales, especially blue whales, by using passive acoustic recorders deployed on the seafloor for 1 to 2 years. The deployment of a large aperture, autonomous, hydrophone array in the antarctic will use passive acoustics as a tool to detect and count mysticete whales.

Southern Ocean GLOBEC: Modeling the effects of eddies and mean flows on Southern Ocean biology.
Glen Flierl, Massachusetts Institute of Technology.

Our objective is to understand the interactions of biological and physical dynamics by modeling the spatial distribution of krill, which form dense aggregations (or patches) on the small scale. The spatial distribution of these patches apparently depends on

• the advance and retreat of sea ice;

• the three-dimensional movement of water masses from small-scale turbulence to the dynamics of the Antarctic Circumpolar Current; and

• the pressure of the food supply and predation.

Earlier studies indicate that physical processes dominate on the larger scale, while biological processes dominate on the smaller scale. However, the relative importance of the two as a function of scale has not been investigated systemically. To accurately represent patchiness in a circum-antarctic model, we will study a detailed model that can resolve the scale of krill patches and help us to analyze and understand the field observations. These results will allow us to improve the parameters of krill distributions in meso-scale and basin-scale models of the Southern Ocean.

previous section | Table of Contents | next section

OCEAN AND CLIMATE STUDIES

Though it borders the world's major oceans, the Southern Ocean system is like no other in the world, with four times more water than the Gulf Stream, 400 times more than the Mississippi River. It is a sea where average temperatures don't reach ºC in 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 and sea below the troposphere (the inner region of the atmosphere, up to between 11 and 16 kilometers). This ocean/atmosphere environment defines and constrains the marine biosphere, and in turn has a dynamic relationship with the global ocean and with weather all over the planet. Few major energy exchanges on Earth can be calculated without factoring in these essential antarctic phenomena. As such, they are both an indicator and a component of climate change.

The Ocean and Climate Systems program sponsors research that will improve understanding of the high-latitude oceanic 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:

• 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 oceanic processes across a range of temporal and spatial scales.

• Sea-ice dynamics: The material characteristics of sea-ice, from the individual crystal level 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.

(OO-179-O)
Air-snow exchange of nitric and nitrous acids at South Pole.
Jack Dibb, University of New Hampshire.

Nitrogen is a ubiquitous species in nature - a routine volume of dry air is over three-quarters nitrogen and converting dinitrogen into a form available to plants and animals is a crucial step in the terrestrial nitrogen cycle (using biological fixation, bacteria and blue-green algae generate about 1.3 x 108 metric tons). Thus, it is to be found all over Antarctica, in the atmosphere, on the surface, and in the ice. Does this current picture extend into the past? Much scientific effort has been expended on sampling snow and ice cores for indications of what the atmosphere contained when a given segment or strata of the core was buried. But the basic model, at least for nitrogen, may be faulty.

During the first field season in 1998-99 field season, scientists working on "Investigations of sulfur chemistry in the antarctic troposphere" (ISCAT, project OO-270-O) found reactive nitrogen in the atmospheric boundary layer above Amundsen-Scott South Pole Station at levels greatly exceeding those predicted from standard gas phase tropospheric chemistry models. Since it is highly unlikely that these nitrogen species could have been transported in from lower latitudes, it was conjectured that there is a local source within the antarctic snow

cover. This supposition has enormous consequences for experimental theory, because it means that the snow does not act as a simple accumulator and integrator of atmospheric trace gases and, significantly, that observed concentrations in snow and ice cores cannot be simply taken as reflecting atmospheric conditions at the time the snow was falling.

ISCAT researchers continue their 4-year study with another season in the field. During the 2000-2001 austral summer, they will look more closely at nitrogen-oxide chemistry. This includes measurements of nitric acid and nitrous acid in the atmosphere and in the snow. These data will in turn guide the ISCAT observational field program as it proceeds.(O-179-O)

(OO-201-O)
Longwave radiation processes on the antarctic plateau.
Stephen G. Warren and Von P. Walden, University of Washington.

Thermal infrared ("longwave") radiation is an important component in the energy balance between the atmosphere and Earth's surface. On the antarctic continent, radiation processes dominate the surface energy budget. In summer the budget involves four terms - Incoming solar radiation, reflected solar radiation, long-wave radiation emitted by the atmosphere, and long-wave radiation emitted by the snow surface. In winter after the sun sets, the short-wave terms fall to zero. The emitted long-wave radiation increases with temperature, so the surface temperature is determined by the balance of radiation fluxes.

This project entails an experimental study of long-wave radiation processes near the surface at Amundsen-Scott South Pole Station. We will take high-resolution spectral measurements of the longwave radiation at the snow surface. A Fourier-transform Interferometer installed in late 2000 will operate through a full year. Supporting observations will also be made of how temperature and humidity vary with height in the lower atmosphere and of the ice crystals in the atmospheric boundary layer. The research also includes experiments concerning the emission characteristics of snow, of ice crystals in the atmosphere, of clouds, and of greenhouse gases near the surface.

Determining the concurrent environmental conditions (such as cloud-base altitude, temperature, and humidity-structure), and the sizes and concentrations of ice crystals, will contribute to the newly developing climatology of cloud properties and should improve climate models with more detailed radiation processes. (OO-201-O)

(OO-204-O)
Atmospheric oxygen variability in relation to annual-to-decadal variations in terrestrial and marine ecosystems.
Ralph F. Keeling, Scripps Institution of Oceanography.

Oxygen, the most abundant element on the 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 flora and fauna that recycle it (both directly and as carbon dioxide) through the processes of photosynthesis and respiration.

Thus scientists are interested in measuring the concentration of molecular oxygen and carbon dioxide in air samples; our project includes a subset of sample collections being made at a series of baseline sites around the world. These data should help to improve estimates of the processes whereby oxygen is cycled throughout the global ecosystem, specifically, through photosynthesis and atmospheric mixing rates; also better predictions of 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. We are also 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 oxygen and carbon dioxide geochemical cycles.

These results should help enhance our understanding of the processes that regulate the buildup of carbon dioxide in the atmosphere and of the change processes - especially climate change - that regulate ecological functions on land and in the sea.(OO-204-O)

(OO-225-O)
Shelf and bottom-water formation near east antarctic polynyas and glaciers.

Richard T. Fairbanks, Lamont-Doherty Earth Observatory.

As seawater becomes colder and more saline, its density increases. Thermohaline circulation involves a deep water flow pattern that arises as such saltier, colder water sinks; it finally reaches an equilibrium level and begins to move more or less horizontally. But how does the increased salinity develop?

One way that water on the antarctic continental shelf increases in salinity is through coastal polynyas; formed by strong offshore winds, polynyas create fields of ice and water often referred to as major sea ice and salt "factories." The newly formed ice is blown seaward, allowing more ice to form along the coast, and this continental shelf water increases its salinity as it freezes. Since polynyas have areas of thin ice and even open water subject to evaporation, heat is lost to the atmosphere more readily; this too increases the density of the shelf water. This heavier shelf water then sinks, fills any depressions in the bottom, and is gravitationally driven down the continental slope into deeper waters.

Researchers in this project are interested in how the formation of dense water masses on the antarctic continental shelves may be affected by the periodic flushing of relatively warm circumpolar deep water; specifically, does the intrusion of warm water enhance the rate at which dense water forms? We also expect to find evidence of an additional process - the intrusion of relatively warm water onto the continental shelf, overriding the shelf water and essentially shutting down the densification processes - at work in this area.

We will observe water-mass modification processes on the continental shelf off the Adélie Coast in East Antarctica, focusing on a quasi-permanent area of open water near the Mertz and Ninnis Glacier tongues, the so-called Mertz polynya. Using the icebreaking research ship Nathaniel B. Palmer, we will obtain data at a closely spaced array of hydrographic stations over the continental shelf and slope along the George V Coast in the austral summer. These data will complement a similar winter study, conducted by the Australian National Antarctic Program. (OO-225-O)

(OO-226-O)
Measurements of the size, shape, scattering-phase function, and extinction coefficient of ice crystals at Amundsen-Scott South Pole Station.
R. Paul Lawson, SPEC, Inc., Boulder, Colorado.

Clouds are both the cause and result of atmospheric phenomena; one of their primary roles is as a reflector of solar energy - coming both from space and radiated/reflected from the Earth. And what are clouds? Broadly, clouds form when rising damp air expands to the point that it approaches saturation. With nowhere else to go, water molecules condense onto any local, available aerosol particles - the aggregation becomes a cloud.

A number of theoretical and experimental studies have demonstrated that a cloud particle's size as well as its shape - and specifically ice crystals - strongly determine how it will reflect and radiate light (and energy). Looking especially at cirrus clouds, this project will classify cloud particles by size and shape and will also investigate the light-scattering properties of ice crystals in the atmosphere above Amundsen-Scott South Pole Station.

In cooperation with an ongoing radiation transfer program, we will deploy two high-resolution, digital cloud-particle imagers. The particle images, concentrations, and size distributions will be processed on site. Our software permits us to reject artifacts, and to compute various size and shape parameters, scattering characteristics, and ice/water proportions.

These data will complement several concurrent experiments concerning the emission characteristics of snow, ice crystals in the atmosphere, and greenhouse gases near the surface. With measurements of such environmental conditions as cloud-base altitude, temperature, and humidity structure, our data should allow us to develop new algorithms to substantially improve representations of radiation processes in general circulation models. We also expect to enhance the climatology of cloud-particle and cloud properties. (OO-226-O)

(OO-254-O)
Chlorine- and bromine-containing trace gases in the antarctic.
Reinhold A. Rasmussen and M.A.K. Khalil, Oregon Graduate Institution of Science and Technology.

Although the Earth's climate is a massively complex system, at certain levels of the atmosphere interactions are predictable. Disregarding the ubiquitous and dynamic water vapor, more than 99.9 percent of atmospheric

molecules are either nitrogen, oxygen, or the chemically inert "noble gases" (chiefly argon). Scientists have confirmed this baseline medium as largely unchanged for several hundred million years.

However, much of the atmospheric "action" - acid rain, ozone depletion, smog - comes from the reactive trace species, which occur in small amounts but precipitate many crucial chemical events. There are thousands of these, but fewer than 200 are commonly present in a typical volume of air. It is not known for how long and in what proportions these have been prominent actors in atmospheric chemistry. Chlorofluorocarbons, for example, are one problematic species, but a suite of other airborne trace constituents to be found in atmospheric gases derive from both biogenic and anthropogenic sources. Scientists monitor them closely, as they have been implicated in depletion of the ozone layer over Antarctica, as well as in other alterations of the Earth's climate.

This project continues to investigate seasonal trends in trace gas concentrations, by collecting a year-long suite of air samples at Palmer Station. They will be analyzed at the Oregon Graduate Center for a number of trace components, especially chlorine- and bromine-containing species. This work should contribute to a better understanding of the buildup of trace constituents, particularly those of high-latitude marine origin. (OO-254-O)

(OO-257-O) and (OO-264-O)
South Pole monitoring for climate change. Amundsen-South Pole Station.
David Hofman, Climate Monitoring and Diagnostics Laboratory, National Oceanographic and Atmospheric Administration; Palmer Station (OO-257-O)

The National Oceanic and Atmospheric Administration (NOAA) has been conducting studies to determine and assess the long-term buildup of global pollutants in the atmosphere. The NOAA Climate Monitoring and Diagnostic Laboratory team will continue long-term measurements of trace atmospheric constituents that influence climate and the ozone layer. Time-series analyses of the data that is being collected over a period of years should provide insight into several phenomena of particular interest:

• seasonal and temporal variations in greenhouse gases,

• stratospheric ozone depletion,

• trans-antarctic transport and deposition,

• the interplay of the 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 will measure carbon dioxide, methane, carbon monoxide, aerosols, chlorofluorocarbons, and other trace constituents; concurrent measurements will be made of water vapor, surface and stratospheric ozone, wind, pressure, air and snow temperatures and atmospheric moisture. Other personnel at Palmer Station also will collect carbon dioxide samples in support of this project.

These measurements will allow us to determine the rates at which concentrations of these atmospheric constituents change and will suggest likely sources, sinks, and budgets. To further determine how the rates of change of these parameters affect climate, we are collaborating with climate modelers and diagnosticians. (OO-257-O) and (OO-264-O)

(OO-260-O)
Drake Passage expendable bathythermograph program.
Ray Peterson, University of California.

The Antarctic Circumpolar Current (ACC) is a powerful force that drives waters in the Southern Ocean - four times as fast as the Gulf Stream, for example. The current is even stronger wherever the distance between Antarctica and neighboring land is narrowed. These are the so-called chokepoints, such as The Drake Passage off the tip of South America and the sea regions between Antarctica and both the Cape of Good Hope and Tasmania. To determine the fluctuations in the transport of the ACC, scientists deploy bottom pressure gauges and similar instruments; this data can then be ranged against currents in the subtropical and subpolar gyres and to the wind field over the southern oceans.

Specifically since 1996, scientists in this research project have been collecting data to characterize the water mass variability in the Drake Passage, to describe temperature and circulation variability in the Southern Ocean, and to define the role of the Southern Ocean in the global climate system. This season, using high-density expendable bathyermographs (XBT) launched from the USAP's research ship Laurence M. Gould, we will measure current, temperature, and depth for seasonal and year-to-year temperature fluctuations in the upper ocean within the Drake Passage. Since the water changes more rapidly there, we will execute frequent casts across the Subantarctic, Polar, and ACC fronts. (OO-260-O)

(OO-263-O)
Katabatic winds in eastern Antarctica and their interaction with sea ice. *Gerd Wendler, University of Alaska, Fairbanks.*

Katabatic winds are driven by the flow of cold dense air down a mountain or glacier slope, especially in regions where radiation significantly cools the Earth's surface. These winds are strong enough to drive the sea ice offshore at any time of the year, which often leads to coastal polynyas - areas of open ocean within the sea ice. As these coastal polynyas (in winter) experience extremely high heat fluxes from the ocean to the atmosphere - two orders of magnitude greaer than would solid ice - the resultant cold tends to breed large amounts of sea ice and Antarctic bottom water.

To obtain more detailed information on these fluxes, the United States Coast Guard ice breakers (for this project, the Polar Sea) maintain instruments to measure the heat fluxes as a function of ice concentration, ice thickness and type of ice. Further, this project continues the international collaboration (France, Australia and the United States) to study katabatic winds and the interaction with sea ice along the coast of Adélie and King George Lands.

A number of weather stations collect meteorological data: One array strings from the interior (Dome D at 3280 meters) to the coast (D 10) near the French station Dumont d'Urville; the other string runs along the coast, including stations at Cape Denison and Port Martin, an area where the highest average surface wind speeds on Earth have been recorded - a monthly average of 27.8 meters per second (mps).

We plan to analyze the effect of these winds on the formation, persistence and size of coastal polynyas. The meteorological data we derive will be ranged against data from satellite-based active microwave imagery (synthetic aperture radar).

We are also interested in assessing the influence of cyclonic storm systems on the drainage flow along the coast; our data on this will be combined with that collected by Australian, French and Japanese station networks (to the west of these stations).

We are also producing a numerical model of the structure of the region's atmosphere, which will incorporate a more detailed terrain map as well as a new mesoscale model developed by French scientists. This model will not only predict average mean winter conditions (previously done), but also extreme events, where wind speeds commonly exceed 50 mps. (OO-263-O)

(OO-270-O)
Investigation of Sulfur Chemistry in the Antarctica Troposphere (ISCAT).
Douglas D. Davis and Fred L. Eisele,Georgia Institute of Technology.

Sulfur is one of the basic elements to be found in nature, and constructing a sulfur budget for a region - or for the planet - is a complex undertaking, especially since so much sulfur is also emitted by industrial activities. Biogenic emissions (coming from a live source) derive primarily from the oceans, where microorganisms emit the gas dimethyl sulfide (DMS).

Atmospheric sulfur chemistry is an important component in the study of climate change issues because of the so-called aerosols. These are minute airborne particles from sources both natural (volcanic emissions and oceanic phytoplankton production) and anthropogenic (emitted sulfur compounds from industry and biomass fires form minute particles in the atmosphere). Their atmospheric fate is complex; they reflect solar radiation, produce atmospheric haze and acid rain, and affect ozone depletion. Sulfate particles in the atmosphere may also act as condensation nuclei for water vapor and thereby enhance global cloudiness. Paleoclimatologists have been able to reconstruct the variability and natural background level of atmospheric aerosols from sulfur

oxidation products preserved in ice cores.

This project brings together over a dozen investigators from five institutions to focus on two major gaps in knowledge -

• to improve substantially our current understanding of the oxidation chemistry of biogenic sulfur in the polar environment, and

• to improve the climatic interpretation of sulfur-based signals in antarctic ice-core records.

The South Pole provides a natural laboratory for this investigation because the atmospheric boundary layer there presents a homogeneous and relatively simple environment from which to unravel the photochemically driven oxidation chemistry of dimethyl sulfide. The results of the ice core work, however, depend on understanding how the physical and chemical environment of the oxidation process affects the relative concentrations of the oxidation products that become buried in the ice. Observations will be made of a wide-ranging suite of sulfur species such as DMS and its oxidation products, as well as photochemically important compounds such as carbon monoxide, nitrous oxide, water vapor, and non-methane hydrocarbons.

We hope to provide, for the first time, a quantitative picture of exactly which atmospheric sulfur compounds are released and conveyed into the antarctic interior, as well as an account of the sulfur chemistry active in the atmosphere over Antarctica. (OO-270-O)

(OO-275-O)
Operation of an aerosol sampling system at Palmer Station.
Gail dePlannque and Colin G. Sanderson, Environmental Measurements Laboratory, U.S. Department of Energy.

Radionuclides are atoms emitting radioactive energy, some of which occur naturally in the surface air. It is these - as well as nuclear fallout and any accidental releases of radioactivity - that the Environmental Measurements Laboratory's (EML) Remote Atmospheric Measurements Program (RAMP) is designed to detect and monitor. Since 1963 EML, as part of the U.S. Department of Energy, has run the Global Sampling Network to monitor surface air. The RAMP system provides on-site analysis in thirteen different locations around the world, including Palmer Station, Antarctica.

Using a high-volume aerosol sampler, a gamma-ray spectrometer, and a link to the National Oceanic and Atmospheric Administration's ARGOS satellite system, these researchers will continue sampling air at Palmer Station for anthropogenic radionuclides. (OO-275-O)

(OO-278-O)
Particulate organic carbon production and export in the Indian sector of the Southern Ocean: A United States-China collaborative research project.
Cynthia Pilskaln, University of Maine at Orono.

The Polar Front Zone, where the cold, dense waters of the antarctic meet the warmer waters of the northern oceans, is subject to major currents and water displacements beneath the sea. Each austral spring, phytoplankton bloom in this region. Scientists believe the blooms are driven by nutrient transport brought to the surface, as intermediate and deep water masses are ventilated. Each year (the theory goes) such blooms are the primary source of particulate organic carbon (POC) and biogenic silica flux to the ocean bottom. But the theory remains to be tested, as no data exist on the amount of particulate organic matter that is sinking through the water column. Without such quantitative measurements in this region, the hypothesized relationships between biomass production and the currents must remain undefined.

As part of a collaboration between the University of Maine and the Chinese Antarctic Research Expedition (CINARE), we will study the biological production and export flux of biogenic matter in response to ventilation of intermediate and deep water masses within the Polar Front Zone. The shipboard work will be done aboard the Nathaniel B. Palmer, working off Prydz Bay in the Indian Ocean sector; we will receive help from project GO-073-O researchers in collecting sediment cores and hydrographic data. Data gathered in this effort will be enhanced by the historical dataset that CINARE has obtained in this area over the past decade.

Our work will be carried out in collaboration with the State Oceanic Administration (SOA) of the People's

Republic of China and the Chinese Antarctic Research Expedition. In addition to providing time on the antarctic resupply vessel, the SOA will sponsor the primary productivity experiments on board ship and will provide the supporting hydrographic measurements. The collaborating American scientists will provide the hardware for the moored sediment trap and will bring their expertise in making these observations to standards developed for the Joint Global Ocean Flux Study. All samples and data will be shared between the U.S. and Chinese investigators, and the data analysis will be carried out jointly. (OO-278-O)

(OO-283-M, P, S)
Antarctic automatic weather station program: 1998-2001.
Charles Stearns, University of Wisconsin at Madison.

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

Their data are transmitted via satellite to a number of ground stations, and put to several uses, including operational weather forecasting, accumulation of climatological records, general research purposes, and specific support of the U.S. Antarctic Program - especially the LTER program at McMurdo and Palmer Stations. The AWS network has grown from a small-scale program in 1980 into a significant data retrieval system that is now extremely reliable, and has proven indispensable for both forecasting and research purposes. This project maintains and augments the AWS, as necessary.

This season three project teams will

• move the AWS at the South Pole away from the dome and toward the Clean Air Sector, anticipating the construction of new facilities;

• maintain and service the AWS stations on Racer Rock, Bonaparte Point and Hugo Island; and

• service other AWS stations, on the Ross Ice Shelf, around the Ross Island region, at Byrd Station, the Siple dome field camp, and along the Adélie Coast, at Terra Nova Bay and on Franklin Island

(OO-283-M)

(OO-283-P)

(OO-283-S)

(OO-314-O)
Measurement of combustion effluent carbonaceous aerosols in the McMurdo Dry Valleys.
Anthony D. Hansen, Magee Scientific Company.

Though Antarctica remains comparatively pristine, there is heightened awareness of the impact the human presence and scientific work being undertaken there could have. To continue a series of assessments of the long-term environmental impact of the U.S. Antarctic Program's operations, we plan to generate a database detailing the abundance of carbonaceous aerosols in the McMurdo Dry Valleys.

The Long-Term Ecological Research (LTER) study site in the Dry Valleys supports a fragile, nutrient-limited ecosystem that could be significantly affected by human activities. Of special concern are deposits of particles from carbonaceous aerosols ("black carbon"). These could be arise from the exhaust of diesel power generators and helicopter operations within the McMurdo Dry Valleys; it is even possible that combustion products from McMurdo Station about 100 kilometers away could migrate to the study area. For three austral summers, we will deploy a real-time optical analyzer at the LTER site to measure the concentration of black carbon, polycyclic aromatic hydrocarbons, and other filterable organic compounds useful in fingerprinting combustion products. (OO-314-O)

(OO-315-O)
Shipboard acoustic doppler current profiling on Nathaniel B. Palmer and Lawrence M. Gould.
Teresa K Chereskin, Scripps Institution of Oceanography.

Currents in the Southern Ocean have a profound influence on the world's oceans - and therefor upon global temperature and the planet's ecosystem - yet some remote regions receive little scientific attention. Using doppler technology (sound wave transmission and reflection), this project is exploring upper ocean current velocities and will try to generate a quality-controlled data set in one such sparsely sampled and remote region, which nonetheless appears to play a significant role in global ocean circulation. We will develop and maintain a shipboard acoustic doppler current profiler (ADCP) program on board the USAP research ships Nathaniel B. Palmer and Laurence M. Gould.

Part of our long-term science goal is to characterize the temporal and spatial velocity structure in the Southern Ocean. This entails measuring the seasonal and annual changes in upper ocean currents within the Drake Passage and combining this information with similar temperature observations, to see how the heat exchange varies and how it drives upper ocean currents. (OO-315-O)

(OO-316-O)
Field experiments and modeling of the breakup of antarctic sea ice.
John P. Dempsey, Clarkson University.

The sea-ice in Antarctica comes and goes with the seasons - from as little as 4 million square kilometers in February to as much as 20 million in September. For scientists this marks something of a moving target, yet the internal dynamics of the ice pack could be much better understood than they are at present. This project focuses on 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. Researchers will conduct experiments on the deformation and fracture of sea ice in McMurdo Sound by applying a series of controlled stresses and observing their effects.

A key effect is the initiation and growth of microcracks within the ice, and large ice floes do not fracture in the same way as small ones do. Thus, for experiments to yield information that is valid for the larger scales that concern scientists, the test scales must be fairly large, some tens of meters. With these m aneuvers we hope to gain detailed information on the microstructure of the ice (such as crystal structure, brine channels, and other flaws in the ice fabric). This will provide a sound theoretical framework to guide the experimental work and the generation of models.

In one component of this project, we are collaborating with the New Zealand Antarctic program; that effort concerns the fracture mechanics of fatigue crack propagation, the use of microstructural observations to verify magnetic resonance measurements of the structure of inclusions in the ice, and the acoustic emissions of fracture zones. (OO-316-O)

(OO-324-O)
Record of atmospheric photochemistry in firn at South Pole.
Roger Bales and Joseph R. McConnell, University of Arizona Desert Research Institute, University of Nevada.

Scientists are eager to develop models about Earth's history, based on their knowledge of current, active dynamic processes. One such process vital to the Earth is photochemistry, how the sun's radiant energy affects conversion of oxygen in the atmosphere. By measuring and interpreting the hydrogen peroxide, formaldehyde, and nitric acid concentrations in the snow and firn at South Pole station, we hope to develop a credible history of the oxidation capacity of the atmosphere over the last two centuries. We also hope to evaluate methods that will confirm statistically significant changes in the concentration of these species over that time.

Amundsen-Scott South Pole station is ideal for this work. The extreme cold makes the chemistry relatively simple; the NOAA Climate Modeling and Diagnostics Laboratory provides a context of high quality meteorological and chemical data; and the station is staffed continuously so that samples can be taken year-round.

We will sample air and near-surface snow throughout the year; during the summer, we will sample and analyze snow pits and firn cores, and will model the air/snow chemistry to try to explain the observed concentrations in the firn. The summer conditions will also permit us to sample two snow pits around the perimeter of the snow stake field intensively (for accumulation observations), a process that will establish markers to maintain time control for stratigraphic and chemical horizons.

During earlier work at South Pole and in central Greenland, we have developed and tested physically-based models of air-snow exchange of hydrogen peroxide. This project extends that work. (OO-324-O)

previous section | Table of Contents | next section

ENVIRONMENTAL MONITORING PROGRAM

Recognizing that scientific research and related logistic support can have effects on the antarctic environment, the Antarctic Treaty Consultative Parties adopted recommendations on environmental monitoring in Antarctica with two important goals: To detect any unforeseen effects and to verify the actual impact and scope of those effects that were anticipated.

The Protocol on Environmental Protection to the Antarctic Treaty also requires that environmental impacts be monitored. The U.S. Antarctic Program (USAP) is developing an Environmental Monitoring Program designed to detect and measure any impacts from science and operations at its research stations in Antarctica. Only with a sustained and coherent monitoring program can a reliable basis for sound environmental management decisions – and possible improvements – be established. Data obtained from the monitoring program will be used to document baseline conditions, verify operational impact, and monitor activities undertaken to recover from accidental impacts to the environment.

(EO-318-O)
Spatial and temporal scales of human disturbance-McMurdo Station, Antarctica.
Mahlon Kennicutt, II, Texas A&M University.

Antarctica represents perhaps one of the most carefully-tended and strictly-monitored habitats on Earth. Aside from the manifest desire to protect the flora, fauna and the atmosphere of a relatively pristine environment, there is the value the extreme southern latitudes provide as a virtual baseline barometer of global pollution. The Antarctic Treaty's Protocol on Environmental Protection, supplemented by the policies and practices of the nations who work and do science there, have combined to focus scrutiny on any anthropogenic impacts that can be foreseen or detected.

This 3-year project will establish a system of observations that should enable the United States to be more aware of any such impacts - on both marine and terrestrial habitats - in and around McMurdo Station, locating them precisely and tracking them over time.

Using a combination of aerial photography and point-data sampling grids at various spatial scales, we will measure a series of attributes indicative of change within these two habitats. Our objectives are to determine:

• the spatial and temporal scales of change and its origin;

• how efficiently this observational system documents relevant changes in important habitat characteristics; and

• the usefulness of various approaches to reference or control locations.

We will use GIS-techniques and geostatistical methods to organize these diverse data sets into a coherent, coordinated framework. The results should provide fundamental scientific information for developing a long-term strategy to document and minimize the impacts of future science and support operations on antarctic resources and values. (EO-318-O)

GEOLOGY AND GEOPHYSICS

Antarctica is not only one of the world's seven continents, but also comprises most of one of its dozen major crustal plates, accounting for about nine 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. The ice sheets average some 3 kilometers deep – 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 thanks to the sciences of geology and geophysics, powered by modern instruments and informed by the paradigm of plate tectonics/continental drift, Antarctica is also a time machine.

Geologists have found evidence that there was once a forested supercontinent in the Southern Hemisphere, which they call Gondwanaland. Before the Earth's constantly shifting plate movement began to break it up 150 million years ago, Antarctica was a core piece of this assembly; its adjoining land has since become Africa, Madagascar, India, Australia and South America. The Antarctic Plate drifted south at little more than a centimeter each year, but geologic time eventually yields cataclysmic results: The journey moved it into ever colder, high-latitude climates, at a rate of about 4ºC for each million years; eventually life conditions had changed dramatically, and Antarctica arrived at a near polar position. This astounding history of rock and life on Earth has left a stratigraphic and fossil record, locked in and beneath the ice, the sea, and in the bedrock below both.

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

• determining the tectonic evolution of Antarctica and its relationship to the evolution of the continents from Precambrian time (600 million years ago) to the present;

• determining Antarctica's crustal structure;

• determining how the dispersal of antarctic continental fragments may have affected the paleocirculation of the world oceans, the evolution of life, and the global climate (from prehistoric times to the present);

• reconstructing a more detailed history of the ice sheets, identifying geological controls to ice sheet behavior, and defining geological responses to the ice sheets on regional and global scales; and

• determining the evolution of sedimentary basins within the continent and along continental margins.

All of these problems will be simplified as scientists improve their models of where, when, and how crustal plate movement wrought Antarctica and its surrounding ocean basins. The program funds investigation into the relationships between the geological evolution of the antarctic plate and the life and processes that can be deduced to accompany it: Paleocirculation of the world ocean, paleoclimate of the Earth, and the evolution of high-latitude biota. A current emphasis is the West Antarctic Ice Sheet Program (WAIS), research on the smaller of the continent's two ice sheets, conducted also under the aegis of the Glaciology program. Several important research support activities are also underway:

• Meteorites: In a partnership with NASA and the Smithsonian Institution, the program supports meteorite collection through ANSMET, the Antarctic Search for Meteorites, and chairs an interagency committee, responsible for curating and distributing samples of the antarctic meteorites.

• Mapping and geodesy: In partnership with the U.S. Geological Survey, the program supports mapping and geodetic activities as an investment for future research in earth sciences. The U.S. Antarctic Resources Center (US-ARC) constitutes the USAP contribution to the Scientific Committee on Antarctic Research (SCAR) library system for earth sciences information; 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 a partnership with the Antarctic Marine Geology Research Facilty at Florida State University, the program manages and disseminates marine sediment and geological drill cores mined in Antarctica. The collection includes an array of sediment cores as well as geological drill cores from the Dry Valley Drilling Project, the CIROS drilling program, and the Cape Roberts Drilling Project. The facility fills requests for samples from researchers worldwide, and also accommodates visiting researchers working on site.

(GF-121-O)
Global positioning system measurement of isostatic rebound and tectonic deformation in Marie Byrd Land, West Antarctica.
Bruce Luyendyk, University of California at Santa Barbara.

The Ross embayment and western Marie Byrd Land are part of the west antarctic rift system. Most scientists agree that this region is undergoing active deformation, but the rates and causes of deformation remain essentially unknown. Tectonic extension may be occurring in the Ross embayment as West and East Antarctica continue to separate. Crustal uplift could be occurring in western Marie Byrd Land due to isostatic rebound following the last glacial age.

If tectonic extension is occurring in the embayment - depending on its magnitude - it could greatly influence global plate circuit calculations. It could also constrain our understanding of the history of extension in the embayment and the consequent uplift history of the Transantarctic Mountains. Postglacial rebound in western Marie Byrd Land would depend on when and how the ice sheet was configured during the Last Glacial Maximum. The big question is whether the ice sheet collapsed in mid-Holocene time.

This study will install three continuous and autonomous global positioning system (GPS) stations on outcrops in western Marie Byrd Land, on baselines of around 100 kilometers. These stations will gather data over a 4-year period and operate in concert with GPS stations being installed in the Transantarctic Mountains in a separate project; the result will be a baseline array deployed all across the Ross embayment. The array will also detect strain gradients in western Marie Byrd Land. This system should determine crustal strain rates to an accuracy of 1 millimeter per year for horizontal, and 2 millimeters per year for vertical. The strain data from western Marie Byrd Land and the Transantarctic Mountains should enable us to construct both tectonic extension and glacial rebound models.

This is a joint project between the University of California at Santa Barbara scientists and a team at the Jet Propulsion Laboratory at the California Institute of Technology. (GF-121-O)

(GO-052-M, GO-052-P & GO-052-S)
Antarctic Mapping and Geodesy.
Jerry L Mullins and Richard E Witmer, U.S. Geological Survey.

Geodetic surveying, aerial photography, remote sensing (principally using several varieties of satellite imagery), and mapping are all activities necessary for the successful operation of a multifaceted scientific and exploration effort in Antarctica. The U.S. Geological Survey provides these support activities to the U.S. Antarctic Research Program.

Year-round data acquisition, cataloging, and data dissemination activities will continue in the U.S. Antarctic Resource Center for geospatial information. Field surveys will be conducted in support of specific research projects, and as part of a continuing program to collect the ground-control data necessary to transform existing geodetic data to an earth-centered system suitable for future satellite mapping programs.

LandSat data will be collected as part of satellite image mapping activities; this will permit continued publication of additional 1:50,000 scale topographic maps in the McMurdo Dry Valleys region. Such topographic studies provide a uniform base map on which to ensure that scientific information (from geology, glaciology, biology and

other areas) is spatially accurate. These, as well as the satellite image maps, are used by scientists to plan and execute future research work. Spatially-referenced, digital cartographic data will be produced in tandem with the published maps. (GO-052-M, GO-052-P & GO-052-S)

(GO-053-O)
Stability of land surfaces in the McMurdo Dry Valleys: Insights based on the dynamics of subsurface ice and sand-wedge polygons. *Bernard Hallet, University of Washington.*

The dynamic nature of climate has received growing public attention because of growing concerns about warming and the recent occurrence of seemingly extreme weather events. In this context, understanding the inherent variability of Earth's climate and how humans can affect Earth's environment is becoming increasingly more important. We are studying features of the landscape and soils of the dry valley region of Antarctica to provide a more complete understanding of past climatic and environmental conditions.

One important means of improving our understanding of the planetary climate system is to treat the Earth as a natural laboratory and examine its past behavior. One of the most extreme changes in the climate system during the last few million years was the transition from a warm period in the Pliocene to an ice-age world. Scientists believe that during this interval relatively mild conditions in Antarctica gave way rapidly to intense glacial conditions that catalyzed the growth of what has become the largest ice sheet on Earth. This inference is based on geologic indicators of past climate, from which some scientists suggest that East Antarctica was relatively warm and largely free of glaciers about 3 to 4 million years ago (during parts of the Pliocene). The mild conditions ended abruptly, with rapid ice-sheet growth and development of the very cold, dry climate that now characterizes this region. A contrasting view, based on substantial geologic evidence, suggests that East Antarctica has been cold and the ice sheet stable for at least 8 million years, and perhaps considerably longer. These views lead to drastically different interpretations of the stability of Earth's climate.

We hope our research will help resolve this important dilemma by introducing independent new evidence and insights derived from studies of the stability of ground ice and land surfaces in the McMurdo Dry Valleys of Antarctica. We will study modern-day processes that have important implications for understanding the occurrence of buried ice found recently in Beacon Valley. This ice may be the oldest ice on Earth, and, if so, will provide strong evidence of long-term stability of the East Antarctic Ice Sheet, and may also provide a rare glimpse into atmospheric conditions millions of years ago.

Specific processes to be investigated include

• exchange at the ground surface that affects ground temperature;

• water-vapor transport and other processes leading to the formation or loss of ice in the soil; and

• frost cracking due to contraction during rapid cooling of the frozen ground in the winter, and its resulting disruptions of the soil. (GO-053-O)

(GO-054-O)
Response of the East Antarctic Ice Sheet to Middle Miocene global change.
David R Marchant, Boston University.

As evidence of global climate change continues to accumulate, scientists concentrate on models that might indicate what impacts such change could have. Among the most important questions: What could happen to the East Antarctic Ice Sheet- One of the largest known global climate shifts occurred in Middle Miocene time (between about 15.6 and 12.5 million years ago). As the isotopic composition of oxygen in the oceans shifted, dramatic global cooling and reorganization of ocean circulation patterns can be seen. This significant and irreversible shift set the stage for modern oceanic and atmospheric circulation, and for the bipolar ice ages that have dominated climate records for the last 12.5 million years. How did Antarctica respond to this great climate shift? Could growth of the antarctic ice sheet have initiated this shift? If so, how might future fluctuations in the volume of ice on East Antarctica influence atmospheric and oceanic circulation?

Recently there was an unexpected breakthrough in antarctic geology - discovery of Miocene-age volcanic ashes interbedded with surficial sediments in southern Victoria Land. These terrestrial deposits provide unambiguous data from which to generate precise climatic and glaciological reconstructions of how the global climate changed

and the ice sheet evolved. This site appears to be the only place in Antarctica where pristine, Miocene-age, unconsolidated deposits are preserved at the ground surface.

These data also permit scientists to address key questions, such as -

• What contributing factors in Antarctica led to the abrupt global cooling about 14 million years ago?

• Does the Middle Miocene shift in the isotopic composition of the oceans signify a major expansion of east antarctic ice?

• Or rather, does this isotopic shift instead reflect a change in ocean temperature or circulation?

• And a related question: When did cold, hyper-arid, polar-desert conditions (signifying the development of a polar East Antarctic Ice Sheet) first evolve in Antarctica? In analyzing these deposits, we expect to obtain a precise chronological sequence, based on 50 laser-fusion isotopic analyses of in-situ volcanic ashes and 20 cosmogenic, exposure-age analyses of ancient deposits. We also expect to develop a coeval record of the Miocene paleoclimate, based on textural changes in alpine drifts, the areal distribution of ice-marginal lakes, the abundance of dated, patterned ground and ventifact pavements, and the geochemistry of buried soils and volcanic-ash deposits. (GO-054-O)

(GO-058-O)
ANSMET (the Antarctic Search for Meteorites).
Ralph Harvey, Case Western Reserve University.

Since 1976, ANSMET (the Antarctic Search for Meteorites program) has recovered more than 10,000 meteorite specimens from locations along the Transantarctic Mountains. Antarctica is the world's premier meteorite hunting ground for two reasons. First, although meteorites fall all over the globe at random, the likelihood of finding a meteorite is enhanced if the background material is plain and the accumulation rate of terrestrial sediment is low; this makes the East Antarctic Ice Sheet the perfect medium.

Second, along the margins of the sheet, ice flow is sometimes blocked by mountains, nunataks, and other obstructions; this exposes slow-moving or stagnant ice to the fierce katabatic winds, which can diminish the ice and expose what is known as 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 millenia, the concentration of meteorites unveiled can be spectacular.

It is important to continue recovering antarctic meteorites because they are the only currently available source of new, non-microscopic extraterrestrial material. As such, they provide essential "ground truth" (existence proof) 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 a sample return mission.

During the 2000-2001 field season, ANSMET will visit the Meteorite Hills region at the headwaters of the Darwin Glacier. This site has been visited twice previously for reconnaissance purposes, yielding about 60 meteorites during a few days searching. Systematically searching this important icefield will be the primary focus of the upcoming season. Other nearby targets will be explored during extended helicopter-supported reconnaissance; we anticipate visiting Bates Nunataks, Butcher Ridge, and other nearby icefields. (GO-058-O)

(GO-059-O)
Tracking the west antarctic rift flank.
Paul Fitzgerald and Suzanne L. Baldwin, University of Arizona.

Reconstructing the motion of the Earth's crustal plates in prehistory is rarely as simple as looking at a blueprint. Geological evidence may suggest conflicting narratives, and newly developing techniques are often the key to resolving the puzzle. The rift system in West Antarctica is an example.

Scientists believe that the uplifted Cenozoic rift shoulder of the west antarctic rift system extends along the Transantarctic Mountains and the northwestern flank of the Ellsworth-Whitmore Mountains crustal block. Fission track data drawn from the block indicate that although most of the erosion exposing the rock strata (denudation) occurred there in Late Jurassic/Early Cretaceous times, a significant component of denudation is permissible in the Cenozoic. In contrast, most of the rock uplift and denudation in the Transantarctic Mountains occurred in the

Cenozoic. We hope to shed some light on this controversy and on the timing of uplift and denudation at key localities, as well as on the patterns of uplift and denudation along the west antarctic rift shoulder, through a series of thermochronologic studies.

Our objectives are:

• to determine the extent and timing of denudation of the west antarctic rift flank;

• to further delineate patterns of uplift and denudation along the length of the Transantarctic Mountains;

• to document the thermal history of basement rocks from different crustal blocks; and

• to compare and contrast the thermal histories of East Antarctica (Transantarctic Mountains) and West Antarctica (Ellsworth-Whitmore Mountains crustal block).

We will address these objectives using thermochronologic techniques, specifically apatite fission track thermochronology and argon-40/argon-39 (40Ar/39Ar) thermochronology. All laboratory work will be undertaken at the Center for Thermochronology and Noble Gas Studies at the University of Arizona. The application of low-temperature thermochronologic methods has made fundamental contributions to our understanding of the uplift and denudation history of the Transantarctic Mountains and the Ellsworth Mountains.

Data that integrates both fission track and 40Ar/39Ar thermochronology will lead to a better understanding of the geological evolution of a continent with a number of mountain ranges and two large crustal plates. We know that the west antarctic rift created the Transantarctic Mountains during the Cenozoic. But did that same event curve into West Antarctica along the northwest flank of the Ellsworth-Whitmore Mountains? Or were the plates aligned such that, instead, it ripped eastward across most of Antarctica? Of such scientific distinctions is the history of the Earth constructed. (GO-059-O)

(GO-065-O)
Global climate change and evolutionary ecology of antarctic mollusks in the Late Eocene.
Richard B. Aronson, Dauphin Island Sea Lab

The Eocene epoch ran from about 65 to 55 million years ago, when evidence suggests that global climate change had an important influence in Antarctica. Formerly cool-temperate conditions in the region began to shift to the polar climate that has persisted until now. As temperatures dropped, shallow-water, antarctic marine communities began to change, and these effects are still evident in the peculiar ecological relationships observed among species living in modern antarctic communities.

In particular this Late Eocene cooling reduced the abundance of fish and crabs, which in turn reduced skeleton-crushing predation on invertebrates. Thus dense populations of ophiuroids (brittlestars) and crinoids (sea lilies) began to appear in shallow-water settings. These low-predation communities appear as dense fossil echinoderm assemblages in the upper portion of the Late Eocene La Meseta Formation on Seymour Island, off the Antarctic Peninsula. Dense ophiuroid and crinoid populations remain common in shallow-water habitats in Antarctica today, but at temperate and tropical latitudes they have generally been eliminated by predators. The persistence in Antarctica of these populations is an important ecological legacy of climatic cooling in the Eocene.

For the antarctic ophiuroids and crinoids, the influence of declining predation is now well documented; but the effects of cooling on the more abundant mollusks have not been investigated. Our project will examine the evolutionary ecology of gastropods (snails) and bivalves (clams) in this same Late Eocene time frame. Based on the predicted responses of mollusks to declining temperature and changing levels of predation, we will test a series of hypotheses in the La Meseta Formation on Seymour Island. The shapes of gastropod shells, the activities of gastropods that prey on other mollusks by drilling holes in their shells, and the effects of predation on the thickness of mollusk shells, should have changed significantly through late Eocene time.

Since Seymour Island contains the only antarctic fossil outcrops readily accessible from this crucial period in Earth's history, such investigations provide a unique opportunity to learn how climate change may have affected antarctic marine communities. In practical terms, models suggest that global climate change - over the next few decades to centuries - is predicted to increase upwelling in some temperate coastal regions, which would lower water temperatures. Recent ecological evidence suggests this could lower predation in those areas. Our model

of the La Meseta faunas' response to global cooling in the late Eocene should enhance understanding of the dynamic structure of modern benthic communities. (GO-065-O)

(GO-066-O)

Formation of the Dry Valleys, Antarctica: Linking thermochronometric (U-Th/He) and cosmogenic constraints on landscape development.

Martha House and Kenneth Farley, California Institute of Technology, and John Encarnacion, St. Louis University.

The formation of mountains (known as orogenesis) occurs over time. Pinpointing the age of sequential episodes helps to elucidate how the Earth's crust was deformed, and to shed light on the dynamics between climate and forming mountains. But accurate dating, especially of older events, remains elusive, because erosion over time changes and compromises the geomorphologic expressions and the sedimentation record. The higher the elevation, the older the originating event, but the more likely there is to have been erosion. Other geochemical tools - such as surface-exposure dating - have been developed for tracking erosion and landform development, but these also provide information on only the most recent history (less than 1 million years). Thus the much greater age of many mountain belts, and their complex internal geometry, present a challenge to scientists trying to understand their temporal and physiographic/tectonic evolution.

One technique for closing this gap of knowledge - apatite fission track thermochronometry - rests on a basic scientific assumption. As rock moves upward away from the Earth's internal molten processes, it cools. Scientists use cooling data to measure both exhumation (movement of a rock upward with respect to the earth's surface) and bedrock uplift (movement of the rock upward with respect to the geoid, or sea-level). These data provide input for landscape-evolution models, with episodes of rapid cooling attributed to the topographic rise of mountain belts (even though some scientists have shown that such a correlation does not always hold).

Such models should be improved by combining low-temperature thermochronometry with surface-exposure dating. The McMurdo Dry Valleys region of the Transantarctic Mountains is an ideal place for such an exercise; many of the modern land surfaces in the region appear to be upwards of 15 million years old, which means there has been comparably little erosion since the mid-Miocene. The apatite fission tracks indicate some rocks in the McMurdo Dry Valleys cooled through approximately 105°C as recently as about 45 million years. This leaves a gap of about 30 million years where our knowledge of the evolution of this mountain range must be inferred very roughly.

This project will focus on this gap by employing a combination of recently developed methods. The newly developed apatite-helium (U-Th/He) thermochronometer (which improves temperature sensitivity to 70°C) can constrain events during this period and will also provide a more fine-grained r ecord of the time sequence when topographic relief occurred. By combining these thermochronometric indications of river valley incision with cosmic-ray exposure ages, we can develop more details of the geomorphologic evolution of the McMurdo Dry Valleys region. In particular, a more accurate formation age for the McMurdo Dry Valleys will constrain the period for the orogenesis of the Transantarctic Mountains. More generally, our work should have implications for the geodynamic evolution of the region and will contribute to the debate over Cenozoic changes due to paleoclimate that would have influenced the growth and stability of the East Antarctic Ice Sheet. (GO-066-O)

(GO-071-O)

Late Cretaceous and Cenozoic reconstructions of the southwest Pacific.

Steven C. Cande, Scripps Institution of Oceanography.

Crustal plate motion is never as predictable as earth scientists would like - witness the devastation wrought by unpredicted earthquakes. In Antarctica, there is controversy regarding a possible missing plate boundary, as well as tectonic uncertainties in the motion between East and West Antarctica; in particular, questions about the relative drift between major hotspot groups. The plates of the Southwest Pacific region are rotational, so that earthquakes are relatively rare. Still, the models that describe the motion of the Pacific, Antarctic, and Australian plates - and the continental fragments of New Zealand, West Antarctica, Iselin Bank, East Antarctica, and Australia - could be improved. This research focuses on these models.

Previous work has documented mid-Tertiary seafloor spreading in a NNW-striking direction, producing magnetic anomalies between East and West Antarctica. This would explain the approximate 150 kilometer-opening of the Adare Trough, north of the Ross Sea. The hypothesized motion, however, is insufficient to resolve the apparent

discrepancy between the actual plate motions and those that would follow from the assumption that the hotspots were fixed.

The motion between East and West Antarctica indicates a very small rotation. Thus, scientists would like to develop models of finite plate rotation in this area to a high degree of accuracy, particularly for older times. This goal is now attainable - using data sets compiled by Japanese and Italian scientists on recent cruises in the region - if our project is able to develop and confirm certain crucial data. By collecting new marine geophysical data on selected transits of the R/V Nathaniel B. Palmer, we hope to

o improve the rotation model for mid-Tertiary extension between East and West Antarctica by directly considering the plate boundary between the Pacific and Australia plates in the calculation of Australia-West Antarctica motion;

• improve the reconstructions for Late Cretaceous and Early Tertiary times by including new constraints on several boundaries not previously used in the reconstructions;

• address the issue of the fixed position of global hotspots through the implications of new rotation models; and,

• re-examine the geophysical data from the Western Ross Sea embayment, in light of a model for substantial mid-Cenozoic extension. (GO-071-O)

(GO-073-O)
Quarternary glacial history and paleoenvironments of the East Antarctic margin.
Amy Leventer, Colgate University.

What was Antarctica like long ago? Geologists refer to the last 11,000 years as the Holocene epoch and have found sedimentary records in the Antarctic Peninsula and Ross Sea (West Antarctica) that suggest a pattern throughout much of this time. Primary biological production, as well as the extent of sea-ice, are seen to vary, on scales of hundreds and thousands of years. How far into the Southern Ocean the antarctic ice sheet extends - as sea-ice forms and retreats seasonally - is to some extent a function of solar energy. Scientists also know that the ice sheet has a central role in global oceanic and atmospheric systems.

This set of theories about Antarctica rest primarily on the study of deposits taken from the west antarctic ridge. In this project, we will focus on a 500 km stretch of the east antarctic margin, including Prydz Bay and the MacRobertson Shelf. Glacial marine sediments present a challenge to researchers trying to reconstruct Holocene paleoenvironments. Scientists from Australia and the United States will use detailed sedimentologic, geochemical, micropaleontological, and paleomagnetic techniques; a multi-faceted approach necessary to extracting reliable paleoenvironmental data. Operating from the research ship Nathaniel B. Palmer, we will conduct high-resolution seismic mapping and coring of sediments deposited in inner shelf depressions. Chronological work performed on the data extracted from these samples should determine the timing and duration of previous periods of glacial marine sedimentation on the east antarctic margin during the late Pleistocene.

These high-resolution Holocene records from the east antarctic margin, supplemented with the data already developed from West Antarctica, will permit us to develop a circum-antarctic suite of data regarding the response of southern glacial and oceanographic systems to Late Quaternary climate change. These results are expected to significantly advance our understanding of the behavior of the antarctic ice-sheet and ocean system in the recent geologic past. (G-O73-O)

(GO-073-A)
Bio-optical properties of Southern Ocean waters.
Kevin Arrigo, Stanford University.

In recent years, more ocean-color satellites have come on line, but these instrument systems function amidst a complex set of operating assumptions. High-quality bio-optical data is needed to calibrate the sensors in this equipment, and algorithms must be developed and validated to make the systems efficiently operational. Unfortunately, the waters in such high-latitude, remote and often inaccessible regions of the Earth present challenges to the gathering of good bio-optical data.

During a 60-day cruise on the R/V Nathaniel B. Palmer (the same cruise as project GO-073-O), we will cover a

large area in the Southern Ocean, from Australia to Prydz Bay to South Africa. We expect to encounter many different water types and masses with different bio-optical properties. By deploying multi-wavelength radiometers at each daylight station and additionally at one-degree latitudes, we expect to collect a grid of baseline data to develop a useful profile of the water column. (GO-073-A)

(GO-078-O)
Dry valleys seismograph project.
Kent Anderson and Carl Mulcahy, U.S. Geological Survey.

One recurrent issue in seismography is noise; that is, background phenomena that can interfere with clear and precise readings. The Dry Valleys Seismograph 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 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 Newell and Crater Hill, and received eventually by the recording computer at the Hatherton Laboratory at Scott Base, where a backup archive is created.

These data will eventually reach the international seismological community; from Hatheton they pass along a point-to-point protocol link to the Internet at McMurdo Station and thence to the Albuquerque Seismological Laboratory for general distribution. This data set has beautifully complemented the data from other seismic stations operated by the Albuquerque Seismological Laboratory at Amundsen-Scott South Pole Station, Palmer Station, and Casey, an Australian base. (GO-078-O)

(GO-081-O)
Mount Erebus Volcano Observatory: Gas emissions and seismic studies.
Philip R. Kyle and Richard C. Aster, New Mexico Institute of Mining & Technology.

Mount Erebus on Ross Island is Antarctica's most active volcano; also the only one with a persistent convecting lake of molten, alkali-rich phonolitic magma in its summit crater. This makes Erebus one of the few volcanoes on Earth with nearly continuous, small explosive activity and continuous internal earthquake (seismic) activity. As such, it provides the ideal natural laboratory to study these phenomena: How gas is given off by magma, and the seismic activity that results from a convecting magma conduit.

This project entails a combination of seismic studies and gas emission rate measurements, designed to elucidate the nature and dynamics of the magmatic plumbing system, as well as eruptions and degassing from the lava lake.

The gas studies will provide some of the first data available on carbon-dioxide degassing from a highly alkalic magma system. They should also help to evaluate how much lead from Mount Erebus (relative to lead released by marine aerosols) gets into the snow on the East Antarctic Ice Sheet, and thus shed light on hypotheses about the anthropogenic origins of lead. Further goals of the gas studies are to

• examine the role of Erebus as a source of gas and aerosols to the antarctic environment;

• understand the role of volcanism as a source of carbon-dioxide emissions to the atmosphere, especially for a highly alkalic magma;

• understand the evolution of the main volatile substances (water vapor, carbon-dioxide, total sulfur, fluorine and chlorine) in the Erebus magmatic system, as well as their role in the eruptive behavior of Erebus; and

• correlate the nature of the gas emissions with the observed seismic activity.

The seismic studies of the volcano will add a permanent broadband seismic station to the array and update the present data acquisition system. We also plan to expand development of the current software to register automatic and precise timing of when and where earthquakes occur.

Deformation studies to monitor the movement of magma inside the volcano will be made using GPS campaign-style geodetic measurements, supplemented by an array of permanent continuous operating GPS stations. Two new stations in the 2000-2001 field season will make the array a set of 3, single frequency, L1 stations and a dual frequency station. The latter station and its associated meteorological package will become part of the global SuomiNet array, providing real-time, atmospheric, precipitable water vapor measurements and other geodetic and meteorological information.

The resultant data should enhance the collection of earthquakes that we are using in a computer model of the interior of the volcano, as well as provide a tool scientists can use for volcano surveillance, eruption monitoring, and for detecting subtle changes in the internal behavior of volcanoes. The broadband data will support a detailed study of the explosion mechanism, especially the very-long-period signals they emit. It should also help us detect temporal and spatial variability in earthquake mechanisms, which in turn might provide more insights into how variations in gas emissions may be implicated. (GO-081-O)

(GO-082-O)
Global positioning system measurements of crustal motion in Antarctica.
Carol Raymond, Jet Propulsion Laboratory.

Geodesy is the mathematically-grounded science of using measurements to map the positions and shapes of the Earth's surface features. The satellite-based global positioning system (GPS) has revolutionized the techniques and enhanced the accuracy of geodetic work. Work on this project has established a geodetic network in the Transantarctic Mountains of Antarctica to measure both vertical and horizontal crustal velocities.

The vertical crustal velocities measured by GPS reflect the viscoelastic response of the solid Earth to antarctic deglaciation. That data will enable us to evaluate discrepancies between models that describe when antarctic deglaciation probably occurred - either in Late Pleistocene/Early Holocene (about 10,000 years ago) or more recently, in the Late Holocene. These data will also constrain the length of time over which the antarctic ice sheet disintegrated and should provide a reconstruction of its changes. If antarcitc deglaciation occurred later (in the mid-Holocene) we would expect this new, high-precision GPS geodetic system to detect a specific pattern of uplift, near the Transantarctic Mountains.

Horizontal deformation induced by rebound can also be measured; these data help constrain models of present-day changes in antarctic ice mass by tracking how the lithosphere is deformed by ongoing glacial loading and unloading. We are predicting that horizontal component (the lithospheric response to ongoing ice-mass changes) to be an order of magnitude smaller than the vertical (the viscoelastic response to late Pleistocene/Holocene deglaciation). Conversely, that predicted rebound signal should be much larger than the associated tectonic uplift rates. Also, our baseline measurements will cross known fault lines in the Transantarctic Mountains, and may capture co-seismic motion, should an aseismic slip or an earthquake occur.

This autonomous GPS station (AGS) network sends daily data reports to McMurdo Station, and has been designed as a permanent installation that will continue to monitor motion in the region. Advanced processing techniques - such as orbit modeling, troposphere correction, ionosphere correction, and extraction of annual and seasonal solid Earth and ocean tidal signals - have been developed to refine the accuracy of these crustal velocity measurements, especially for the vertical component. (GO-082-O)

(GO-089-O)
TAMSEIS: A broadband seismic experiment to investigate deep continental structure across the east-west antarctic boundary.
Douglas Wiens, Washington University.

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

This project will collect 3 years worth of seismic measurements - using three different arrays and a total of 44 seismic stations - all geared to evaluating geodynamic models of the evolution of Antarctica that rely on data about the crust and upper mantle. To analyze the data, we will use a variety of proven modeling techniques, including body- and surface-wave tomography, receiver function inversion, and shear-wave splitting analysis.

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

Another focus will be the structure of the east antarctic craton, the highest ice block in the world. Was this anomalous elevation a prime driver in the onset of glaciation there? More to the point, how did it arise? Proposed models include isostatic uplift from thickened crust, anomalously depleted upper mantle, and thermally modified upper mantle, as well as dynamic uplift. How far the old continental lithosphere extends is also uncertain. In particular, it is unknown whether the old lithosphere extends to the western edge of East Antarctica beneath the crustal rocks deformed during the Ross Orogeny (formation).

When completed and analyzed, this comprehensive set of data and theory testing will enable new maps of the variation in crustal thickness, upper mantle structure, anisotropy, and mantle discontinuity topography across the boundary of East and West Antarctica, providing a much enhanced foundation for understanding the geodynamics of the antarctic. (GO-089-O)

(GO-090-P and GO-090-S)
Logistics support for global seismographic network stations at the South Pole and Palmer Stations.
Rhett Butler, Incorporated Research Institution for Seismology.

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

IRIS is a consortium of universities with research and educational programs in seismology. Ninety-seven universities are currently members, including nearly all U.S. universities that run seismological research programs. Since 1986, IRIS (through a cooperative agreement with the National Science Foundation and in cooperation with the U.S. Geological Survey) has developed and installed the Global Seismographic Network (GSN). The GSN now has about about 135 broadband, digital, high-dynamic-range, seismographic stations around the world, all with real-time communications.

The GSN seismic equipment at Amundsen-Scott South Pole Station and at Palmer Station, Antarctica, were installed jointly by IRIS and ISGS, who together continue to operate and maintain them. The GSN sites in Antarctica are vital to seismic studies of Antarctica and the Southern Hemisphere. The state-of-the-art seismic instrumentation is an intrinsic component of the National Science Foundation effort to advance seismology and Earth science globally. (GO-090-P and GO-091-S)

(GO-093-O)
Paleoceanography of Eocene decapod-rich rocks in Antarctica and southern South America.
Rodney A. Feldman, Kent State University.

Climate is intimately associated with many of the variations found in life on Earth, and nowhere is this more evident than at the extreme high latitudes. Thus fossils often contain clues to paleoclimate and, in turn, to other aspects of peleoecology. Certain fossil mollusks known to contain decapod crustaceans (crabs and lobsters) can be found in Eocene rocks in Antarctica and southern South America. In this project we are targeting the sites rich with these rocks, because the decapods provide a unique, diverse database on biogeographic distribution throughout the high southern latitudes. These mollusk fossils permit us to estimate proxy seasonal temperature at the time - and in the precise habitat - in which the decapods lived, by determining their oxygen isotopic compositions (del-18-O values).

We also hope to refine global paleoceanographic models, and to run a series of oceanic and atmospheric circulation models. The water temperature data derived from analysis of fossil material will be used to select the most reasonable atmospheric and oceanic circulation models, and to evaluate the effects of various gateways to circulation in the antarctic region. Our work should therefore provide two important results. First, detailed information on seasonal variation in water temperature in near-shore environments of the high southern latitudes. Second, refinements on the paleoecological interpretations of the decapods that will be essential for comparing related fossil and extant species. This kind of study provides a unique opportunity for modelers to develop efficient ways to use specified seasonal sea-surface temperature data developed by paleontology. During this project, we will collaborate not only with colleagues at Woods Hole Oceanographic Institution, but also with scientists from the Instituto Antartico Argentino. (GO-093-O)

(GO-094-O)
Permian-Triassic basin history of southern Victoria Land and the Darwin Mountains.
John Isbell, University of Wisconsin.

The Earth is believed to have once consisted of a single land mass, a supercontinent called Pangea, composed of all the continental crust that now makes up the various continental and island surfaces. As tectonic forces began to break up the land mass about 150 million years ago, Gondwanaland was born (as was Laurasia); its southern portion would eventually become Antarctica. Before this split, around 250 million years ago, geologic features extended across what would become separate continents. One of the largest depositional basins was the "Gondwanide foredeep," more than 10,000 kilometers long, extending across the land that would become southern South America, South Africa, the Falkland Islands, Antarctica, and Australia.

Antarctica's central location in this ancient assemblage, between South Africa and Australia, make southern Victoria Land and the Darwin Mountains key areas for testing paleogeographic and paleoclimatic models. Such work will further constrain the paleoenvironmental, tectonic, biotic, and paleogeographic histories of southern Pangea, and provide a unique polar view of the world during an icehouse to greenhouse transition.

Our project is a collaborative sedimentological, palynological, and paleomagnetic study of Permian and Lower Triassic strata in these areas. We will recover paleomagnetic signatures from Permian and Triassic petrified wood, silicified peat, and coal, which were cemented during early diagenesis (the process of undergoing chemical, bioilogical and physical change until metamorphism is reached). Paleopalynological analyses - the study of fossilized microscopic organisms - will provide time control for the succession.

We hope to be able to

• determine a Late Paleozoic (as Gondwanaland drifted over the South pole) glacial/deglaciation history for southern Victoria Land and the Darwin Mountains,

• document Permian strata to better understand the environments of high-latitude fluvial coal-bearing deposits,

• document Triassic lithofacies to better understand high-latitude conditions during the Early-to-Middle Triassic "coal gap" interval,

• provide a well-constrained stratigraphic framework for the Permian-to-Lower Triassic succession,

• test the diachronous and inversion tectonic models for the Panthalassan Margin of southwestern Pangea, and

• construct better paleogeographic models for Gondwanaland by obtaining new Gondwanaland reference poles for the Permian and Triassic. (GO-094-O)

(GO-97-O)
Acquisition and operation of broadband seismograph equipment at Chilean bases in the Antarctic Peninsula region
Douglas Wiens and Gideon P Smith, Washington University.

The present-day tectonics and seismological structure of the Antarctic Peninsula and Scotia Plate region are among the most poorly understood of any location in the world. This region offers a unique and complex geodynamic setting, as illustrated by recent changes in the pattern of volcanism and other tectonic activity. We constitute the U.S. component of an international effort, using a large-scale deployment of broadband

seismographs to study the seismotectonics and seismic structure of these regions.

During the 1996-97 field season, broadband seismographs were installed at strategic locations; one on the tip of South America and three more in the South Shetland Islands and on the Antarctic Peninsula. In succeeding years, seven more were added to the network, which has yielded excellent data and some suggestive early results. As the project continues, cumulative data should enhance understanding of the seismicity of the South Shetland Trench, an unusual subduction zone where young lithosphere is subducting very slowly.

The continuing collaboration between Washington University and the Universidad de Chile will contribute important seismological data to the IRIS data center, as well as to other international seismological collaborators. Such mutual exchanges with other national antarctic seismology research programs will accumulate data from a variety of other proprietary broadband stations in the region.

These data will support seismic studies of the upper mantle velocity structure of several complicated tectonic regions in the area, including the South Shetland subduction zone, the Bransfield backarc rift, and diffuse plate boundaries in the areas around Patagonia, the Drake Passage, and along the South Scotia Ridge. Such studies should provide important constraints on the crustal structure beneath the stations; in turn improved structural models will help to pinpoint better locations for future instruments. (GO-97-O)

(GO-099-O)
Neogene-Quaternary volcanic alignments in the Transantarctic Mountains-Ross Sea region.
Terry J. Wilson, Ohio State University.

Plate tectonics has become the reigning paradigm to explain both the evolution and the current dynamics of the Earth. But in addition to the more dramatic movement of the Earth's crustal plates, the crust also contains buoyancy forces that contribute to basic calculations, and distinguishing between these and plate boundary forces is important. The "Antarctic Stress Map Project" (ASMAP) initially will obtain data on these forces from Neogene/Quaternary volcanic vent alignments within the Transantarctic Mountains and adjacent West Antarctic rift system in the Ross Sea region.

We will map the distribution, alignments, and morphologies of volcanic cones and other volcanic features using high-resolution satellite imagery (SPOT, SAR) and aerial photographs. Field tests will assess any structural associations that we can find between faults and volcanic vent alignments. These data will be coupled with existing chronological and petrological information on the volcanic rocks, as well as other dike and fault data, to interpret alignments and to define neotectonic stress states throughout this sector of Antarctica.

We will be able to analyze the stress regime in the context of other ongoing studies of contemporary tectonics and paleo-kinematics of the Transantarctic Mountains rift flank and adjacent rift system. This new stress field data, derived from the unique antarctic setting, will help to constrain the role of plate-boundary and crustal buoyancy forces in actively deforming intraplate regions. (GO-099-O)

(GO-116-O)
Geology and geochronology of the Byrd Glacier discontinuity, Antarctica-A pilot study.
Edmund Stump, Arizona State University.

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

This project continues the probe into this area and structure, by mapping the Byrd Group (Early Cambrian Shackleton Limestone and younger Douglas Conglomerate) for structure, and trying to develop the basis for understanding its kinematic evolution. Another target of interest is Mt. Madison; its geochronology and structural and metamorphic history should be revealed from samples of outcropping, amphibolite-grade metamorphic rocks (Selbourne Marble).

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

Douglas Conglomerate.

All rock samples will be returned to for further study. Structural data will be reduced at Arizona State University; metamorphic studies of the Selbourne Marble will be conducted at the University of Siena; and isotopic studies at both the Ohio State University (40Ar/39Ar, Sm-Nd) and the University of Kansas (U-Pb). (GO-116-O)

(GO-180-O)
Antarctic network of unattended broadband integrated seismometers (ANUBIS).
Sridhar Anandakrishnan, University of Alabama.

Despite much attention in recent years, the structure and dynamics of the antarctic crust and the composition and geometry of the mantle are still poorly understood. Seismology remains the primary method for studying these structures, as well as processes in the Earth's deeper asthenosphere, but Antarctica lags behind in the effort to improve global seismic imaging and tomography. On this huge continent, there are only eight broadband seismic observatories. Except for the installation at South Pole, those stations are along the margins of the continent and none are in West Antarctica. By contrast, there are 200 permanent stations worldwide in the Federation of Digital Seismograph Networks (FDSN), and some 1,000 more, in national networks not yet integrated into the FDSN.

We have developed a passive seismic network of 11 long-term broadband seismic stations on the continent itself. Because 98 percent of the continent is ice covered, these stations will be installed at the surface of the ice sheet. The body-wave data thus recorded from regional and teleseismic earthquakes can be analyzed at each station for local crustal thickness, lamination, Poisson's ratio (a measure of crustal composition), crust and mantle anisotropy (a measure of current and former stress regimes), and identification of rift zones and crustal block boundaries. In addition, the data from all stations (including the existing peripheral ones) can be used for seismic tomographic analysis to detail lateral variations in these properties. Four of the stations will be installed at existing automatic geophysical observatory sites (in East Antarctica), which will provide heat and power for the data loggers. The remaining seven stations will be established in West Antarctica and will be powered and heated by wind turbines during the austral winter. (GO-180-O)

(GO-295-O)
High precision GPS survey support.
Bjorn Johns, University NAVSTAR Consortium (UNAVCO).

UNAVCO provides year-round support for scientific applications of the Global Positioning System (GPS) to the National Science Foundation's Office of Polar Programs (NSF/OPP) Antarctic Program. This support includes pre-season planning, field support, and post-season follow-up, as well as development work for supporting new applications. UNAVCO maintains a "satellite" facility at McMurdo Station during the austral summer research season, providing a full range of support services including geodetic GPS equipment, training, project planning, field support, technical consultation, data processing, and data archiving.

UNAVCO also operates a community differential GPS (DGPS) base station that covers McMurdo Sound and Taylor Valley, provides maintenance support to the MCM4 continuous GPS station as contractual support to the NASA GPS Global Network (GGN), and supports remote continuous GPS stations for scientific investigations.

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

(GO-306-O)
The young marginal basin as a key to understanding the rift-drift transition and andean orogenesis: OBS refraction profiling for crustal structure in Bransfield Strait.
James A Austin, Gail L Christeson, Ian W Dalziel, and Yosio Nakamura; U. of Texas Austin.

Bransfield Strait (in the northern Antarctic Peninsula) is one of a small number of modern basins that may be critical for understanding ancient mountain-building processes. The Strait is an actively-extending marginal basin in the far southeast Pacific, situated in an inactive volcanic arc between the Antarctic Peninsula and the

South Shetland Islands. Widespread crustal extension, accompanied by volcanism along the Strait's axis, may be associated with slow underthrusting of oceanic crust at the South Shetland Trench.

Some 140 million years ago (during the Jurassic/Early Cretaceous), similar "back-arc" extension is known to have occurred along the entire Pacific margin of the supercontinent known as Gondwanaland. This area has become western South America and West Antarctica. Then, some 100 million years ago, mid-Cretaceous deformation of these basins initiated the uplift that produced the Andes. Thus, scientists believe that elucidating the deep structure and evolution of Bransfield rift could provide a model of crustal precursor activity that will more fully describe the early evolution of this globally important mountain chain.

Years of international earth sciences research in Bransfield Strait have produced consensus on important aspects of its geologic environment. It is a young rift (probably about 4 million years old) in pre-existing Antarctic Peninsula crust; continued stretching of this crust results in complex fault patterns and associated volcanism. The volcanism, high heat flow, and mapped crustal trends are all consistent with the basin's continuing evolution as a rift. The volcanism occurring there is recent and continues to occur along a "neovolcanic" zone centralized along the basin's axis (another point of consensus). Multichannel seismic data collected aboard R/V Maurice Ewing in 1991 illustrate the following basin-wide characteristics of Bransfield Strait -

• widespread extension and faulting,

• the rise of crustal diapirs or domes associated with flower-shaped normal-fault structures, and

• a complicated system of fault-bounded segments across the strike.

The geophysical evidence also suggests northeast-to-southwest propagation of the rift, with initial crustal inflation/doming followed by deflation/subsidence, volcanism, and extension along normal faults.

Although Bransfield Strait exhibits geophysical and geologic evidence for extension and volcanism, continental crust fragmentation in this "back-arc" basin is still underway and has yet to generate ocean crust. Instead, the Bransfield rift lies near the critical area that marks the transition from intracontinental rifting to seafloor-spreading. Because the basin is asymmetric and appears to manifest shallow intracrustal detachment faulting, it is near the edge of the spectrum of models that explain how continents break up. As such, the region is an excellent "natural lab" for studying the diverse processes that form continental margins. Thus a couple of significant questions arise: What stage of evolution is the Bransfield rift experiencing? Does it provide a basis for constructing models of Andean mountain-building? The answers are to be found by defining Bransfield rift's deep crustal structure. Our project begins this task by collecting and analyzing high-quality, high-density, ocean-bottom seismometer (OBS) profiles, both along and across the Strait's strike. The scientific objectives are to

• develop a detailed seismic velocity model for this rift;

• calibrate velocity structure and crustal thickness changes associated with presumed northeast-to-southwest rift propagation, as deduced from the multichannel seismic interpretations;

• document the degree to which deep velocity structure corresponds to along- and across-strike crustal segmentation; and

• assess structural relationships between the South Shetland Islands "arc" and Bransfield rift.

The OBS data we expect to collect will also be integrated with other geophysical explorations of the region (such as both Ewing profiles). This piece of the puzzle will complement ongoing deep seismic analysis of Antarctic Peninsula crust to the southwest, as well as additional OBS monitoring for deep earthquakes. Ultimately, the complex plate tectonic evolution of this region may be clarified. (GO-306-O)

(GS-098-A)

Understanding the boundary conditions of the Lake Vostok evnironmen: A site survey for future work.

Robin Bell, Lamont-Doherty Earth Observatory.

Antarctica is often referred to as a hostile environment, but many scientists welcome the unusual and extreme

conditions to be found there as a pathway to key insights into the development of Earth and other bodies in the solar system. Looking beneath the ice, for example, can reveal lakes with oligotrophic environments - ecosystems deficient in plant nutrients, and which have extremely high levels of dissolved oxygen. Study of such subglacial systems could reveal:

• the processes associated with rapid evolutionary radiation after the extensive Neoproterozoic glaciations;

• the overall carbon cycle through glacial and interglacial periods; and

• the possible adaptations organisms may require to thrive in environments like Europa, the ice- covered moon of Jupiter.

Antarctica's ice sheets, several kilometers thick, sit atop many of these subglacial lakes - over 70 have been identified thus far. Of these, Lake Vostok is large enough to be clearly seen from space with satellite altimetry. Though about the area of Lake Ontario, Vostok has much more water, with depths up to 600 meters. The overlying ice sheet is a kind of conveyer belt, continually delivering new water, nutrients, gas hydrates, sediments, and microbes as it flows across the lake. These lakes are not abiotic and sterile as might be presumed but generally support mosses, algae and bacteria.

This project undertakes a kind of frontier exploration by air of Lake Vostok; we hope to determine the fundamental boundary conditions for this subglacial lake as an essential first step toward understanding the physical processes to be found within its waters. We will conduct an aerogeophysical survey, with gravity, magnetic, laser-altimetry, and ice-penetrating radar studies, refining and testing methods first in other lakes. Then we expect to compile a basic set of ice-surface elevation, subglacial topography, gravity and magnetic anomaly maps for the water cavity; and also to estimate the thickness of the sediments beneath the lake from magnetic data.

These maps will become tools to distinguish between two competing models for the geologic origin of the lake - either, the lake is an active tectonic rift, like Lake Baikal; or the lake is the result of glacial scouring. Any extensional rift can be easily identified with our aerogeophysical survey.

When we interpret the airborne geophysical survey with geologic models, we should have the first geological constraints of the interior of the east antarctic continent based on modern data. And biology will come into play as well, since the underlying geology will influence the ecosystem within the lake. For example, one of the critical issues for the subglacial ecosystem of Lake Vostok will be the flux of nutrients. Based on the distance between distinctive internal layers observed on the radar data, we should be able to estimate regions of freezing and melting. Such basic boundary conditions are crucial as a guide for any future international effort to explore the lake in situ. And these results will also improve our understanding of east antarctic geologic structures more generally. (GS-098-A)

(GO-098-O)

Support Office for Aerogeophysical Research (SOAR).

D.D. Blankenship, D.L. Morse, I.W.D. Dalziel and J.W. Holt. University of Texas at Austin.

Since 1994, the Support Office for Aerogeophysical Research (SOAR) has operated and maintained an aerogeophysical instrument package (aboard a de Havilland Twin Otter aircraft) that consists of an ice-penetrating radar sounder, a laser altimeter, a gravimeter and a magnetometer. All are tightly integrated with one another, as well as with the aircraft's avionics and power packages. In addition, we maintain an array of aircraft and ground-based GPS receivers to support kinematic differential positioning using carrier-phase observations. SOAR activities have included

• developing aerogeophysical research projects with NSF/OPP investigators;

• upgrading the aerogeophysical instrumentation package to accommodate new science projects and advances in technology;

• fielding this instrument package to accomplish SOAR-developed projects; and

• managing, reducing, and analyzing the acquired aerogeophysical data.

Since its inception, SOAR has flown 377 missions during six field campaigns over a six-year period, and surveyed approximately 200,000 line-kilometers over both East and West Antarctica. During the 2000-2001 austral summer the University of Texas at Austin will conduct an aerogeophysical campaign to accomplish surveys for two SOAR-developed projects -

• "Understanding the boundary conditions of the Lake Vostok environment: A site survey for future studies" (Bell and Studinger, LDEO, GS-098-A); and

• "Seismic investivation of the deep continental structure across the east-west antarctic boundary" (Weins, Washington University, and Anandakrishnan, University of Alabama, GO-089-O).

We will configure and test the survey aircraft in McMurdo, conduct survey flights from an NSF-supported base adjacent to the Lake Vostok drilling camp, and briefly occupy one or two remote bases on the East Antarctic Ice Sheet. We will reduce and distill these aerogeophysical data to produce profiles and maps of surface elevation, bed elevation, gravity and magnetic field intensity; these images will be used not only by these investigators, but will be published and released to national geophysical and glaciological data centers. (GS-098-O)

Pagodroma Group stratigraphy and paleontology: Participation in ANARE 2000- 2001.
David Harwood, University of Nebraska.

The East Antarctic Ice Sheet covers an enormous area, and contains Lambert Glacier, the largest glacier in the world. Over 40 kilometers wide and some 2500 meters deep in places, Lambert Glacier makes a 400-kilometer journey across East Antarctica past the Prince Charles Mountains. A part of this range, the Padroma Group, bears strata with marine fossils left behind in ancient times as the ice sheet drains into Prydz Bay some 300 kilometers away.

Russian and Australian scientists have been exploring this formation, and this investigator teams up with the Australian National Antarctic Research Expedition (ANARE) to try to use sedimentary deposits and other geological evidence to reconstruct how the ice sheet may have varied, especially over the last 20 million years (the Upper Tertiary epochs of the Miocene and the Pliocene are often referred to collectively as Neogene time). Ice sheet history is largely a record of advances and retreats. Marine microfossil data indicates open water at some point and therefore a relative retreat; advance of the ice sheet can be deduced from erosional and ice-grounding features evident in the strata.

Recent scientific debate about the Neogene history of antarctic glaciation use the age of the Sirius Group as a baseline, deduced from marine diatoms found in these strata. Preliminary results from coeval strata of the Pagodroma Group suggest there may have been significant variation in the volume of the East Antarctic Ice Sheet during the Late Neogene. Some have held that these marine microfossils could have been driven and delivered by the wind, but the abundance of diatoms in some intervals of the Pagodroma Group (up to 3.5 percent biogenic silica) that we expect to verify, and the stratigraphic position of in situ marine diatomaceous laminites should reaffirm the ice sheet retreat hypothesis.

Documenting such stratigraphy in the field and verifying the paleontological content in the laboratory are essential for placing the disparate deposits into a temporal and stratigraphic framework. Once done, this area's ice sheet history can then be correlated with other regions in the Prince Charles Mountains and also with other areas of Antarctica.

previous section | Table of Contents | next section

GLACIOLOGY

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

The Glaciology Program is concerned with the history and dynamics of the antarctic ice sheet; 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. Some current program objectives include:

• correlating antarctic climatic fluctuations (from ice core analysis) with data from arctic and lower-latitude ice cores;

• integrating the ice record with the terrestrial and marine records;

• investigating the physics of fast glacier flow with emphasis on processes at glacier beds;

• investigating ice-shelf stability; and

• identifying and quantifying the relationship between ice dynamics and climate change.

(II-163-O)
History and evolution of the West Antarctic Ice Sheet, Marie Byrd Land.
Charles F. Raymond, University of Washington.

The West Antarctic Ice Sheet (WAIS) has been an object of intense study for years, yet much remains to be specified about its evolution and dynamics - and therefore its possible futures. And, almost certainly, those potential futures are vital to the Earth's global climate and its ocean systems. Because its base consists of a series of archipelagos, the WAIS is a marine ice sheet. The Siple Coast Ice Stream system is a principal dynamic process by which the ice sheet drains ultimately into the Ross Sea. This seaward movement runs primarily through the Byrd subglacial trough, its flanks defined by the Ellsworth Mountains; such movement will usually leave behind tell-tale scars in the ice.

This project focuses on scar-like features in this region; some are well known, other margin scars are poorly constrained and need better dating, and still other as-yet unvisited scars require primary identification and exploration. To locate and map these features, we will use Advanced Very High Resolution Radiometer (AVHRR) and Radarsat image data, which will enable us to place them more exactly within the region's known topography.

Our goal for these initial data is a better description of the recent history of the Siple Coast glaciers and a more coherent account of the history of their configuration. For this, we will use low-frequency RES and high-frequency ground-penetrating radar (GPR) profiles to image internal layers and measure the depths of buried crevasses or disrupted layering. These depths, seen in the context of accumulation rates determined from shallow ice cores, will provide "shutdown" ages for when the margin features ceased actively flowing; that is, times after which they could not have formed. The field data should allow us to develop simple ice-flow models - for the margins and inter-ice stream ridges - during active shearing and after shutdown. One primary output of such models would be closer estimates than we have at present of the initial elevation of a given scar,

and the corresponding ice-stream elevation, at the time of shut down. (II-163-O)

(II-168-O)
West Antarctic Ice Sheet surface melting: Recognition, controls, and significance.
Richard Alley, Pennsylvania State University, State College, Pennsylvania.

Glaciologists work to discover the history of dynamic processes, such as ice melting and climate. For example, surface melting on polar ice sheets can be said to occur when the temperature increases above some threshold. With data on these parameters, scientists try to link observed patterns to detectable changes in the macro glacial terrain, in hopes of developing models that may predict the future of antarctic ice.

This project focuses on the critical Ross Ice Shelf and Siple Dome regions of West Antarctica. There are currently in use several different procedures to measure melting:

• space-based microwave sensors record the occurrence of liquid water or refrozen ice layers in the near surface;

• Automatic Weather Stations (AWS) record the high temperatures that are linked to development of liquid water; and

• snow-pit and ice-core studies show layers where re-freezing of sufficient liquid water has caused a visibly distinct layer to form.

Each approach is different, and they are presently not well calibrated to one another. We hope to determine how the different measures of melting may be correlated, using a combination of techniques - snow-pit, ice-core, AWS, remotely sensed data, and experiments on melt generation. By looking at a variety of records of past surface melting events in Antarctica, we hope to develop a context that will pinpoint especially high temperatures. With all of this data, we hope to develop a model for a seasonally resolved paleothermometry, based on a joint approach to measuring ice melt, as well as complementary paleothermometers such as borehole temperature, and isotopes. (II-168-O)

(II-171-O)
High precision borehole temperature measurements at Siple Dome, Antarctica, for paleoclimate reconstruction and ice dynamics studies.
Edwin D. Waddington and Gary D. Clow, University of Washington.

One of the procedures involved in ice coring is high-precision borehole temperature profiling. By constructing continuous temperature logs, scientists can develop data vital to paleoclimate reconstruction and ice dynamics studies. This project will work in the 1 kilometer (km) deep fluid-filled Siple Dome borehole and in several 160 meter-deep holes along a 20 km north-south transect across Siple Dome. The borehole temperature data will be used to:

• establish the conductive heat flux across the basal interface of the ice sheet;

• reconstruct the surface temperature history at Siple Dome, using geophysical inverse methods, known as borehole paleothermometry;

• constrain how thick the ice sheet was during the late Wisconsin, the magnitude of the Wisconsin/Holocene deglacial warming, and the background geothermal heat flux;

• determine calibration constants for the oxygen-isotope paleothermometer at Siple Dome in the past; and

• establish the spatial variability of surface temperature over the last century on the 20-km scale near the main drill site.

We expect the results to provide information needed to assess the short-term stability of the West Antarctic Ice Sheet; also to improve estimates of the pore close-off ages in the past, which should in turn provide a more accurate age-scale for the Siple Dome ice core. Ultimately, this work should enhance our understanding of the magnitude of past temperature changes at this significant southern hemisphere site. (II-171-O)

(IO-157-O)

Basal conditions of Ice Stream C and related borehole studies of antarctic ice stream mechanics.
Barclay Kamb and Hermann Engelhardt, California Institute of Technology

To obtain observational evidence for the cause of rapid flow of the great ice streams in the West Antarctic Ice Sheet, we have drilled a number of boreholes through ice streams B, C, and D. With them, we measure physical conditions and can sample materials at the base of the ice, where lubrication of the rapid ice-stream motion (approximately 1 meter per day) is thought to take place.

Ice Stream C poses a special problem; though it has nearly stopped streaming, the basal materials and physical conditions are scarcely if at all different from those in the other ice streams, yet those streams continue to move rapidly. This season we will return to Ice Stream C for more intensive study, trying to find what physical conditions there might differ enough from those in Ice Streams B and D to explain why C has virutally stopped, while B and D continue to stream. In particular, we need more accurate measurements of the basal water pressure and ice overburden pressure, as well as more accurate measurements of the strength of the basal till.

Using a new borehole video camera developed at JPL, we'll be able to observe the basal zone; including the ice structure, rock debris in basal ice, the basal water-conduit system in the gap between ice and till, and, finally, the basal till itself. These observations will be interpreted in terms of basal sliding, basal melting or freeze-on, and deformation of basal ice. We will study the variation in basal conditions in the transition from unfrozen to frozen bed along a traverse from Ice Stream C across the shear margin to Ridge BC, and along a traverse from UpC to a major "sticky area" about 10 kilometers north of UpC, where the flow velocity drops from about 20 meters per year to 3 meters per year. (IO-157-O)

(IO-162-O)
Climate studies using antarctic deep ice cores and firn air sampling.
Michael Bender, Princeton University.

Scientists probe many of the atmospheric processes in the high latitudes by exhuming evidence trapped in the ice. But before snow or surface condensation can become ice, it must make the transition through firn (that is, be subjected to its first summer of relative warmth and consequent melting) and then harden into glacier ice, impermeable to liquid water. In extreme cases, the conversion can take thousands of years, and the firn can extend to 100 meters. As it continues to be overlaid with new material, its depth and contents - revealed when scientists remove sediment and ice cores - will often tell a fairly detailed story about the chemistry in the atmosphere, and in some cases even the biology, that was current when the material first hit the surface. Here, for example, the variations evident in the total gas content in the Siple Dome ice core provides a framework to reconstruct aspects of the glacial history of West Antarctica during the last glacial maximum (less than 20,000 years ago).

This project demonstrates the wide range of such techniques, extracting information from antarctic ice cores, as well as from the overlying firn layer. How gas is trapped in ice in the first place is the subject of several ongoing studies. We will collaborate with other projects at Vostok, Siple Dome, and South Pole in probing the process of firn-air chemistry, and examining the concentration history and isotopic composition of greenhouse gases, oxygen, trace biogenic gases and trace anthropogenic gases during the last 100 years.

Another important result of such work is to better establish stratigraphic time-series records - essentially a map in time. The concentration of methane and certain oxygen-isotopes permit us to fairly precisely correlate these cores to others extracted in Greenland, as well as to other climatic records previously established. From these data, variations in the concentration and inter-hemispheric gradient of methane permit us to deduce changes in both continental climates and other biogeochemical processes dependant on atmospheric methane. (IO-162-O)

(IO-164-O)
Ice dynamics, the flow law, and vertical strain at Siple Dome.
William Harrison, University of Alaska, Fairbanks.

Ice flow near a divide such as Siple Dome is unique because it is predominantly vertical. As ice is deformed vertically, the vertical strain rate component is the dominant one and must be known to calibrate dynamic models of ice flow. This 5-year project - a collaboration among the Universities of Alaska, Washington, and UC-San Diego - is measuring the vertical strain rate (as a function of depth) at two sites on Siple Dome, Antarctica. We hope the results will help us to:

• develop a better analysis of the Siple Dome ice core than was possible from recent coring sites in central Greenland,

• interpret the shapes of radar-revealed internal layering as indicators of the accumulation patterns and dynamic history of Siple Dome over the past 10,000 years,

• interpret deep temperatures, and

• address a more fundamental problem, the appropriate form of the flow law of ice at low effective stress.

During the 1997-98 field season we installed two relatively new, high-resolution systems for measuring strain rate, using holes drilled with the CalTech hot water rig. The data are being collected in subsequent seasons. One system measures strain over a gauge length of 1 meter (m) by electrical methods, and the other over a length of 200 m by optical methods. The electrical system has the advantage of high spatial resolution but remains more subject to the effects of installation transients and therefor requires several years of data. (IO-164-O)

(IO-173-O)
West Antarctic Glaciology - V.
Robert Bindschadler, National Aeronautic and Space Administration.

The West Antarctic Ice Sheet (WAIS) shows patterns of ice flow that are not fully understood. One so-called surge hypothesis has been put forth to explain the basis of these patterns; to test it, two critical questions must be answered: "Are ice streams B, D, and E currently surging? And, "What has been the buttressing effect of an enlarging Crary Ice Rise on the flow of ice stream B?"

This 3-year project addresses these questions by collecting data from the air, from space and from the surface. Many of the studies of change in West Antarctica have been based on interpolations and the use of calculations with large uncertainties. We hope to take advantage of global positioning system (GPS) data to minimize field logistic requirements and collect more accurate data. Specifically, we plan to obtain direct measures of (what we expect to be) thinning in the upper portion of ice stream D; as well as repeated satellite image measurements at the heads of ice streams B, D, and E. Should these indicators demonstrate inland migration of the onset area, we may be able to verify sustained surging and strengthen the hypothesis.

We will also take new measurements of the thickness, surface elevation, and velocity of the ice, in order to compare the current buttressing impact (of Crary Ice Rise) on ice stream B's flow with data collected during the 1950s, 1970s, and 1980s. This part of the study should yield a time series of change in the WAIS over the last half century. (IO-173-O)

(IO-175-O)
Retreat history of the West Antarctic Ice Sheet, Marie Byrd Land.
John O. Stone, University of Washington

The Earth undergoes periodic glaciation (though the exact causes and period cycle times remain scientifically debatable) - where ice advances and appears in previously non-ice environments. The full cycle brings deglaciation, when the ice retreats. This phenomena is of vital interest for the West Antarctic Ice Sheet (WAIS), since a complete meltdown would add sufficient water to the world's oceans to raise global sea levels by tens of meters; further, the effect on the atmosphere would be dramatic, with a consequent impact on the weather. This is no theoretical scenario, because it appears that the WAIS (as opposed to its neighbor the East Antarctic Ice Sheet) disappeared completely during the last deglaciation.

In this project, we will focus on reconstructing the retreat history of the West Antarctic Ice Sheet (from the last glacial maximum to now) along a flowline through the Ford Ranges in northwest Marie Byrd Land. We plan to reconstruct the ice surface- and elevation-histories of the region, using cosmogenic-isotope exposure dating of moraine boulders and ice-abraded bedrock surfaces in the Clark [present ice surface: 1,200 meters (m)], Allegheny (800 m) and Sarnoff (200-400 m) Mountains.

By taking altitude transects at each of these three sites, we will date the thinning of the WAIS. This deglaciation chronology for Marie Byrd Land should help to resolve competing models of ice-sheet retreat (among which the

more prominent are the surge theory and the disintegration theory); the basic data set will also become available for testing numerical models of the WAIS throughout the glacial cycle. Further, such indicators of how much ice was where and when will help constrain scientists' models that require the past ice load in West Antarctica; these computations can help to predict the effect of glacio-isostatic motion on geodetic surveys being undertaken in the region. (IO-175-O)

(IO-190-O)
Iceberg drift in the near-shelf environment, Ross Ice Shelf, Antarctica.
Douglas MacAyeal, University of Chicago.

Icebergs command a lot of attention. The Titanic disaster at sea illustrates only one important reason. Such a massive piece of glaciology on the move is a process that scientists would like to have better models for. One theoretical benefit entails harnessing the extraordinary freshwater volume of large tabular icebergs - possibly even harvesting it - as a natural resource of potential economic value, especially for water-poor regions of the earth. And though feasibility studies of towing icebergs to such areas in need have largely been dismissed as science fiction, it is tantalizing to realize that tabular icebergs commonly travel thousands of miles as a result of natural processes. Might a better understanding of the behavior and dynamics of icebergs one day lead to such a boon of human economic and social value?

The recent calving of an extraordinarily large iceberg (dubbed B-15) from the Ross Ice Shelf presents a unique opportunity to measure the processes - such as wind-driven and thermohaline currents, tides, sea ice, and winds - that control the drift of large tabular icebergs. Such an event rarely occurs within the logistical reach of the U.S. Antarctic Program, and provides us with the opportunity to study iceberg drift, as well as other aspects of iceberg behavior that are associated with the long-term stability of the antarctic environment.

In this project, we plan to make direct measurements of the drift of icebergs B-15a, B-15b and a smaller iceberg (either B-16, B-17 or B-18, depending on circumstances) to o constrain parameters that will improve the models of iceberg drift, by determining drag coefficients appropriate to atmospheric and oceanic interactions, including drag induced by sea ice;

• improve our ability to predict calving events and the subsequent iceberg drift trajectory;

• complement ongoing remote sensing studies of the iceberg and its behavior; and

• measure the progress of the iceberg and its progeny toward logistically sensitive areas.

It is now in two pieces and has caused smaller bergs to calve from the Ross Ice Shelf, a situation that could complicate normal shipping to and from McMurdo Station on Ross Island, the main U.S. research and logistics station in Antarctica. (IO-190-O)

(IO-192-O)
Collecting micriometeorites form the South Pole water well.
Susan Taylor, U.S. Army Cold Regions Research and Engineering Laboratory.

Ever since Mawson discovered the first meteorite in Antarctica in 1912, scientists have harvested a rich vein of information about life in space from what is probably the best area on Earth to collect specimens of extra-terrestrial origin. This project follows up on the discovery (in 1995) of thousands of micrometeorites that were collected from the bottom of the South Pole water well. Using these samples, we were able to determine a precise flux and mass distribution for four centuries (1100-1500 A.D.) of cosmic spherules (melted micrometeorites) in the 50-700 millimeter (mm) range.

This austral summer we will collect new samples to follow up on a number of implications from that previous cache. First, we hope to verify that the polar plateau itself preserves the original surface flux of micrometeorites, and to quantify both melted and unmelted micrometeorites for the same period. Next, we will try to determine the flux for smaller pieces in the 1-50 mm range, commonly classified as interplanetary dust particles (IDP's). These data may also permit us to assess whether IDPs derive from different cosmic sources, or rather comprise a subclass of micrometeorites. We will revisit the well to recover as many micrometeorites from the well as possible. With the cumulated data, we will look for quantifiable variations (if any are to be found) in the flux or compositional distribution of micrometeorites on 10- to 100-year scales for that Middle Ages time frame.

In addition, we will also collect diatoms, opal phytoliths, and terrestrial mineral grains from the well. Such collections will provide additional indicators for researchers who are trying to determine the sources of terrestrial particles landing on the antarctic plateau. Johnson Space Center/NASA will curate the samples and make them readily available to researchers in earth and planetary sciences. (IO-192-O)

(IO-196-L)
AMS radiocarbon chronology of glacier fluctuations in the South Shetland Islands during the last glacial/interglacial hemicycle: Implications for the role of Antarctica in global climate change.
Brenda Hall, University of Maine.

The Antarctic Ice Sheet is an integral component of the world's atmospheric and hydrologic systems. Paleoclimatologists have found a roughly predictable pattern to Earth's glacial cycles and see that over the next several millenia we are heading for another cooling. These two scientific ideas converge on the question, What would significant changes in antarctic ice auger for the rest of the planet, and how might such future changes be modeled? The search for the answer begins in the paleoclimatic record in the high latitudes.

This project joins the effort by gathering data to produce a new reconstruction of ice extent, elevation and thickness at the Last Glacial Maximum (LGM) for the South Shetland Islands in the Antarctic Peninsula. (This general area anchors an ice sheet, has active geothermal springs, and is the site of an extinct volcanic arc; clearly plate motion is occurring here.) The Drake Passage is an area of significant maritime and general scientific interest; our data should contribute to studies of ocean circulation and ice dynamics in this area. It will also contribute to the production of a deglacial chronology that will afford important clues about the mechanisms controlling ice retreat in this region of the Southern Hemisphere.

We plan to map the areal extent and geomorphology of glacial drift and to determine the elevation and distribution of trimlines on Livingston Island; also, by mapping the elevation of erosional features and the position of erratic boulders, we expect to determine the direction of the ice flow. One of our main goals is to discover if sufficient organic material exists in the South Shetland Islands to radiocarbon dating and, if so, to determine the age of the deposits by measuring the carbon-14 age of plant, algal and fungal remains that we find preserved at the base of the deposits, as well as those that have been incorporated into marine shells, seal skin, and other organic material we may find in raised beach deposits. Sea-level histories are also valuable to the overall paleoclimate studies, and we will search two or three key areas to show whether construction of such curves for the South Shetland Islands is possible. (IO-196-L)

(IO-196-M)
Deglacial chronology of the northern Scott Coast from relative sea-level curves.
Brenda Hall, University of Maine.

This project dovetails with the previous one (IO-196-L). A key unresolved question in antarctic glaciology concerns the stability of the marine-based West Antarctic Ice Sheet (WAIS). Marine-based means that (unlike the base of the East Antarctic Ice Sheet sitting on a lithospheric plate) the substratum for the WAIS is a series of archipelagoes, such that the sheet at its relatively fixed position is grounded on the continental shelf - in the northwestern Ross Sea Embayment off the northern Scott Coast - with plate boundaries nearby. As deglaciation began after the Last Glacial maximum (LGM), the WAIS eventually became unmoored. Scientists believe this was likely the first area of the shelf to become free of grounded ice. Learning how and when (and in what sequence) this has occurred in the past is a critical step for isolating the mechanisms (sea level, climate, ocean temperature, and internal dynamics) that control WAIS dynamics.

Thus the northern Scott Coast is of particular interest to researchers looking for mechanisms that may have triggered the key stages of deglaciation. But an important first step is to better constrain the age where the inquiry is focused. The Barbados coral record suggests the initial retreat from the Ross Sea Embayment may have begun as early as 17,000 years ago. In contrast, recent glacial geologic mapping and relative sea-level work from the southern Scott Coast suggests that deglaciation here is more recent, during the Holocene (between the present and 11,000 years ago), with southward grounding-line migration past Ross Island shortly before 6,500 carbon-14 years ago. This chronology suggests that rising sea level could not have driven grounding-line retreat to the Siple Coast, because deglacial sea-level rise essentially would already have occurred by mid-Holocene.

To begin to resolve this conflict, one deficiency in the southern Scott Coast work might be corrected. Those data

cannot differentiate among the possible triggering mechanisms because they come from 450 kilometers south of the LGM grounding-line position. We will try to overcome this by constructing relative sea-level curves on a transect along the northern Scott Coast. We hope to get the ages for this work from accelerator mass spectrometer carbon-14 dates of seal skins and shells within raised beaches. These curves should tell us when the grounded ice from the northwestern Ross Sea Embayment cut loose. (IO-196-M)

previous section | Table of Contents | next section

INTERNATIONAL TRANS-ANTARCTIC SCIENTIFIC EXPEDITION (ITASE)

(IU-133-O)
Radar studies of internal stratigraphy and bedrock topography along the U.S. ITASE traverse.
Robert W. Jacobel, Saint Olaf College.

The U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE) conducts radar studies to determine the internal stratigraphy and bedrock topography of the terrain along the traverses. To help in the selection of core sites as the traverse proceeds, the radar provides immediate information (to those working in the field) on ice thickness and the structure of internal layers. These data can also be used to site deeper, millennial scale cores (planned at less frequent intervals along the traverse), and to provide a context for selecting the location of the deep inland core (planned for the future). In addition to mapping the traverse route, radar is used to examine a grid surrounding each of the core locations, to better characterize the accumulation and bedrock topography in each area.

This radar system works as a complement to that operated by the Cold Regions Research and Engineering Laboratory (CRREL). Theirs is a high-frequency radar, most suited to the shallower portion of the record down to approximately 60 meters (m); it can detect near-surface crevasses. Our radar system is most sensitive at depths below 60 m and is able to depict deep bedrock and internal geological layers deep into the ice. (IU-133-O)

(IU-153-A)
Science Management for U.S. ITASE
Paul A. Mayewski and Mark S. Twickler, University of New Hampshire.

The Science Management Office (SMO) coordinates the effort developed for U.S. ITASE, the broad aim of which is to develop an understanding of the last 200 years of west antarctic climate and environmental change. ITASE is a multidisciplinary program integrating remote sensing, meteorology, ice coring, surface glaciology and geophysics. To marshal this effort, SMO runs a series of annual workshops to coordinate the science projects that will be involved in ITASE. They also establish and operate the logistics base that supports ground-based sampling in West Antarctica. (IU-153-A)

(IU-153-B)
U.S. ITASE Glaciochemistry
Paul A. Mayewski and Loren D. Meeker, University of New Hampshire.

Among the research targets for scientists in U.S. ITASE are the impact of anthropogenic activity on the climate and atmospheric chemistry of West Antarctica and the variations in biogeochemical cycling of sulfur and nitrogen compounds over the last 200 years.

This 5-year project is conducting glaciochemical analyses of the major anions and cations to be found in shallow and intermediate depth ice cores collected on the U.S. ITASE traverses. The ionic composition of polar ice cores provides one of the basic stratigraphic tools for relative dating. These data can also be used to document changes in chemical-species source emissions, which in turn facilitate mapping and characterization of the major atmospheric circulation systems affecting the West Antarctic Ice Sheet. (IU-153-B)

(IU-155-O)
Snow and firn microstructure and transport properties: U. S. ITASE
Mary R. Albert and Robert E Davis,
U.S. Army's Cold Regions Research and Engineering Laboratory.

Not all valuable data are buried deep within the ice. The microstructure and bulk properties of snow and firn near and at the surface control the air/snow/firn transport processes; i.e., how heat, vapor, and chemical species in air are incorporated into snow and polar firn. Since many of the snow and firn properties will also affect how radiation in different parts of the electromagnetic spectrum behaves, such field measurements provide a valuable baseline profile against which to range complementary efforts that use remote sensing to map the spatial variations of snow, firn and ice properties.

This project does the field and lab work to characterize snow and firn properties along the U.S. ITASE traverses in West Antarctica. We provide field measurements of snow and firn properties near the surface (down to 2 meters), including surface roughness, permeability, density, grain size, surface-to-volume ratio, and tortuosity. In the laboratory, firn cores from as deep as 20 meters will be analyzed for these properties and for their microstructure. Ultimately, we will develop a transport model to elucidate the nature of the air/snow/firn exchange and the firnification process at the various sites along the U.S. ITASE traverse. (IU-155-O)

(IU-158-O)
Hydrogen peroxide, formaldehyde, and sub-annual snow accumulation in West Antarctica: Participation in west antarctic traverse.
Roger C. Bales, University of Arizona.

Atmospheric photochemistry leaves valuable traces in snow, firn and ice; it has been verified that the efficiency of atmosphere-to-snow transfer and the preservation of hydrogen peroxide and formaldehyde are both strongly related to temperature and also to the rate and timing of snow accumulation. Thus measurements of these components in the firn and atmosphere will provide data needed to study changes in tropospheric chemistry of the boundary layer over West Antarctica.

This project will collect samples and take atmospheric measurements along the U.S. ITASE traverses. The wide-ranging extent of these traverses will train the scientific lens upon a variety of locations, covering much of the west antarctic region, and reflecting a range of different depositional environments.

We will measure the concentration of seasonally dependent species (such as hydrogen peroxide, nitric acid, formaldehyde and stable isotopes of oxygen) on all samples and feed them into a recently developed, physically based, atmosphere-to-snow transfer model in order to elucidate the photochemistry that led to the depositions. In addition, data we develop on current atmospheric levels of hydrogen peroxide, higher peroxides such as methylhydroperoxide, and formaldehyde will constrain model boundary conditions and the state of photochemistry in the austral summer. (IU-158-O)

(IU-178-O)
Mass balance and accumulation rate along U.S. ITASE routes.
Gordon S. Hamilton, University of Maine; Ian M. Whillans, The Ohio State University.

The polar ice sheets and the snow falling on them are important components of the global hydrological cycle. Yet, because of their very large size and remote locations, we have only a limited understanding of their mass balance (rate of thickness change) or the spatial distribution of snow accumulation. Work conducted as part of the U.S. ITASE seeks to improve this understanding.

This 5-year project involves measuring the rate of ice-sheet thickening (or thinning) at selected sites along flow lines, on ice divides, and along elevation contours. The measurements compare the vertical velocity of ice (obtained from precise global positioning system surveys of markers buried 5-20 m deep in the surface firn) with the local, long-term average snow accumulation rate evident in ice-core stratigraphy. Earlier work demonstrates that very precise rates of thickness change can be measured using this technique.

We are also studying spatial variations in accumulation rates, probing the link between snow accumulation and surface topography. Continuously operating, autonomous instruments will be deployed at several closely spaced sites that have very different slope gradients. The instruments will record snow accumulation, wind speed and direction, firn compaction and firn temperature. These results will enable us to test hypotheses of the physical processes of snow deposition and erosion.

We shall also investigate the ice flow effects on accumulation rates derived from U.S. ITASE ice-core records. At sites along flow lines, ice cores record the integrated accumulation rate history for a certain distance

up-glacier of the core site. Changes in surface topography along this flow line will lead to apparent accumulation rate variations in the ice-core record. By studying local ice dynamics (horizontal velocities, surface slope) around each ice core site, we will be able to better understand the cause of accumulation rate variations in the core records. (IU-178-O)

(IU-193-O)
Stable-isotope studies at West Antarctic U.S. ITASE Sites.
Eric Steig, University of Pennsylvania; James White and Christopher Shuman, University of Colorado-Boulder, Institute of Arctic and Alpine Research.

As participants in U.S. ITASE, we will perform stable isotope analyses of samples collected during the traverses in West Antarctica. Using instrumental and remote-sensing temperature histories, we will focus on the spatial and temporal distribution of oxygen-18 and deuterium in West Antarctica (where data are particularly sparse) and the calibration of the isotope/climate relationship on a site-by-site basis.

Our objectives are to

• obtain detailed oxygen-18, deuterium, deuterium-excess, and stratigraphic histories in snowpits at most or all of the U.S. ITASE coring sites;

• provide direct calibration of the isotope/climate relationship at each site, through a combination of direct (Automatic Weather Stations) and indirect (passive microwave satellite) temperature measurements;

• obtain isotope profiles covering the last 200 years; and

• use the results to provide climate histories at high temporal and broad spatial resolution across West Antarctica for the past two centuries.

These climate histories will provide the context to test relationships that have been proposed among isotopes, moisture source conditions, synoptic scale climatology, and site-specific meteorological parameters. They will also enhance our ability to interpret isotope records from older and deeper antarctic ice cores. (IU-193-O)

(IU-311-0)
High-resolution radar profiling of the snow and ice stratigraphy beneath the U.S. ITASE traverses, West Antarctic Ice Sheet
Steven Arcone, U.S. Army Cold Regions Research and Engineering Laboratory

Ice core measurements provide historical profiles of snow accumulation and chemistry at only the point where the core was drilled which - along the U.S. ITASE traverses - is every 100 kilometers (km). Subsurface radar, by contrast, provides reflection profiles of continuous horizons, generally related to density and chemistry contrasts; but their continuity strongly suggests that they are isochronal (that is, demonstrate regularity of period). Thus they can be used to track particular years between core sites and to provide a broad and more meaningful average of year-to-year accumulation rates, given the time versus depth calibrations from the cores.

This project is tracking these reflection horizons between core sites using high-resolution ground-penetrating, short-pulse radar. Our main antenna system uses a pulse centered near 400 MHz, which provides vertical resolution of about 35 centimeters (cm), and records reflections from a depth in firn of about 60 meters (m). During the first year of U.S. ITASE, we tracked some horizons for distances of more than 190 km and found depth variations as great as 22 m over a 5 km stretch. The variations are caused by surface topography, which affects local accumulation rates and ice movement.

We are also using a wide range of frequencies (as high as 10 GHz and as low as 100 MHz) to distinguish between conductivity and density as a cause of the reflections. The horizon tracking develop spatially averaged, historical accumulation rates; these can be correlated with GPS data to find the effects of topography upon local accumulation rates. In addition, the radar is also being used for advanced crevasse detection. (IU-311-0)

previous section | Table of Contents