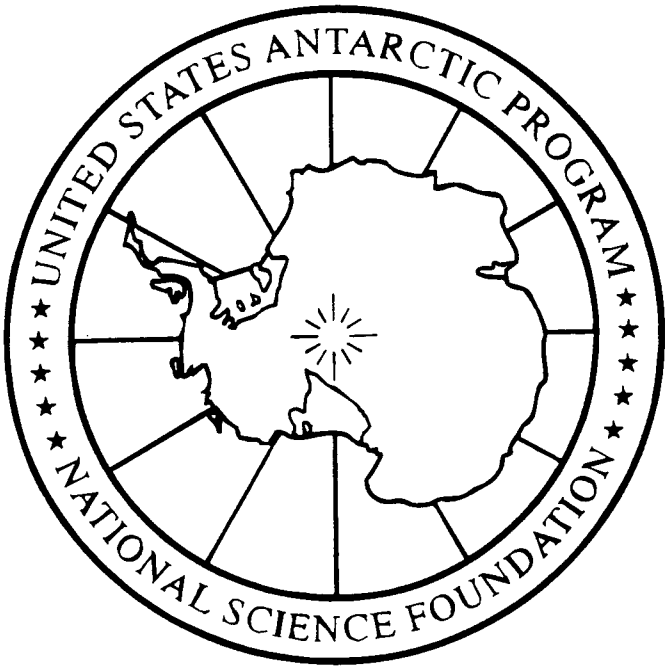
U.S. Antarctic Program 1998-1999



National Science Foundation
Office of Polar Programs

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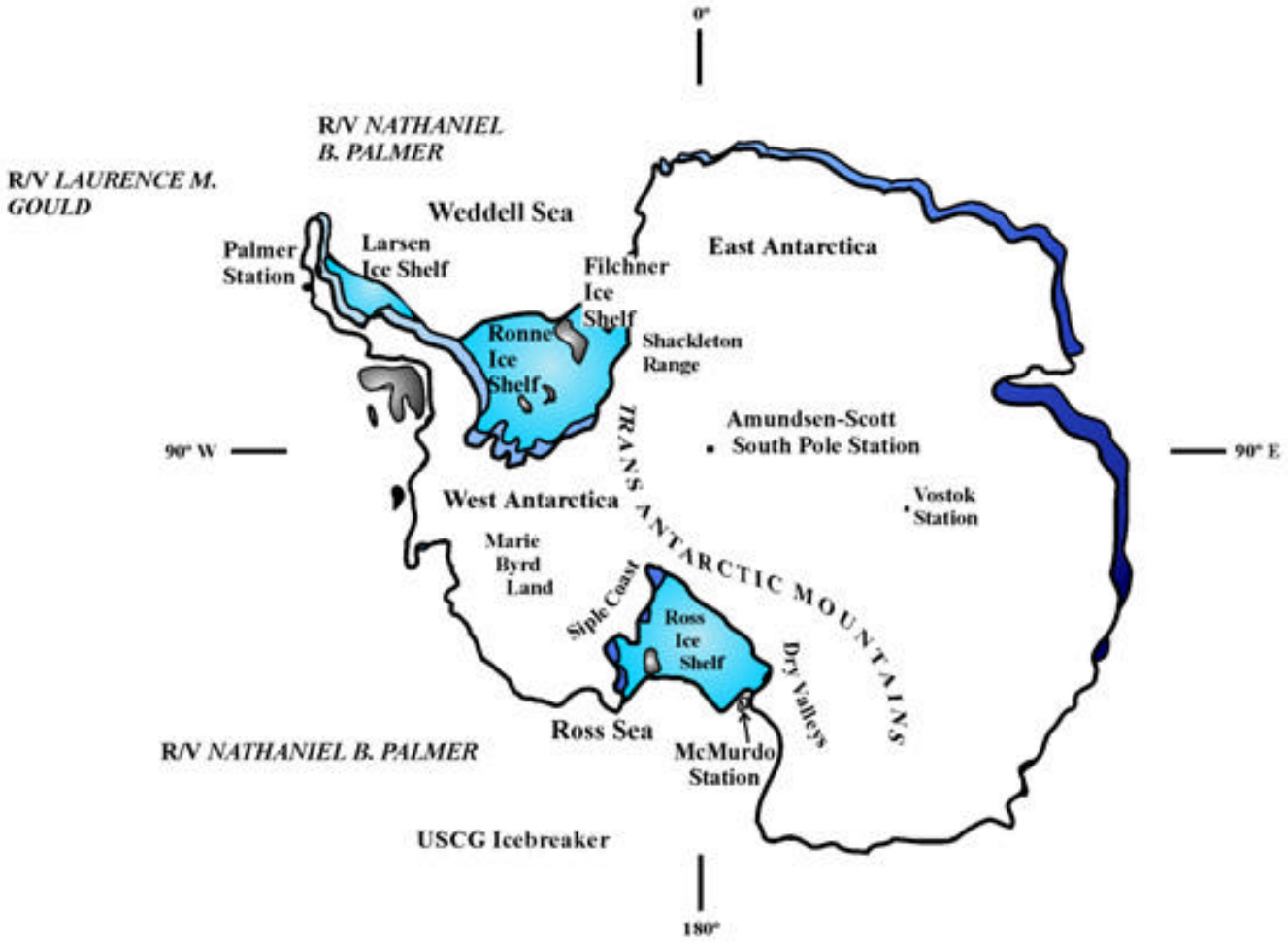


U.S. Antarctic Program, 1998-1999

In Antarctica, the U.S. Antarctic Program will support 142 research projects during the 1998-1999 austral summer and the 1999 austral winter at the three U.S. stations (McMurdo, Amundsen-Scott South Pole, and Palmer), aboard its 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. Many of the projects that make up the program, which is 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 who will conduct the projects described in this book come primarily from U. S. universities and have won NSF support in response to *Antarctic Research Program Announcement and Proposal Guide.* Operational resources in Antarctica are also used to support scientists from other Federal agencies.

Highlights of this year's austral summer program include:

- continued geological work at Cape Roberts near McMurdo Station
- long-term ecological research in the McMurdo Dry Valleys and in the Palmer Station region of the Antarctic Peninsula
- recovery of a 1,000-meter ice core from Siple Dome in West Antarctica
- interdisciplinary study of atmospheric forcing, ocean hydrography, sea-ice dynamics, primary productivity, and pelagic-benthic coupling in the southwestern Ross Sea
- a U.S.–French–Australian collaboration to study katabatic winds along the coast of East Antarctica
- continued support of the Center for Astrophysical Research in Antarctica at the geographic South Pole
- measuring, monitoring, and studying atmospheric trace gases associated with the annual depletion of the ozone layer above Antarctica.

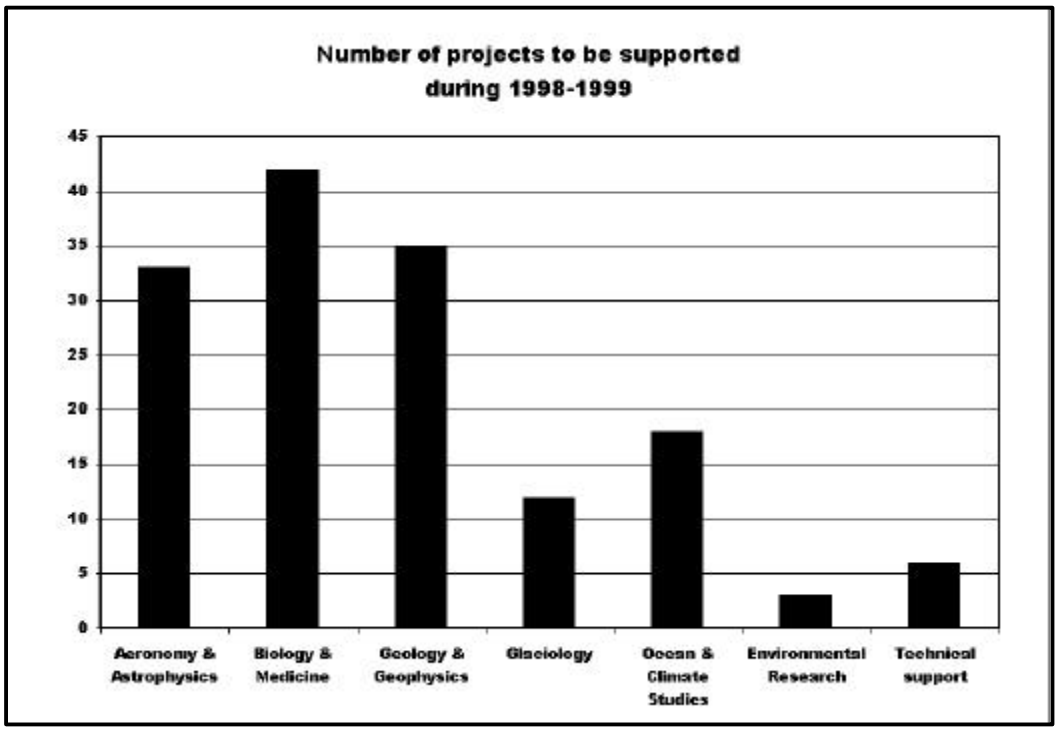
Science teams will also make use of a continent-wide network of automatic weather stations, a network of six automated geophysical observatories, ultraviolet-radiation monitors at the three U.S. stations, and a high-altitude, long-duration balloon that will circumnavigate the continent and carry instruments for two projects—a study of cosmic microwave background radiation and an optical investigation of the genesis of solar activity.

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

This book, which is intended to keep scientists and others informed about the U.S. antarctic research program, is arranged in scientific discipline order, except for one section focused on multi-investigator, multi-disciplinary long-term ecological research projects and a short list of technical 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 703-306-1070.
- *Antarctic Journal of the United States* review issues, which contain short reports by investigators about research recently performed in Antarctica. These issues are online (http://www.nsf.gov/od/opp/antarct/journal) and are available in print from the Office of Polar Programs (dfriscic @nsf.gov).
- A Library of Congress bibliography covers the world literature back to 1951. Principal products are the monthly *Current Antarctic Literature*—online at http://www.crrel.usace.army.mil/ library/aware/ antlit.htm—and annual *Antarctic Bibliography*—available from the Government Printing Office, Washington, D.C. 20402. National Information Services Corporation (410-243-0797 or sales@nisc.com) sells a CD-ROM holding this database and other polar bibliographies.



This graph shows the number of projects (by science program) that the U.S. Antarctic Program will support in Antarctica during 1998-1999. Technical support includes maintenance and upgrade of such equipment as the UV monitors at McMurdo and Palmer Stations and other projects like ice core drilling at Siple Dome. The table below shows the number of projects by science program and location. The "McMurdo Station and vicinity" count includes projects in the McMurdo Dry Valleys and at Cape Roberts.

	Aeronomy & Astrophysics	Biology & Medicine	Geology & Geophysics	Glaciology	Ocean & Climate Studies	Environmental Research	Technical support
McMurdo Station and vicinity	9	13	13	1	1	1	2
McMurdo and South Pole Stations	7	1	2	0	0	0	2
Remote continental sites	0	3	12	11	3	0	0
Palmer and McMurdo Stations	1	1	0	0	0	0	1
McMurdo/Ross Sea region, shipboard	0	5	0	0	6	0	0
Palmer Station/ Peninsula region	1	9	1	0	4	0	0
Peninsula region (ship-board only)	0	10	6	0	1	1	0
South Pole only	14	0	1	0	3	1	1
TOTAL	32	42	35	12	18	3	6

Biology and medical research

Photochemical and optical properties of antarctic waters in response to changing ultraviolet-B radiation. *Kenneth Mopper, Washington State University, and David Kieber, State University of New York.* The decrease in stratospheric ozone over the Antarctic results in an increase in the ultraviolet-B (UV-B) flux in the euphotic zone. The increase leads to cellular damage to aquatic organisms, as documented by photoinhibition and decreased productivity. Cellular damage can occur either intracellularly or externally at the cell surface from biomolecular reactions with externally generated reactive transients. The extent of this extracellular damage will depend on the photochemistry of the seawater surrounding the cell. Until recently, nothing was known about the type of photochemical processes, rates, and steady-state concentrations of transients in antarctic waters.

Our field experiments will allow the construction of predictive models of photochemical production rates in surface waters and with depth. These studies will involve further quantum yield measurements, development of a sensitive underwater actinometer system, and use of a new underwater multichannel photometer. The model will allow the prediction of the impact of varying levels of UV-B on the photoproduction and steady-state concentration of several key reactive transient species in the upper water column. In addition to this effort, experiments will also be performed to study the photodegradation of dissolved organic matter and to determine whether biologically utilizable substrates that are formed photochemically can enhance secondary productivity in antarctic waters. (BO-002-A and BO-002-B)

Impacts of climate change on antarctic vascular plants: Warming and ultraviolet-B radiation. *Thomas Day, Arizona State University.* Evidence is strong that the climate of the Antarctic Peninsula has changed appreciably in this century. Weather records indicate that mean summer air temperatures have risen more than 1°C over the past 45 years at some peninsula locations. In addition to this warming trend, springtime ozone depletion events have resulted in well-documented increases in ultraviolet-B (UV-B) radiation levels. These rapid changes in regional climate provide a unique opportunity to assess the impacts of climate change on vascular plants.

Although the presence of only two native vascular plant species (*Deschampsia antarctica* and *Colobanthus quitensis*) and their sparse distribution in Antarctica attest to the severe conditions for plant survival, there are already indications that climate changes are exerting a strong influence on these species. Regional warming appears to be leading to rapid increases in populations of these species, based on censuses taken along the peninsula. The influence of enhanced UV-B levels on these species is less clear.

An experiment has been initiated in which temperature and UV radiation levels are manipulated around naturally growing *Deschampsia* and *Colobanthus* plants on the Antarctic Peninsula to assess their responses to these factors. Assessment involves examining changes in photosynthesis, growth, and reproduction of these plants following warming or exclusion of different UV components.

During the first two field seasons, growth significantly improved under warming treatments. Although exclusion of UV did not have any significant effects over the first field season, over the second field season, exclusion of UV improved vegetative growth, and it appears that levels of UV in Antarctica can reduce leaf elongation as well as leaf production in native plants. Field manipulations will be

continued and expanded in the current assessment of plant responses in four key areas: photosynthesis, general thermal adaptations, reproduction, and soils. These areas are critical to understanding plant responses to climate change in Antarctica. (BO-003-O)

LEXEN: Biology and ecology of South Pole snow microbes. *Edward J. Carpenter, State University of New York at Stony Brook.* Scientists have always assumed that the interior ice sheets of the continent of Antarctica are devoid of indigenous organisms. Although plants, protozoa, and bacteria are present at the fringes of the continent, the combination of low temperatures, long periods of darkness, and the absence of liquid water makes the interior extremely hostile to life.

Recent examination of snow from the South Pole, however, indicates the presence of microbes that contain DNA and photosynthetic pigments. Snow samples were collected at Amundsen–Scott South Pole Station in January 1997 and flown immediately to the Crary Laboratory at McMurdo Base. Examination of snowmelt using epifluorescence microscopy showed the presence of rod-shaped particles approximately 1×2.5 micrometers in size and a concentration of 130 (standard deviation = 64) cells per milliliter. The particles fluoresced orange under blue excitation light and reddish-orange under green excitation, indicating the presence of phycobiliproteins and chlorophyll. These fluorescence signatures, combined with the particles' shape, suggest that they are cyanobacteria. Subsequent analysis using fluorescent DNA stains and scanning electron microscopy confirmed the presence of DNA-containing microbes identical in shape to the autofluorescing particles seen with epifluorescent microscopy.

Further research will confirm whether these microbes are indigenous to the antarctic interior and will investigate their biology and ecology. The discovery of organisms capable of survival in interior Antarctica would provide us with new insight into the adaptability of life. Their biomolecules and metabolism must be unique and could have great value for molecular engineering research. (BO-004-O)

Role of antifreeze proteins in freezing avoidance in antarctic fishes: Ecological and organismal physiology, structure-function and mechanism, genetics, and evolution. *Arthur DeVries, University of Illinois.* Ongoing and new studies of the role of antifreeze glycopeptides (AFGPs) and peptides (AFPs) in freezing avoidance of antarctic fishes in five specific areas constitute this project:

- the relationship of the severity of environment and association of ice in fish,
- the uptake of endogenous ice and its fate,
- structure-function of antifreeze proteins including the molecular mechanism of antifreeze proteins adsorption and inhibition of ice growth,
- structures and organizations of antifreeze protein genes and gene families and their relationship to protein characteristics and gene evolution, and
- tissue specificity of AFGP expression.

The extent of exogenous and endogenous ice will be determined for McMurdo area fishes, which experience the coldest and most ice-laden waters of the antarctic region. Similar experiments will be conducted for the less severe marine environment of the Antarctic Peninsula. These studies will correlate freezing extremes with circulating levels of AFGPs in the fishes associated with these two environments. (BO-005-M)

The Polar T_3 Syndrome: Metabolic and cognitive manifestations, their hormonal regulation and impact upon performance. *H. Lester Reed, H.M. Jackson Foundation for Military Medicine.* People who live and work in Antarctica for longer than 4 to 5 months develop a characteristic constellation of symptoms and hormonal changes called the *Polar T3 Syndrome.*

These people have previously been described as having a 40 percent increase in energy requirement; frequent mood disorders; doubling of the production, utilization, and tissue stores of the most active thyroid hormone, triiodothyronine (T_3); a decline in central nervous system thyroxine (T_4); and acquisition of physiologic cold adaptation.

Over a 4-year period, we are studying these apparent discordant and compartmentalized tissue responses using a multidisciplinary approach carried out by experienced polar physiologists, endocrinologists, and psychologists. We are examining the possible cognitive and metabolic changes in performance from declines in central nervous system T_4 and elevations in skeletal muscle T_3 content. We use placebo-controlled T_4 replacement directed at the central nervous system deficit and measure with cognitive instruments. T_3 content within the cardiovascular system is evaluated by using submaximal exercise testing to differentiate resting from activity-mediated energy-use contributions by the skeletal muscles. Additionally, tissue samples of skeletal muscle provide information regarding the genetic coding for T_3 responsive proteins to help better characterize the thyroid status of these muscles. Moderate energy restriction is used along with T_4 supplementation to study the dependence of T_3 production, distribution, and tissue stores upon both pituitary generation of thyrotropin and energy intake. We compare each subject's baseline in the predeployment situation of California to periods and standardized measures obtained during the antarctic summer and winter.

We believe that a correction of the low T_4 state in the central nervous system can be managed with T_4 supplementation without dramatically changing energy requirements as suggested by previous human studies using cold air chamber experiments. If this thesis is correct, then characteristic declines in mood and memory during winter seasons in circumpolar regions may be attenuated by T_4 supplementation without disadvantageous effects upon their energy metabolism. Additionally, this project will expand information regarding the ultimate regulation and maintenance of the increased T_3 production, which is a central determinant of the Polar T_3 Syndrome. (BO-008-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 is found in regions of pack ice or fast ice close to the antarctic continent. This species has been the focus for long-term population studies in McMurdo Sound since the mid-1960s. This data set, one of the few of its kind in the world, has provided valuable knowledge leading to an understanding of the survival and reproductive patterns of a long-lived vertebrate.

Using recently developed molecular biology techniques, we will examine the breeding system and reproductive fitness. By examining the behavioral ecology and mating system through paternity analysis of breeding males, we will be able to estimate reproductive success and effective population size in this aquatic breeding species. A second aspect of the study will examine population demographics (which is a continuation of the annual analyses), parameter estimation, and hypothesis testing associated with the existing 30-year database. As part of this second aspect, a comprehensive analysis of the population dynamics will focus on the role that immigration and emigration play in the population dynamics.

As the southernmost breeding mammal in the world, the Weddell seal exemplifies an extreme in environmental adaptability. Understanding the strategies seals employ in this environment will contribute to the basic understanding of pinniped evolution and popu-

lation dynamics and competition in marine mammals. (BO-009-O)

New approaches to measuring and understanding the effects of ultraviolet radiation on photosynthesis by antarctic phytoplankton. *Patrick Neale, Smithsonian Institution.* Increases in ultraviolet-B radiation (UV-B, 280-320 nanometers) associated with the antarctic ozone hole have been shown to inhibit the photosynthesis of phytoplankton, but the overall effect on water column production is still a matter of debate and continued investigation. Investigations have also revealed that even at "normal" levels of antarctic stratospheric ozone, UV-B and UV-A (320-400 nanometers) appear to have strong effects on water column production. The role of UV in the ecology of phytoplankton primary production has probably been underappreciated in the past and could be particularly important to the estimation of primary production in the presence of vertical mixing. We will quantify UV effects on photosynthesis of antarctic phytoplankton by defining biological weighting functions for UV-inhibition.

We will use new theoretical and experimental approaches to investigate UV responses in both the open waters of the Weddell-Scotia confluence and coastal waters near Palmer Station. In particular, we will measure the kinetics of UV inhibition and recovery on timescales ranging from minutes to days. Variability in biological weighting functions will be calculated for pelagic and coastal phytoplankton in the Southern Ocean. Our results will

- provide absolute estimates of photosynthesis under *in situ*, as well as under altered, UV irradiance;
- broaden the range of assemblages for which biological weighting functions have been determined; and
- clarify how kinetics of inhibition and recovery should be represented in mixed-layer models. (BO-010-O)

The role and regulation of chloride cells in antarctic fish. *David Petzel, Creighton University.* Antarctic fish have the highest serum osmolality of any seawater teleost. Maintenance of fluid balance is crucial for survival. Upon warm acclimation from -1.5° to 4°C, the fish lose 20 percent of their serum osmolality through extrusion of sodium chloride (NaCl) across the gill. NaCl extrusion in fish is primarily performed by chloride-secreting cells located on the gill arches and gill opercula. The driving force for NaCl transport is the sodium/potassium-ATPase. To date, no information is available concerning the role and regulation of the elevated serum osmolarity in antarctic fish. Questions that arise include these:

- What role does the chloride cell play in mediating salt extrusion?
- Which hormones regulate chloride cell activity?

We will compare the chloride cell physiology and regulation in antarctic fish with a New Zealand fish that is eurythermal. We hope to determine the plasticity of antarctic and New Zealand fish gill function at the physiological level (through studies of ion transport activity) and molecular level (through studies of the sodium/potassium-ATPase enzyme). Specifically, this research will

- determine the gill extrusion mechanisms underlying the increase in gill sodium/potassium-ATPase activity upon warm acclimation in antarctic fish and
- determine the hormonal regulation of the gill extrusion mechanisms.

The results of our research will, for the first time, describe in detail the underlying mechanism(s) mediating the enhanced hypo-osmoregulation observed in antarctic fish and will allow the comparison of these results to those observed in a eurythermal New Zealand fish. (BO-012-O)

Weddell seal foraging: Behavioral and energetic strategies for hunting beneath the antarctic fast ice. *Randall Davis, Texas A&M University at Galveston.* To forage efficiently beneath the extensive, unbroken fast ice along the antarctic coast, Weddell seals (*Leptonychotes weddellii*) have adapted to an environment that is very challenging for an air-breathing predator. These adaptations enable Weddell seals to hunt for prey at depth while holding their breath for 20 minutes or longer. This feat is analogous to a lion or other large terrestrial predator holding its breath while it locates, pursues, and captures prey. In addition, Weddell seals must return to the same hole at the end of a dive or know the location of other breathing holes. Failure to locate a breathing hole will result in a seal's death by drowning.

We will investigate the behavioral and energetic adaptations that enable Weddell seals to forage in the antarctic fast-ice environment. To achieve this goal, we will measure the underwater behavior, locomotor performance (swimming velocity, stroke frequency and amplitude, and three-dimensional movements), and energy metabolism of Weddell seals during foraging dives. We will test hypotheses on general foraging strategies, searching behavior, searching mechanics, modes of swimming, metabolic costs of foraging, and foraging efficiency for different environmental conditions and prey type. Until now, it has not been possible to investigate the foraging behavior of marine mammals in detail. To accomplish this study, we will attach a small video system and data logger to the seals' backs and measure oxygen consumption during voluntary dives from an isolated ice hole in McMurdo Sound, Antarctica.

Observing the foraging behavior and prey of marine mammals has been and continues to be a major obstacle to the advancement of studies on their foraging ecology. The Weddell seal may be the single best species in which to study the foraging behavior and energetics of deep-diving pinnipeds because

- data are available on their diving ability,
- the isolated-ice-hole protocol in McMurdo Sound enables recorders to be attached and recovered reliably, and
- they make daily foraging dives when placed in the isolated ice hole. (BO-017-O)

Impacts of increased solar ultraviolet-B radiation on antarctic marine heterotrophs. *H. William Detrich, III, and Kirk D. Malloy, Northeastern University.* Recent decreases in stratospheric ozone have resulted in dramatic increases in the flux of mid-ultraviolet light (UVB) reaching the Earth's surface, especially over Antarctica but, to a lesser extent, in temperate zones. Ozone depletion is expected to continue well into the next century and to worsen at lower latitudes over time. Recent evidence suggests that present intensities of UVB are sufficient to produce significant impacts on phytoplankton communities in the Southern Ocean, as well as to negatively affect tropical marine communities and populations of temperate amphibians. The abbreviated trophic structure of the antarctic marine ecosystem places an increased importance on primary and secondary consumers, especially on many species of zooplankton, which form a critical link between primary production and top predators such as adult fish, marine mammals, and birds. Although these zooplankton species and other heterotrophs, which include larval and adult fish, krill, and copepods, are important components of the trophic structure in the antarctic ecosystem, researchers have no information regarding the effects of increased UVB on natural populations of these organisms. Laboratory and field studies on nonpolar species suggest, however, that the impact of increased UV on antarctic heterotrophs, and therefore on the antarctic ecosystem, could be substantial.

Using established methods, we will

- measure the vulnerability of antarctic zooplankton to UVB damage in the field and in the laboratory,

- measure DNA repair rates of antarctic heterotrophs at ambient temperatures (-2°C to +4°C), and
- determine the relationship between UVB exposure and decreases in organismal fitness (measured as RNA-to-DNA ratios and transcription rates).

The field component of this research is a unique effort to determine the *in situ* vulnerability of natural populations of antarctic heterotrophs during normal and depleted ozone conditions. These studies are critical for developing predictive models of the relative impact of increased UVB on antarctic marine heterotrophs and for relating ozone depletion on decreased fitness, survival, and population dynamics of these species. (BO-029-O)

Factors regulating population size and colony distribution of Adélie penguins in the Ross Sea. *David G. Ainley, H.T. Harvey and Associates.* In this collaborative project, we will investigate the demographic mechanisms responsible for dramatic growth in existing Adélie penguins (*Pygoscelis adeliae*) colonies over the past few decades. We will also investigate the possibility that growth is related to documented climate change in the region by

- distinguishing the relative importance of the key resources that constrain growth of colonies (availability of nesting habitat versus access to food) and
- examining behavioral and demographic mechanisms (philopatry— the immigration/emigration balance, and/or breeding effort/success) that influence colony growth as a function of initial size and distribution.

This will be the first empirical study to consider the geographic structuring of a seabird population. Results will increase understanding of

- population regulation and patterns of dispersion and
- effects of climate change, mediated through changes in sea-ice cover, on penguin populations.

In addition, results will provide a context in which to interpret conflicting data on penguin population trends from existing programs that use Adélie penguins as an indicator species for point-source anthropogenic impact on antarctic resources (e.g., fishery catches, disturbance by tourism).

Our 5 years of research (3 full years funded by the National Science Foundation) include intensive field study conducted at three Ross Island penguin colonies. 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). Methods will bring together several well-established techniques that have been successfully but infrequently used in antarctic biological research:

- aerial photography to evaluate availability of nesting habitat,
- microwave images of sea-ice concentration to assess availability of feeding habitat,
- analysis of stable isotopes to evaluate food quality,
- radio telemetry to assess overlap in colony feeding areas, and
- automatic systems to log aspects of reproductive effort.

Our research builds on, and collaborates with, the efforts of Landcare Research New Zealand (LCRNZ), which has conducted two preliminary field seasons, including testing of new equipment, and will continue their effort and 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, and Beigel Technology, will collaborate with those from H.T. Harvey and As-

sociates and LCRNZ to accomplish project goals. (BO-031-O)

Evolution of an oxygen-binding hemoprotein in a unique environment: Myoglobin in the hemoglobinless antarctic icefishes. *Bruce D. Sidell, University of Maine at Orono.* For approximately the last 40 million years, a unique fish fauna has been evolving in the frigid seas surrounding Antarctica. Physiological function of these water-breathing animals has demanded many adaptations to ensure proper metabolism and regulation of biochemical processes at cell temperatures of about 0°C. Among the polar fishes, one family is particularly unusual: the Channichthyid icefishes. Species in this family lack hemoglobin in their circulating blood and, at least the majority, do not possess the intracellular respiratory protein, myoglobin, that is normally responsible for enhancing movement of oxygen through aerobic muscle tissues. Recently, however, two species of icefish that express myoglobin, *Pseudochaenichthys georgianus* and *Chionodraco rastrospinosus*, have been found, but these species express myoglobin in only one tissue—heart ventricle. The metabolism of all icefish species is highly aerobic and is based largely on the combustion of fatty fuels as energy sources.

Our fieldwork will consist of a combination of shipboard trawling to capture icefish species and laboratory work at Palmer Station using tissues from these animals. At Palmer Station, we will conduct experiments and prepare purified, fixed, and/or frozen material for shipment back to the United States for further analyses. The overall goals of this project are

- to determine whether myoglobin protein remains physiologically significant at the cold body temperatures of antarctic fishes,
- to reconstruct the evolution of the myoglobin gene within the icefish family, and
- to identify the mechanisms controlling expression of myoglobin within icefish and related species. (BO-036-O)

Structure, function, and expression of cold-adapted tubulins and microtubule-dependent motors from antarctic fishes. *H. William Detrich, III, Northeastern University.* Microtubules, which are subcellular "pipelike" filaments composed of the protein tubulin, and their associated motors, dynein and kinesin, participate in many fundamental cellular processes, including cell division, nerve growth and regeneration, cell motility, and the organization and transport of organelles within cells. In these processes, microtubules serve as rigid "railroad tracks" for the movement of motors and their cargoes ("trains"), and the motors themselves are 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, at the molecular level, the adaptations that enhance the assembly of microtubules, the expression of tubulin genes, and the activity of microtubule motors from antarctic fishes in this extreme thermal regime. 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 fish flagellar dynein motors at low temperatures.

We will determine molecular adaptations of the antarctic fish tubulins by comparing the amino acid sequences of alpha- and beta-tubulins from *N. coriiceps*, to those from

its temperate relative, the New Zealand black cod, *Notothenia angustata.* We will analyze gene expression in *N. coriiceps* by defining the organization and transcription-regulating elements of an alpha-tubulin gene cluster. In the broadest sense, this research should advance the molecular understanding of the cold-adapted mode of life. (BO-037)

Penguin-krill-ice interactions: The impact of environmental variability on penguin demography. *Wayne Trivelpiece, Montana State University.* We will study populations of Adélie, gentoo, and chinstrap penguins at Admiralty Bay, King George Island. These populations have exhibited fluctuations in abundance that have been related to long-term changes in environmental conditions, in particular sea-ice coverage and its possible effects on prey (krill) availability.

We will test the following five hypotheses relating penguin demography to environmental variability via its effect on krill recruitment in the antarctic marine ecosystem.

- Krill population structure is strongly affected by pack ice extent through its impact on female fecundity and larval survival.
- Recruitment of penguins to their respective populations is affected by the extent of pack-ice cover during the winter prior to the breeding season.
- The survival of penguin fledglings is correlated to the extent of pack ice cover the winter following the breeding season.
- Adélie penguins return to the pack-ice habitat during their first 2-week-long foraging trips following clutch competition to recover from the prolonged fasting of the courtship period.
- Accessible pack ice in the early breeding season has led to the evolution of discrete population centers of Adélies from the Bellingshausen, Weddell, and Ross Sea populations.

The Pygoscelis species, the major predators of krill (*Euphausia superba*) in the Antarctic Peninsula region, are key species used to monitor the potential impacts of fishery activities in this area. To understand the structure and function of the antarctic marine ecosystem thoroughly, it is imperative to determine the impact of environmental variation on the structure and regulation of upper trophic level predators such as the *Pygoscelis* penguins. (BO-040-O)

Shell morphogenesis in giant agglutinated foraminifera. *Samuel S. Bowser and Charles R. Hauer, Health Research, Inc.* A dominant member of cold, deep-sea sediments ecosystem is a group of giant protozoa, the aggulatinated foraminifera, also known as *forams.* For protection, these single-celled organisms encase themselves in architecturally elegant shells that they construct by collecting, sorting, and cementing together sediment grains. The unique occurrence of these giant cells (greater than 1 millimeter in size) in the shallow waters of McMurdo Sound, Antarctica, allows for the study of the cellular and molecular aspects of shell constructions.

In our project, we will use novel light-microscopic methods to examine how agglutinated forams secrete and sculpt the adhesive matrix that binds sediment particulate in their shells. Comparative time-lapse photography of different foram species constructing shells will identify key steps in the processes that lead to the various shell morphologies. Peptide sequence analyses of the elastic proteins of the shells will provide valuable insight into the chemical nature of foram bioadhesives. From a practical standpoint, these cements have important biotechnological and medical applications.

We will also continue a study of the effects of collection activities, as well as natural physical disturbances, in this unique environment. The interdisciplinary research conducted for this project has implications in a number of fields,

including cellular development, evolution, paleontology, marine products chemistry, and ecosystem management. (BO-043-O)

LEXEN: Microbial life within the extreme environment posed by permanent antarctic lake ice. *Christian H. Fritsen, Edward E. Adams, James A. Raymond, John C. Priscu, and Christopher P. McKay, Montana State University.* The 3- to 20-meter-thick permanent ice covers on lakes in the McMurdo Dry Valleys, Antarctica, contain viable microbial cells in association with sediment aggregates. These aggregates are now recognized as sites where physical, chemical, and biological interactions promote microbial growth under extreme conditions inherent to the ice environment.

In this interdisciplinary research program, we will define specific processes that allow

- the creation of liquid water (the essential element for life) in the permanent ice,
- the survival and structuring of microbial populations subjected to freezing and thawing,
- the production of substances that alter the physical attributes of the ice-crystal habitat, and
- the nutrient supply to the microbial populations, which is essential not only for survival but also for net microbial growth and biomass accumulation.

We will study ice aggregates embedded in the permanent ice covers on the lakes in the Taylor Valley, which have been tentatively characterized in previous studies.

Research on microbes in permanent ice provides information on the ecology of microbes in ice ecosystems and promises to have biotechnological implications. Furthermore, these studies will provide insights into the conditions that support or have supported life beyond our own planet in association with water ice, which has been detected within and beyond our own solar system. (BO-044-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—cause primary production to fluctuate extensively and to affect strongly the pelagic and benthic communities. We will initiate a long time-series study of the water column and seafloor using long-term, autonomous monitoring and sampling systems developed for use in the Antarctic. Our study will be located in Post Foster, Deception Island, which supports a pelagic and benthic fauna representative of the antarctic coastal zone and experiences seasonal ice cover.

We will deploy a bottom-moored, upward-looking acoustic instrument on the seafloor for 1 year 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. The instrumentation development 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 on the distribution, abundance, size, and movements of the epibenthic megafauna will be addressed. Results from this study will provide a valuable database for the evaluation of the pelagic and benthic community responses to seasonal variability in the Southern Ocean. (BO-050-O)

Adaptations of organisms at the sulfide- and methane-containing hydrothermal areas of Deception Island, Antarctica. *Horst Felbeck, Scripps Institution of Oceanography.* Deception Island is a flooded caldera in the South Shet-

land Islands, Antarctica. The most recent eruption, in the 1970s, caused the formation of new islands in the caldera and various other structures. Deception Island harbors many hot springs and fumaroles submerged in the caldera and intertidally. Sulfide and methane are prominent chemicals in the outflowing waters. Bacterial densities in the caldera reach unusually high values probably due to the input of reduced chemicals as energy sources. The environment around the springs resembles that found at hydrothermal vents where whole communities are based on the input of chemical energy by the hot waters. Similarities to hydrothermal vent environments include cold waters surrounding the hot springs resulting in large distances to the next warm-water habitat and a lack of external food sources. The latter is due to ice cover during winter at Deception Island and the large distance to the euphotic zone at the vent sites. These parameters encourage the evolution of alternative ways to support life such as the establishment of a bacterial symbiosis.

In this project, we will examine the warm springs around Deception Island for the presence of marine invertebrates with chemoautotrophic symbionts. We will map any submerged fumaroles as well as warm and hot springs in the intertidal zone. If animals are found near the fumaroles or in the hot springs, we will collect specimens and examine them for the presence of chemoautotrophic bacteria and other adaptations to a hot sulfide- and methane-rich environment using enzyme test experimental incubations to analyze metabolic pathways and microscopic examination. (BO-085-O)

Biological baselines and responses for assessing environmental impacts in antarctic coastal areas. *Paul Berkman, Ohio State University.* Antarctic coastal environments have been the site of recent studies on the effects of human activities on marine ecosystems. This international, collaborative study will develop methodologies to generate biological baselines for the benthic nearshore habitat in the Ross Sea region of Antarctica. These baselines will be useful in distinguishing between natural environmental variability from anthropogenic impacts and in assessing the recovery capacity of coastal marine populations that have been exposed to natural and anthropogenic stresses.

Our study, which will take place in Terra Nova Bay, will be conducted in cooperation with the Italian Antarctic Program. We will study populations of the scallop *Adamussium colbecki* from a natural-impact site (meltwater stream), an anthropogenic-impact site (near Terra Nova Bay Station in Tethys Bay), and a control site (no meltwater stream in a pristine area of Tethys Bay). Integration of biochemical, physiological, and population assays will provide examples of biological baselines for assessing indicator species' responses to natural and anthropogenic impacts in the antarctic coastal zone. (BO-086-O)

Ultraviolet-radiation-induced DNA damage in bacterioplankton in the Southern Ocean. *Wade H. Jeffrey, University of West Florida.* Strong evidence now shows that ultraviolet (UV) radiation is increasing over certain locations in Antarctica and the Southern Ocean as a result of ozone depletion. A reduction in ozone concentration selectively limits stratospheric adsorption of UV radiation and results in a higher UV irradiance reaching the Earth's surface. Although research on the impact of increased UV radiation due to ozone depletion has focused primarily on phytoplankton, a much smaller effort is being directed to other trophic levels.

During this collaborative project, we will address UV-radiation-induced damage and UV-radiation effects on bacterioplankton. We will examine interactions between bacterioplankton and photochemical processes and interactions with higher trophic groups such as phytoplankton and zooplankton. We will address these topics:

- whether bacterial-phytoplankton coupling modifies bacterial response to UV radiation,
- how seasonal changes in UV radiation affect bacterial community dynamics, and
- how chemical photoproducts affect bacterial production.

We will elucidate the molecular determinants responsible for changes in productivity and the molecular and physiological responses to changing UV radiation. The overall goal is to provide a greater understanding of the potential impact that changes in UV radiation have on marine microbial communities. (BO-200-O)

LEXEN: Protistan biodiversity in antarctic marine ecosystems: Molecular biological and traditional approaches. *David A. Caron and Rebecca J. Gast, Woods Hole Oceanographic Institution.* The analysis of microbial biodiversity of extreme environments is difficult because traditional methods for examining diversity are often ineffective for assessing species richness within these communities. Additional obstacles arise because of the difficulties of recreating and maintaining pertinent environmental features during sample collection and procession.

We will study the protistan assemblages (algae and protozoa) in the sea-ice, sediment, and ocean environments of the Ross Sea, Antarctica. The identification of protistan species in natural assemblages traditionally has entailed direct microscopical analyses as well as enrichment and culture techniques for assessing biodiversity. Determining diversity for these assemblages is, therefore, susceptible to biases as a consequence of sampling, enrichment, and culture, as well as selective losses due to sample preservation and concentration for microscopy.

Our goals are

- to develop and apply molecular biological approaches to assess species diversity of small protists (algae and protozoa smaller than 100 micrometers) in ocean water, sea-ice, and sediment environments and
- to obtain baseline physiological information on the growth rates, feeding rates, and growth efficiencies of cultured protozoa under pertinent temperature regimes.

As part of our molecular biological studies, we will examine small subunit ribosomal RNA gene (srDNA) diversity. Approaches and techniques developed will be applicable to any other water body or sediment and would provide a means to examine the representativeness of protistan cultures in extant culture collections. (BO-207-O)

The role of oceanographic features and prey distribution on foraging energetics and reproductive success. *Daniel Costa, University of California at Santa Cruz.* Marine coastal and pelagic environments of the Southern Ocean are characterized by seasonal high productivity. Over the last several decades, it has become clear that these environments, although generally productive, also undergo considerable inter- and intra-annual variability. Consequently, available prey resources for vertebrate predators can be highly variable spatially and temporally.

This spatial and temporal variability of prey resources has been measured empirically for the northern South Shetland Islands region of the Antarctic Peninsula since the late 1980s. The antarctic fur seal, a subpolar migratory otariid with a short lactation period, is an increasingly dominant marine predator of the South Shetlands region. Its life-history pattern is characterized by foraging trips alternating with short visits to provide for a single offspring; this pattern allows scientists to measure maternal investment on the same temporal and spatial scale as measurements of distribution and abundance of prey.

In our project, we will quantify the foraging costs and maternal investment associated with changes in strategies observed in populations

of South Shetland antarctic fur seals. Using state-of-the-art techniques, we will determine energetic costs and benefits of different foraging patterns while simultaneously measuring energy expenditure, food intake, dive depth, dive duration, time of day, and 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 is also contributing to the support of this project. The research will allow scientists to link biological characteristics (prey composition, distribution, and abundance) and physical characteristics of the foraging environment with foraging success, maternal investment, and reproductive success for a free-ranging marine vertebrate predator. (BO-267-O)

Characterization of indigenous and introduced toxic phytoplankton in Antarctica. *Donald Anderson, Woods Hole Oceanographic Institution.* Of the thousands of species of marine phytoplankton, only a few produce potent toxins. These species are found in the massive "red tides" or blooms of cells that discolor the water. More commonly, the organisms are present at low concentrations and are noticed only by the effects their toxins have on aquatic organisms and humans. The nature of the toxic phytoplankton problem has changed considerably in recent years: many areas that were previously unaffected are now subject to recurrent outbreaks. Therefore, it is alarming that marine algal toxins (saxitoxins) have been found in antarctic mollusks.

The implications of this discovery are profound given the low number of trophic levels between primary producers and top predators and the proven ability of the saxitoxins to alter the food web structure and dynamics. Saxitoxins can affect zooplankton, fish larvae, whales, porpoises, seabirds, and humans. Researchers are concerned that the saxitoxin-producing alga, presumably the dinoflagellates in the genus *Alexandrium*, has been introduced to antarctic waters, possibly by vessel traffic between South America and the Antarctic Peninsula. This mechanism of species dispersal has been implicated in the sudden appearance of toxic algae in other areas of the world. Short and frequent transport pathways do exist between Antarctica and the high-toxicity waters of southern Chile and Argentina. It is also possible that the saxitoxin-producing organism is indigenous to Antarctica and was only recently noticed. In either case, the implications to the antarctic food web are significant.

The objectives of our project are to identify and characterize the possible source(s) of saxitoxins in Antarctica to determine whether the causative organisms are indigenous or introduced species, and if introduced, to identify the probable origin and transport pathway. (BO-300-O)

1998–1999 McMurdo Station biology course. *Donal Manahan, University of Southern California.* This international, advanced-level, graduate training course will be organized and taught in Antarctica for 1 month during austral summer 1998–1999. The course will introduce students to the diversity of biological organisms in antarctic regions and allow them to study unique aspects of biology that permit life in such extreme environments. Long-standing questions in evolution and ecology (such as cold adaptation and food limitation) concerning the biology of antarctic organisms will be 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 will emphasize physiological, biochemical, and molecular biological approaches to understanding the ecology and biological adaptations of antarctic organisms. Student research projects will follow these interwoven themes. The students will gain a rigorous understanding of the power, but also the limitations, of physio-

logical, biochemical, and molecular biological methods that are currently being used to answer research questions in environmental science and biological 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 and collections of material will be made. The course will be taught as four modules:

- Biological diversity of antarctic organisms: Evolution and molecular phylogeny;
- Ultraviolet radiation: Effects on antarctic organisms;
- Invertebrates: Physiology, energy metabolism, and development; and
- Fish: Biochemical adaptations.

By attracting an extremely competitive group of young scientists, this course will introduce new researchers to Antarctica and will teach students to use modern research methods to study the mechanisms that are unique to biology in Antarctica. (BO-301-O).

Viruses in pack-ice communities of the Ross Sea, Antarctica. *Marcia M. Gowing, University of California at Santa Cruz.* Primary productivity of sea-ice algal communities in the Southern Ocean is significant. In lower latitudes, processes such as grazing and destruction by viruses are thought to control algal populations, but science has little data on grazing within ice communities and no data on viruses of ice algae. Ice communities should be excellent sites for studying viral control of populations of eukaryotic algae and protozoans because populations are extremely dense and many habitats are nearly closed for parts of the year.

We will use transmission electron microscopy (TEM) of individual eukaryotic algal and protozoan cells and light microscopy and TEM of water samples to assess viral infections and viral populations in a variety of pack-ice communities from the Ross Sea. Our objectives are

- to determine the extent of the occurrence of viruses within cells of algae and protozoans in ice communities and to estimate the percentage of infected cells,
- to relate the extent of the occurrence of viruses within cells to the stages of succession of sea-ice communities,
- to assess the potential for ice communities to seed viruses to the pelagial,
- to determine the extent of ingestion of viruslike particles by sea-ice protozooplankton,
- to compare these features of ice communities to those of phytoplankton and protozooplankton assemblages in the seawater directly under the ice, and
- to describe and quantify the size structure of the free viruslike particles in the interstitial water of ice communities and in the seawater directly under the ice.

Our study will contribute to the understanding of sea-ice community ecology and will allow us to incorporate viruses of eukaryotic algae and protozoans into models of carbon flow for the Antarctic. (BX-039-O)

Ecological studies of sea-ice communities in the Ross Sea, Antarctica. *Marcia M. Gowing, University of California at Santa Cruz.* Sea ice forms an extensive habitat in the Southern Ocean. Reports dating from the earliest explorations of Antarctica have described high concentrations of algae associated with sea-ice, suggesting that the ice must be an important site of production and biological activity. The magnitude and importance of ice-based production are difficult to estimate largely because the spatial and temporal distributions of ice communities have been examined in only a few regions, and the processes controlling

production and community development in ice are still only superficially understood.

We will examine sea-ice communities in the Ross Sea region of Antarctica in conjunction with studies of ice physics and remote sensing. The specific objectives of our study are

- to relate the overall distribution of ice communities in the Ross Sea to specific habitats that are formed as the result of ice formation and growth processes;
- to study the initial formation of sea ice to document the incorporation and survival of organisms, in particular to examine winter populations within "snow-ice" layers to determine if there is a seed population established at the time of surface flooding;
- to sample summer communities to determine the extent that highly productive "snow-ice" and "freeboard" communities develop in the deep-water regions of the Ross Sea:
- to collect basic data on the biota, activity, and general physical and chemical characteristics of the ice assemblages, so that this study contributes to the general understanding of the ecology of the ice biota in pack ice regions. (BX-325-O)

Long-term ecological research

McMurdo Dry Valleys: A cold desert ecosystem. *W. Berry Lyons, University of Alabama at Tuscaloosa.* The McMurdo Dry Valleys, located on the western coast of McMurdo Sound, form the largest ice-free area in Antarctica. In 1993, this area was selected as a study site in the National Science Foundation's Long-Term Ecological Research (LTER) program. The dry valleys are among the most extreme deserts in the world, far colder and drier than any of the other LTER sites. The biological systems in the McMurdo Dry Valleys are composed of only microbial populations, microinvertebrates, mosses, and lichens. Nevertheless, complex trophic interactions and biogeochemical nutrient cycles exist in the lakes, streams, and soils of the dry valleys. Solar energy produces glacial meltwater in the austral summer, and in turn, this meltwater exerts the primary influence on the dry valleys by replenishing water and nutrients to the ecosystems there. All ecosystems are shaped to varying degrees by climate and material transport, but nowhere is this more apparent than in the McMurdo Dry Valleys.

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. These objectives will be accomplished through a program of systematic environmental data collection, long-term experiments, and model development. In addition, LTER researchers will study dry valley lakes as analogs for past Martian environments. The objectives of this aspect of the project are

- to define the biogeochemical processes responsible for controlling the isotopic carbon-13 signature in present-day antarctic lake sediments and use this calibration to infer the environment of paleolakes and
- to determine other environmental markers left in the lake sediments as well as describing the nature of ice / water / sediment interactions in the lakes.

During the 1998–1999 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 (Andrew Fountain, Portland State University);
- chemistry of streams, lakes, and glaciers (W. Berry Lyons, University of Alabama);

- flow, sediment transport, and productivity of streams (Diane McKnight, University of Colorado);
- lake pelagic and benthic productivity and microbial food webs (John Priscu, Montana State University at Bozeman);
- soil productivity (Diana Wall, University of Nevada, Desert Research Institute, and Ross A. Virginia, Dartmouth College);
- aeolian transport processes (Gayle L. Dana, Desert Research Institute); and
- meteorological data collection (Peter T. Doran, Desert Research Institute).

The McMurdo LTER project will emphasize the integration of the biological processes within and material transport between the lakes, streams, and terrestrial ecosystems in the dry valley landscape. This season, several experiments will examine community structure and function within benthic bicrobial mats of the dry valley lakes. In addition, tracer tests will be performed to investigate nutrient transport and uptake in the streams. (BM-042B-O, BM-042-F, BM-042-L, BM-042-M, BM-042-P, BM-042-W, and BM-118-O)

Long-Term Ecological Research on the antarctic marine ecosystem: An ice dominated environment. *Maria Vernet, Scripps Institution of Oceanography*. The central hypothesis of the Palmer Long-Term Ecological Research (LTER) project is that the annual advance and retreat of sea ice is a major physical determinant of spatial and temporal changes in the structure and function of the antarctic marine ecosystem. Evidence shows that this dynamic variability of sea ice has an important, perhaps major, 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 (e.g., access to open water or preferred habitats) or indirectly (e.g., food availability, which in turn may be affected by the variability in sea ice). We hypothesize 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.

The magnitude and timing of sea ice may have different consequences for different key species, and it is still unclear what the ramifications would be for the whole antarctic ecosystem. For example, high levels of survivorship and reproductive success of Adélie penguins appear to depend on high levels of availability of antarctic krill, which in turn appear to be correlated with greater ice coverage. On the other hand, high levels of breeding success of south polar skuas appear to be determined by the availability of antarctic silverfish, which in turn appear to be associated with lesser ice coverage. Thus, the 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;
- to quantify the processes that cause variation in physical forcing and the subsequent biological response among the representative trophic levels;
- to construct models that link ecosystem processes to environmental variables and which simulate spatial/temporal ecosystem relationships; and then
- to employ such models to predict and validate ice-ecosystem dynamics.

A key challenge for the Palmer LTER project is to characterize and understand the link between the different spatial and temporal scales of the various physical and biological components of the antarctic ecosystem.

The participants for the 1998–1999 field season will be

- Maria Vernet, Scripps Institution of Oceanography (BP-016-O);
- Douglas Martinson, Columbia University (BP-021-O);
- Langdon Quetin, University of California at Santa Barbara (BP-028-O);
- Raymond Smith, University of California at Santa Barbara (BP-032-O);
- William Fraser, Montana State University (BP-013-O); and
- David Karl, University of Hawaii (BP-046-O).

Environmental research

Diagnostic indicators of biological community stress using benthic community analysis to tease apart impacts of organic enrichment and toxicity: An experiment in McMurdo Sound. *Charles Peterson, University of North Carolina at Chapel Hill.* Communities of benthic invertebrates are widely used to monitor and evaluate biological impacts of pollution in the marine environment because their sessile lifestyles, longevity, functional diversity, well-known taxonomy, and ecological significance render this system an ideal ecological template on which biological consequences are imprinted. Benthic communities have been used successfully in environmental assessments for convincing demonstrations that impacts of pollution are readily detectable at the level of family and phylum for macrofaunal invertebrates.

Our project is designed to test the hypothesis that indices of abundance and production for individual phyla of macrofauna and/or meiofauna can be used as independent diagnostics to tease apart the typically confounded impacts of these two separate classes of marine pollution. We will test the hypothesis that annelid worms and nematodes are enhanced by modest organic loading and arthropods and echinoderms are depressed preferentially by modest exposure to toxic contaminants (trace metals). This hypothesis will be tested near McMurdo Station because

- its relatively constant environment allows experimental work to proceed on the seafloor without compromise by confounding disturbances;
- previous benthic studies at this site have revealed significant confounded patterns of sediment contamination and benthic community degradation; and
- low rates of natural bioremediation in cold polar oceans make study of pollution impacts especially critical at high latitudes.

Our first objective will be to establish a field experiment near McMurdo Station where the investigators will manipulate organic loading and trace metal concentrations in sediment within colonization trays to test whether the separate taxa respond independently to the classes of pollution. Treatments will also include access of larger mobile predators and time for community development to assess whether biological interactions within the ecosystem with the diagnostic capability of the indices of pollution stress. Second, we will complete a rigorous review and meta-analysis

of all available data sets on effects of pollution on marine invertebrate communities to test the hypothesis using the wealth of pre-existing information from monitoring discharges, oil spills, and previous experimentation. (EO-302-O)

Measurement of combustion effluent aerosols from the Amundsen–Scott South Pole Station. *Anthony Hansen, Magee Scientific Company.* Anthropogenic activities in Antarctica have the potential of producing both contemporaneous and long-term environmental impacts on the nearly pristine surroundings. One of these impacts arises from the emission of "black" or "elemental" carbonaceous aerosols from the exhaust of diesel-powered generators and vehicles used to support antarctic operations. When deposited on the snow and ice cover, this pollutant may be preserved indefinitely. Its high optical absorption will alter the surface albedo and the radiative properties of surface cover. Its ability to promote catalytically certain chemical reactions may lead to modifications of snow and ice chemistry. Its absorbed content of fuel-derived organic species, such as polycyclic aromatic hydrocarbons and other toxics, may harm marginal biota and near coastal stations.

Previous work showed that extremely small, but detectable, concentrations of black carbon aerosol are brought to the Amundsen–Scott South Pole Station in the background atmosphere in amounts consistent with models of long-range transport; however, the program that made this determination terminated in 1990. A 1986 study of surface snow and ice showed a clear plume of soot downwind of the station. We will install more modern equipment both upwind and downwind of the South Pole Station to re-establish the background aerosol measurements and to provide a direct assessment of the station's emissions. The results of our work will contribute to determining the station's environmental impact resulting from combustion-derived emissions. This information may be used to design mitigation and abatement strategies. The upwind data will contribute to the global monitoring record and to assessments of the global circulation of anthropogenic emissions capable of influencing atmospheric optics and chemistry. (EO-314-O)

Geology and geophysics

Air-ground study of tectonics at the boundary between the eastern Ross embayment and western Marie Byrd Land, Antarctica: Basement geology and structure. *Christine S. Siddoway, Colorado College.* Our project combines air and ground geological–geophysical investigations to understand the tectonic and geological development of the boundary between the Ross Sea Rift and the Marie Byrd Land volcanic province. Our objective is to determine the Cenozoic tectonic history of the region and to learn whether Neogene structures that localized outlet glacier flow developed within the context of Cenozoic rifting on the eastern Ross embayment margin or within the volcanic province in Marie Byrd Land. The geological structure at the boundary between the Ross embayment and western Marie Byrd Land may be a result of

- Cenozoic extension on the eastern shoulder of the Ross Sea rift;
- uplift and crustal extension related to Neogene mantle plume activity in western Marie Byrd Land; or
- a combination of the two.

Faulting and volcanism, mountain uplift, and glacier downcutting appear to be active now in western Marie Byrd Land, where generally east-to-west-flowing outlet glaciers incise Paleozoic and Mesozoic bedrock, and deglaciated summits indicate a previous north-south glacial flow direction.

Our study requires data collection using SOAR, or Support Office for Aerogeophysical Research, a facility that uses high-precision differential global positioning system technology to support a laser altimeter, ice-penetrating radar, a towed proton magnetometer, and a Bell BGM-3 gravimeter. Data will be acquired over several key features in the region including, among others,

- the eastern edge of the Ross Sea rift,
- the transition from the Edward VII Peninsula plateau to the Ford Ranges,
- the continuation to the east of a gravity high known from previous reconnaissance mapping over the Fosdick Metamorphic Complex, and
- the extent of the high-amplitude magnetic anomalies (volcanic centers?) detected southeast of the northern Ford Ranges by other investigators.

SOAR products will include glaciology data useful for studying driving stresses, glacial flow, and mass balance in the west antarctic ice sheet.

During our ground program, centered on the southern Ford Ranges, we will map small-scale brittle structures for regional kinematic interpretation, glaciated surfaces and deposits, and datable volcanic rocks for geochronologic control. We will also determine the relative significance of fault and joint sets, the timing relationships between them, and the probable context of their formation along with exposure ages for erosion surfaces and moraines. To aid in the interpretation of potential field data, we will sample magnetic properties and density as well as take ground-based gravity measurements and oriented samples for paleomagnetic studies.

By combining airborne and ground investigations, we will obtain basic data for describing the geology and structure at the eastern boundary of the Ross embayment both in outcrop and ice covered areas. These data may also help and may be used to distinguish between Ross Sea rift-related structural activity from uplift and faulting on the perimeter of the Marie Byrd Land dome and volcanic province. Outcrop geology and structure will be extrapolated with the aerogeophysical data to infer the geology that resides beneath the west antarctic ice sheet. The new knowledge of Neogene tectonics in western Marie Byrd Land will contribute to a comprehensive model for the Cenozoic Ross rift and to understanding of the extent of plume activity in Marie Byrd Land. Both are important for determining the influence of Neogene tectonics on the ice streams and the west antarctic ice sheet. (GF-088-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 separate today. Crustal uplift could be occurring in western Marie Byrd Land due to isostatic rebound following the last glacial age.

Tectonic extension, if it is occurring in the embayment, could greatly influence global plate circuit calculations, depending on its magnitude. The tectonic extension rate also can constrain our understanding of the history of extension in the embayment and the uplift history of the Transantarctic Mountains. Postglacial rebound in western Marie Byrd Land would depend on the configuration of the ice sheet during the Last Glacial Maximum and when this occurred. The main question is whether the ice sheet collapsed in mid-Holocene time.

Our plan is to 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, which will gather data over a 4-year period, will operate in concert with GPS stations being installed in the Transantarctic Mountains in a separate project, resulting in a long baseline array across the Ross embayment. We will download data twice each season to acquire up to 6 months of coverage. If a cost-effective satellite communications system is in operation at the time of our survey, we will use that.

We expect to determine crustal strain rates to an accuracy of 1 millimeter per year horizontal and 2 millimeters per year vertical. The array will also detect strain gradients in western Marie Byrd Land. The strain data from western Marie Byrd Land and the Transantarctic Mountains will enable us to construct models for tectonic extension and glacial rebound.

This is a joint project between Bruce Luyendyk of the University of California at Santa Barbara and Andrea Donnellan, Carol Raymond, and Erik Ivins of the Jet Propulsion Laboratory at the California Institute of Technology. Our team brings together experts in western Marie Byrd Land geology and tectonics, tectonic geodesy, and lithospheric deformation. (GF-121-O)

Cretaceous-Paleogene foraminifera of the Victoria Land Basin (Cape Roberts Project). *Peter-Noel Webb, Ohio State University*. We will characterize the foraminifera in drill core recovered by the Cape Roberts Project (CRP) in the southwest Ross Sea. Geophysical site surveys suggest that the drill holes will provide an aggregate thickness of about 1,500 meters of core and span about 30 to about 100 million years (Cretaceous-Paleocene). This interval of geological time is not yet documented by *in situ* stratigraphic sections in either the Ross Sea or East Antarctica. The nearest comprehensive data sources for the Cretaceous and Paleocene occur in New Zealand, the northern Antarctic Peninsula, and the Southern Ocean. Benthic and planktic foraminifera from the core will be used, together with data from other fossil groups, to provide on-site age and stratigraphic control as drilling progresses. Age correlations will be made with Deep-Sea Drilling Project/Ocean Drilling Project (DSDP/ODP) biostratigraphy from Southern Ocean drill sites and also with New Zealand planktic and benthic zonal/stage schemes.

Our principal task is to provide a comprehensive accounting of foraminiferal material present to assist planning of postdrilling investigations. Basic information to be recorded on the foraminifera will include presence, abundance, preservation, species dominance and diversity, stratigraphic distribution, levels of endemism or cosmopolitanism in faunas, and completeness or fragmentation of population structures.

The data we record will be used to address a variety of geological problems. Disconformities and acoustic reflectors, which extend across the rift system basins and are also expected to be encountered in the drill hole, will be dated. Major basin subsidence/uplift trends resulting from compaction and/or rift margin faulting will be deduced from benthic foraminiferal bathymetric indicators. More subtle cyclicity in the stratigraphic distribution of benthic species will be used to recognize and document phases of transgression and regression, which, in turn, may indicate a relationship between sea level oscillation and terrestrial glacial events.

The final disintegration of Gondwanaland occurred during the Cretaceous–Paleocene; specifically, New Zealand and Australia moved north, away from Antarctica. Foraminifera from the CRP drill holes will contribute to an understanding of the paleogeography and paleoceanography between the highlands and Pacific margin of East Antarctica (the location of the proto-Transantarctic Mountains), and

the west antarctic rift system basins between this suspected island chain and the highlands of West Antarctica. This will help scientists know whether the marine margin of East Antarctica, near the drill holes, was located in a Cretaceous cul-de-sac, or whether it occupied, at times, a position on a major oceanic circulation pathway between the southwest Indian Ocean, southwest Pacific, and southwest Atlantic Oceans. (GL-049-A and GL-049-B)

Diatom biostratigraphy and paleoenvironmental history of Cape Roberts Project cores. *David Harwood, University of Nebraska at Lincoln.* We will characterize the diatom fossils in drill core recovered by the Cape Roberts Project (CRP), a major program in the international antarctic earth science community designed to sample antarctic continental margin strata of late Cretaceous through Paleogene age (30 million to 100 million years ago). Drilling operations will include continuous coring from a sea-ice platform on the flank of the Victoria Land basin in the western Ross Sea.

Our particular project involves initial field-based paleontologic analysis of siliceous microfossils in Cape Roberts cores. Core sections will be ferried to the Crary Science and Engineering Center (CSEC) for immediate analysis. Diatoms and other siliceous microfossils will provide rapid age-and-paleoenvironmental information during drilling operations. Each season will include preparation of a preliminary biostratigraphic/paleoenvironmental report based on siliceous microfossils. This report will become part of the *CRP Initial Reports* volume, which will include the preliminary results from other microfossil groups, lithostratigraphic, magnetostratigraphic, and other analyses.

Analysis of diatoms and other siliceous microfossils in CRP cores will greatly aid in the development of an integrated biostratigraphy for this poorly known interval in the southern high latitudes. Diatoms will provide evidence of, for example, environmental changes in water depth, primary productivity, and the presence or absence of sea ice. CRP cores will provide an excellent opportunity to study adaptation of diatoms to strong polar seasonality and diatom evolution. By integrating CRP studies with ongoing studies of Paleogene siliceous microfossils in Arctic strata (for example, Ocean Drilling Program Leg 151), the CRP cores will also offer the possibility of gaining a bipolar perspective on Paleogene high-latitude phytoplankton evolution. (GL-051-O)

Downhole logging for the Cape Roberts Project. *Richard Jarrard, University of Utah.* We will do continuous-core and downhole logging at the Cape Roberts Project (CRP) scientific drill holes. The goal of CRP is to study the Early Tertiary and Cretaceous record of climate, tectonics, and sea-level change and to determine the time of onset of antarctic glaciation. Geophysical well logs will be converted into continuous records of variation, and these records can be interpreted as indicating variations in mineralogy and porosity. The detailed one-dimensional records at each hole will be integrated with available high-resolution seismic data to produce a two-dimensional interpretation of the stratigraphy. This geophysical logging program is an essential component of basic characterization of the drill site and is a fundamental part of the effort to produce a stratigraphic framework for interpretation of other scientific work on the core. (GL-055-O)

Calcareous nanofossil biostratigraphy and paleoenvironmental history of the Cape Roberts Project cores. *James J. Pospichal and Sherwood W. Wise, Florida State University.* We will characterize calcareous nanofossils as part of the development of the biostratigraphic framework for drill core recovered by the Cape Roberts Project (CRP). CRP is a major program in the international antarctic earth science community, designed to sample the stratigraphic record that spans the time interval from 30 to 100 million years ago, by drill-

ing four sites on the flank of the Victoria Land basin. We will support the drilling program by providing rapid age-and-paleoenvironmental information through the study of calcareous nanofossils. Working at the Crary Science and Engineering Center (CSEC) at McMurdo Station, Antarctica, we will systematically sample the recovered sedimentary cores and analyze their calcareous nanofossil content. The preparation of an initial reports volume at the end of each of the two drilling seasons will include the results of our work as part of the initial characterization of the cores. The calcareous nanofossil biostratigraphic record spans the entire interval to be cored by the CRP.

Recent work on calcareous nanofossils from ocean drilling sites around Antarctica has yielded a refined zonation for the Paleogene and Upper Cretaceous of the Southern Ocean that will provide a high-resolution biostratigraphic framework for hemipelagic and pelagic sediments recovered by Cape Roberts drilling. This research, when combined with data from other fossil groups, magnetostratigraphic data, and other age-dating methods, will provide integrated age control that is essential for other geological investigations. In addition, calcareous nanofossils are excellent paleoenvironmental indicators for surface-water temperature and productivity. Statistical analysis of quantitative population census data will be used to infer paleoenvironmental variations during the Paleogene and Cretaceous. These data, in combination with data from other fossil groups and sedimentological studies, will be useful for assessing climatic change through the critical period of 30–100 million years before the present. (GL-057-O)

Initial characterization of organic matter in Cretaceous–Paleogene sedimentary rocks, Cape Roberts, Antarctica. *Richard M. Kettler, University of Nebraska at Lincoln.* We will characterize the organic geochemical nature of Cretaceous–Paleogene sedimentary rocks from drill core recovered during the Cape Roberts Project (CRP). The core will be described, curated, and sampled for scientific research. The CRP has the potential to answer significant questions regarding the history of the west antarctic rift system, the development of continental ice sheets in Antarctica during the Cretaceous and Paleogene, and the response of biota to climatic deterioration and the development of seaways.

Organic geochemical measurements are relevant to these issues and so are included in the initial core characterization studies. We will measure whole-rock carbonate carbon, total carbon, total nitrogen, and total sulfur, analyze the elemental composition of kerogen in selected samples, and perform gas chromatographic analysis of the solvent-soluble organic matter in selected samples. These data will be collected in the Crary Science and Engineering Center (CSEC) at McMurdo Station and will be reported as part of the initial core characterization study of the CRP. (GL-064-O)

Beryllium in granulite-facies pegmetites in Archean Napier Complex, Antarctica. *Edward S. Grew, University of Maine.* I will accompany the Japanese Antarctic Research Expedition (JARE) to study beryllium-enriched minerals in Enderby Land. Beryllium is a rare element in crustal rocks, and enrichments are especially unusual in granulite-facies (high temperature and pressure and relatively dry conditions) metamorphic rocks. I will study unique beryllium-enriched pegmatites in the Archean ultrahigh temperature (up to 1,000°C) granulite-facies Napier Complex in eastern Casey Bay, Enderby Land, East Antarctica. My primary objective is to test the hypothesis that the beryllium originated in the metasediments hosting the pegmatites rather than being a component of a pegmatitic magma.

My fieldwork will be conducted during the 1998–1999 austral field season in Enderby Land as a part of the Japanese Antarctic Research Expedition's project entitled "Structure and Evolution of East Antarctic Lithosphere." I

will use mineral and rock compositions to determine the evolution and conditions of crystallization of the pegmatites and their host rocks. The results of the project will provide some important insights into geochemical behavior of beryllium under the high-temperatures and low-water regime characteristic of the granulite facies. (GL-067-O)

Initial sedimentological characterization of the Late Cretaceous-Early Cenozoic drill cores from Cape Roberts, Antarctica. *Ross Powell, Northern Illinois University, and Lawrence Krissek, Ohio State University.* An international initiative to collect 1,500 meters of drill core from offshore of Cape Roberts, McMurdo Sound, Antarctica, is intended to provide a better understanding of antarctic history through the late Cretaceous and early Cenozoic. Events during this period, which extends from before the final breakup of Gondwanaland through the onset of antarctic glaciation, are ill-defined by existing data. The Cape Roberts Project (CRP) aims to provide new data about the development of the west antarctic rift system, the subsidence history of the Ross Sea, and ice-sheet fluctuations on Antarctica through this critical time interval.

CRP is partly an extension of previous drilling efforts on the antarctic continental margin and is partly a new initiative to document more completely the developmental history of the Ross Sea sector of the Antarctic and southern Pacific region through the late Cretaceous-early Cenozoic. It will draw on the successes of previous drilling efforts to document regional and environmental development with good spatial and temporal resolution, and it will also draw upon newly compiled geophysical databases.

CRP is a collaborative endeavor and is currently being supported by six participating countries. Tasks involved in our segment of the project will include initial description and characterization of the stratigraphic successions; these results will be used as the fundamental database for other analyses. The stratigraphic sections will also be used as reference sections for modeling observed marine and geophysical events. Initial sedimentological characterization of the successions will allow the definition of facies, the construction of facies sequences, and the interpretation of depositional environments through time. The end result of the proposed work will be an Ocean Drilling Program-style initial report for each drilling season. These reports will include the stratigraphic log, initial facies and depositional system interpretations, sedimentary petrologic and petrogenetic analyses, and initial clay mineralogical analysis. Information provided by other specialists will also be included in the reports, including biostratigraphy, magnetostratigraphy, geophysical logs, and geochemical interpretations. The initial interpretations of regional history will be presented in these reports, and the regional and global ramifications of this history will be highlighted. (GL-070-O)

Paleomagnetic and mineral magnetic characterization of drill cores from the Cape Roberts Project. *Kenneth Verosub, University of California at Davis, and Gary Wilson, Ohio State University.* The goals of the Cape Roberts Project (CRP) are to elucidate the history of fragmentation of the Pacific margin of Gondwanaland and the history of antarctic glaciation from Cretaceous through Oligocene time. The CRP will operate with an integrated science plan in which all of the initial scientific characterization of the cores will be done at McMurdo Station. The scientific activities associated with characterization of the cores will include magnetostratigraphy, biostratigraphy, petrography, mineralogy, and sedimentology. Age determination is of principal importance in such a project because a temporal framework is necessary to obtain a history of climatic and tectonic events.

Our research will determine high-quality paleomagnetic stratigraphy, with the appropri-

ate mineral magnetic studies, in support of the CRP. For the on-site magnetic studies, we will

- undertake logging of the whole-core magnetic susceptibility, which will help correlate the several overlapping cores to be recovered during the CRP;
- determine a magnetostratigraphic framework for dating the cores;
- undertake mineral magnetic and environmental magnetic studies to assess the reliability of the paleomagnetic signal; and
- determine if environmental magnetic properties yield information concerning changes in the tectonic, sedimentologic, diagenetic, or climatic influences on the sedimentary record at Cape Roberts.

Detailed environmental and mineral magnetic studies will also enable evaluation of the sediments as recorders of the geomagnetic field. The Cape Roberts records provide the potential to obtain rare high southern latitude constraints on geomagnetic field behavior. Paleomagnetic studies should also provide important data concerning crustal movements and rift development in the Ross Sea sector. (GL-075-O)

Stress field history, Cape Roberts, Antarctica. *Terry Wilson, Ohio State University.* As part of a collaborative research program, we will obtain the first age-calibrated stress-field history within the west antarctic rift system of Antarctica. The opportunity to acquire the stress data is provided by the international drilling program planned at Cape Roberts, which is located along the margin between the uplifted Transantarctic Mountains and the rifted crust of the Victoria Land basin. Information on the paleostress history of the Mesozoic and Cenozoic rift-basin fill will be obtained from the core and downhole logging of natural fractures and faults.

To establish the contemporary stress state, we will examine the cores for coring-induced stress fractures, and we will examine the borehole via downhole televiewer and dipmeter for any wellbore breakouts and fractures reactivated by the contemporary stress field. The stress data will be analyzed to address questions relevant to the paleo- and neotectonic evolution of the antarctic plate. The results will contribute to the resolution of outstanding questions such as the cause of the anomalous aseismicity of the continent, the geometry of stresses along the lithospheric boundary between the Transantarctic Mountains and the west antarctic rift system, and the evolution of the antarctic intraplate stress field and its relation to rifting episodes associated with Gondwanaland breakup. Contemporary stress data obtained from this research will be added to the global stress database and will help to fill the current void in the global stress coverage marked by the Antarctic Plate. (GL-079-O)

Initial palynological characterization of Cape Roberts drill cores. *Rosemary Askin, Ohio State University, and John Wrenn, Louisiana State University.* We will characterize palynomorph assemblages recovered from cores from the Cape Roberts Project (CRP). The CRP is designed to core submarine deposits in the western Ross Sea that range in age from middle Late Cretaceous through Miocene. Objectives include

- obtaining a late Cretaceous–Cenozoic paleoclimatic record,
- studying glacial-deglacial and eustacy cycles, and
- determining the Gondwanaland breakup and rifting history of the Ross Sea embayment.

Palynomorphs have proven to be invaluable tools for biostratigraphic and paleoenvironmental interpretation of younger Ross Sea sequences drilled in the Ross Sea embayment. They include both marine (dinocysts) and nonmarine (spores, pollen) types, record extensive and diverse geologic information, and

are preserved in a wide variety of lithofacies formed in various paleoenvironments. This project will provide initial palynological characterization of the CRP drill cores in collaboration with New Zealand palynologists. Analyses will focus on providing palynological input for an integrated biostratigraphic and paleoenvironmental framework based on all microfossil groups present. This framework is of fundamental importance to all future geologic, geophysical, and paleontologic studies conducted on the cores and in the drilling area. (GL-080-O)

Structure and sedimentology of the Beardmore Group, Antarctica: Latest Neoproterozoic to Early Paleozoic tectonic evolution of the east antarctic margin. *John W. Goodge, Southern Methodist University*. The Neoproterozoic to early Paleozoic transition (700–500 million years ago) was a critical period in Earth history. During this period, one supercontinent known as *Rodinia* was coalesced, then fragmented, prior to amalgamation of a second supercontinent referred to as *Gondwanaland*. During these events, major mountain building, continental erosion, species diversification, sea-level fluctuations, and changes in seawater composition took place. Continental margin sedimentary sequences from this era provide detailed records of sea-level fluctuations, faunal distributions, and postdepositional tectonism.

One of these sequences, the Beardmore Group in Antarctica, represents a significant element in the evolution of the east antarctic craton, yet very little is known about its depositional or tectonic history. Previous workers have suggested that the entire Beardmore Group is Neoproterozoic in age and that it records two distinct deformations, the well-known Ross orogeny and an earlier cryptic "Beardmore" orogeny. Reconnaissance field and geochronologic studies indicate that portions of the Beardmore Group are significantly younger than previously thought, and that it shows evidence for Ross deformation only. These preliminary data reflect uncertainty in the geologic relations of these rocks, and they indicate that the Neoproterozoic tectonic history for the region must be revised.

To improve understanding of its depositional history and its role in orogenic events shaping the outer margin of Gondwanaland, we will investigate the Beardmore Group. The project will include

- detailed field study of the stratigraphy, sedimentology, and structure;
- provenance (source) study of graywackes to constrain the depositional setting of the turbidites;
- determination of carbonate isotopic compositions for comparison with the global carbon-isotopic refinement of depositional age(s) through uranium-lead dating of detrital and igneous zircons; and
- constraint on the age(s) of deformation(s) with argon-isotope thermochronology.

During the 1998–1999 and 1999–2000 austral summers, we will test a recently proposed model for Beardmore Group deposition and deformation that involves latest Neoproterozoic–early Paleozoic(?) rift-margin sedimentation and structural inversion as an early expression of Ross activity. The results will help to resolve directly long-standing uncertainties in the geologic history of the Antarctic, and they will improve our understanding of global paleogeographic and plate-tectonic relations during supercontinent transformation at the close of the Proterozoic. (GO-014-O)

Antarctic surveying and mapping program. *Richard E. Witmer and Jerry L. Mullins, U.S. Geological Survey*. Production and publication of maps of Antarctica serve four U.S. policy objectives.

- Maps are essential for research, the principal expression of U.S. interest in Antarctica.

- Maps are also essential for operations and logistics in support of research or other activities (including search and rescue).
- Maps provide a knowledge base for support of future U.S. antarctic interests.
- By their authoritative coverage of large portions of the continent, maps serve to maintain the active and influential presence of the United States in Antarctica.

Surveying and mapping comprise a variety of activities necessary for the successful operation of a multifaceted scientific and exploration effort in Antarctica. Year-round data acquisition, cataloging, and data dissemination will continue in the Scientific Committee for Antarctic Research (SCAR) Library for Geodesy and Geographic Information. Field surveys are planned as part of a continuing program to collect data suitable for future satellite mapping programs and to densify extant data for 1:50,000-scale mapping programs. These maps will provide a base to portray scientific information, such as geologic data, in an especially accurate manner for expert analysis. They will also support future expeditions with a base to design scientific investigations and data-collection activities.

The U.S. Geological Survey has been selected to perform the nation's antarctic mapping because it is the designated agency for mapping of the United States and because it possesses the necessary expertise, antarctic experience (developed since 1959), and institutional continuity. A 1991 Memorandum of Agreement between the U.S. Geological Survey and the National Science Foundation established the purpose and tasking for the antarctic mapping. (GO-052-O)

Stability of land surfaces in the dry valleys: Insights based on the dynamics of subsurface ice and sand-wedge polygons. *Bernard Hallet, University of Washington.* We will study 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. The dynamic nature of climate has received growing public attention because of the occurrence of seemingly extreme weather events recently, and growing concerns about warming. El Niño and global greenhouse warming have become familiar topics in the news. In this context, understanding the inherent variability of Earth's climate and how humans can affect Earth's environment is becoming increasingly more important.

One important means of improving our understanding of the Earth's climate system is to treat the Earth as a natural laboratory and examine its past behavior. One of the most extreme changes in the Earth's climate system during the last few million years has been the transition from a warm period in the Pliocene to an ice-age world. Scientists believe that during this interval in Antarctica, relatively mild conditions gave way rapidly to intense glacial conditions that catalyzed the growth of 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 3–4 million years ago (during parts of the Pliocene). The mild conditions ended abruptly by 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 this project will contribute to resolving this important dilemma by introducing independent new evidence and insights derived from studies of the stability of ground ice and land surfaces in the dry valleys of Antarctica. We will study modern-day processes that have important implications for un-

derstanding 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 provide a rare glimpse at 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)

Antarctic search for meteorites. *Ralph Harvey, Case Western Reserve University*. Since 1976, ANSMET (the Antarctic Search for Meteorites program) has recovered more than 9,000 meteorite specimens from locations along the Transantarctic Mountains. Antarctica is the world's premier meteorite hunting ground for two reasons.

- Although meteorites fall in a random fashion all over the globe, the likelihood of finding a meteorite is enhanced if the background material is plain and the accumulation rate of terrestrial sediment is low, making the east antarctic ice sheet the perfect medium.
- Along the margins of this ice sheet, ice flow is sometimes blocked by mountains, nunataks, and other obstructions, exposing slow-moving or stagnant ice to the fierce katabatic winds. These winds, in turn, ablate away the ice, leaving behind a lag deposit of meteorites representing those that were sprinkled throughout the volume of ice lost to the wind. When such a process continues for a long enough time (10s or 100s of thousands of years), the concentration of meteorites can be spectacular.

Continued recovery of antarctic meteorites is important because they are the only currently available source of new, nonmicroscopic extraterrestrial material, and they provide essential ground truth about the composition of asteroids, planets, and other bodies of our solar system.

During the 1998–1999 field season, ANSMET will travel to the Graves Nunataks icefields near the top of the Scott Glacier, just east of the La Gorce Mountains. The general region is just a little "northeast" of where the Transantarctic Mountains reach their most southerly point. The region was visited by ANSMET for 11 days during the 1995–1996 field season, and although weather conditions reduced our searching to only a few days, the area proved its potential as a meteorite concentration when 33 specimens were recovered. ANSMET's objective for the 1998–1999 season is to return to these icefields and conduct systematic searching there, as well as reconnoiter several other icefields within a short traversing distance. (GO-058-O)

Tracking the west antarctic rift flank. *Paul Fitzgerald and Suzanne L. Baldwin, University of Arizona.* 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. Available fission track data from the Ellsworth–Whitmore Mountains block indicate that although most of the erosion exposing the rock strata (denudation) occurred there in Late Jurassic–Early Cretaceous, 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. The timing of uplift and denudation at key localities, plus the patterns of uplift and denudation along the west antarctic rift shoulder, revealed from the thermochronologic studies we will conduct, will be used to address this hypothesis.

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 and 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: namely, apatite fission track thermochronology and argon-40/argon-39 ($^{40}Ar/^{39}Ar$) thermochronology. During our first field season, we will be in the Thiel Mountains and travel from there to selected nunataks in the Ellsworth–Whitmore Mountains crustal block: Pagano Nunatak, Stewart Hills, Mount Moore, and Mount Woollard. Our second field season will be in the Horlick Mountains and the Ohio Range. Each field season will be followed by a year for sample preparation, data collection and analysis, and ongoing interpretation and presentation of results. 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. It is expected that additional data that integrates both fission track and $^{40}Ar/^{39}Ar$ thermochronology will lead to a better understanding of the geological evolution and relationship between the west antarctic rift system, its uplifted rift shoulder, and East and West Antarctica. (GO-059-O)

Heat and chemical exchange during the early stages of back-arc rifting in a polar region: Hydrothermal activity in Bransfield Strait, Antarctica. *Gary Klinkhammer and Martin R. Fisk, Oregon State University*. We will investigate hydrothermal venting in Bransfield Strait, between the South Shetland Islands and the Antarctic Peninsula. During earlier explorations in the strait, researchers found several sites where hot hydrothermal fluids emanate from the seafloor. An instrument package designed to detect and map the thermal and chemical signature that hydrothermal activity leaves on the overlying water column enabled scientists to locate the hydrothermal sites, which range in water depth from less than 200 meters to 1,300 meters and occur on the volcanic outcrops that periodically protrude through the sediment cover along the strike of the rift zone. These sites are aligned with the Deception Island caldera, which has active hot springs. Because these sites are the first submarine hydrothermal sites discovered in Antarctica, they represent unique research opportunities.

We will return to the strait to continue mapping and sampling these areas. Four compelling reasons lead scientists to believe that further exploration of vent systems in the Bransfield will yield exciting new information.

- The vent fluids and mineral deposits associated with venting in the Bransfield Strait (a back-arc system) appear to be unlike anything sampled so far from submarine vents.
- Preliminary evidence suggests that venting in the Bransfield Strait region occurs in two different volcanic substrates: andesite and rhyolite. This situation provides a natural laboratory for investigating the effects of substrate chemistry on vent fluid composition.
- The Bransfield Strait, isolated from the system of midocean ridges, has a relatively short history of rifting (approximately 4

million years). So, although the region straddles the Atlantic and Pacific, vent biota in the strait may well have a distinct genealogy. Biochemical information on vent species in the Bransfield will add to our knowledge of the dispersal of life in the deep ocean. In the past, such discoveries have led to the identification of new species and the isolation of previously unknown biochemical compounds.

- The fire-and-ice environments of hydrothermal sites in the Bransfield Strait may prove to be the closest analog for primordial environments on Earth and extraterrestrial bodies. The Bransfield Strait is one of the most productive areas of the world's oceans and lies close to the antarctic continent, far removed from the midocean ridge system. The combination of organic-rich sediment and heat produced by volcanism in this back-arc setting creates a situation conducive to unusual fluids, unique vent biota, and exotic hydrothermal deposits. (GO-060-O)

Maestrichtian Land Mammals of Vega Island, Antarctic. *Judd A. Case, St. Mary's University.* The Maestrichtian is considered to have been a key interval in the development of the land mammal fauna of southern Gondwanaland from Australia to Antarctica and South America. Until now, no Maestrichtian fossil land mammals have been found in any of these continents. The Lopez de Bertodano Formation of Vega Island, Antarctic Peninsula, shows the best potential of yielding remains of land mammals of Maestrichtian age in any southern Gondwanaland location. This project, a collaborative venture between St. Mary's University, the University of California at Riverside, and Argentine scientists, is designed to take advantage of that opportunity. Current theory predicts that the presently unknown Maestrichtian-age land mammal fauna in Antarctica should consist

- of a suite of nontherian taxa remnant from an Albian–Campanian fauna that occupied southern Gondwanaland from Australia to Antarctica to South America and
- of a complex of marsupials composed of relict peradectids and more derived early members of australidelphians.

The australidelphians should include early members of the (currently) South American Microbiotheriidae as well as early lineages of the (currently) Australian Peramelina, Dasyuromorphia, and Diprotodontia.

We will test this hypothesis in terms of the composition of the Maestrichtian land mammal fauna by conducting field research in Vega Island of the James Ross Island basin, Antarctic Peninsula. The location has been chosen on the basis of its known productivity in yielding Maestrichtian-age vertebrates (presbyornithid birds and hypsilophodont dinosaurs) in near-shore fine-grained shallow-water marine sandstones of the Lopez de Bertodano Formation that are amenable to dry or wet sieving collecting methods. Such methods have proven successful in obtaining fossil mammals from similar facies in the medial Eocene La Meseta Formation of Seymour Island.

This is a cooperative project with the Antarctic Institute, Argentina, (IAA) and the Museo de La Plata, Argentina (MLP). MLP personnel are collaborating on research into the evolutionary history of Late Cretaceous to early Tertiary therian mammals in South America and Antarctica and the potential relationship of these to the early population of Australia. The collaboration with IAA personnel is focused on litho- and biostratigraphy of the marine successions. The first grant year (1997–1998) focused on examining existing material. Years 2 (1998–1999) and 3 (1999–2000) will focus on fieldwork on Vega Island and follow up examination of any fossil discoveries. (GO-061-O)

The SWEAT model and Neoproterozoic–Cambrian orogenies in Antarctica: Tests from

the Nimrod Glacier region. *Anne Grunow, Ohio State University.* The Southwest U.S.–East Antarctica (SWEAT) model, which places the ancient continent Laurentia against East Antarctica and Australia in the Neoproterozoic, continues to be a controversial and exciting subject for researchers. We will test the SWEAT hypothesis by providing tighter age constraints on the purported Rodinia rifting-related sedimentary and volcanic rocks and determining a paleolatitude and paleopole for the central Transantarctic Mountains at this time.

Researchers believe that following rifting, these Neoproterozoic rocks were deformed during the poorly understood Beardmore and Ross orogenies. In addition to testing the SWEAT hypothesis, we will also provide further structural and geochronologic data to constrain the timing and kinematics of these deformational events. (GO-062-O)

A test for Tertiary-age deep fluvial incision and strongly melting valley-glaciers in the dry valleys using ground-penetrating radar: A pilot project. *Michael Prentice, University of New Hampshire.* During our project, we will study two types of large morphologic features in the McMurdo Dry Valleys using ground-penetrating radar (GPR), a technique not previously used on antarctic sediments.

- *Spurlike aprons.* Situated below tributary valleys that project into trunk valleys, spurlike aprons are inferred to be remnants of bedrock fluvial spurs that document preglacial fluvial incision of trunk-valley floors to sea level. If this interpretation is correct, the implication is that a major sector of the Transantarctic Mountains landscape is largely fluvial and not glacial in origin. For this to be true, the antarctic ice/climate system must have been restricted to its current high-polar state and so quite stable throughout the Tertiary ice ages. We think that the bedrock-spur interpretation is unsupported and, from the standpoint of form and structure analyses, unlikely. We will conduct a GPR survey of the best example, which is below Denton Glacier in eastern Wright Valley.
- *Large moraines.* Using form and structure analyses, we postulate that large moraines are stratified. If we are correct, these features reflect deposition from valley glaciers with strong melting margins. Deposition of this type implies that at least the regional antarctic ice/climate system was in a subpolar state that was warmer, wetter, and more dynamic than the high-polar state. Using GPR, we will study two such moraines in central McKelvey Valley possibly associated with glaciolacustrine sediment and one such moraine in central Wright Valley associated with glaciomarine sediment. The internal composition of these features is presently unknown.

In addition, we will use conventional surficial geologic techniques to examine a few distinctive drift patches that crop out asymmetrically on trunk-valley walls. These patches appear to be traceable into high alpine valleys and so may have been deposited from expanded alpine glaciers that merged with trunk-valley glaciers. If we are correct, these patches record the synchronous advance of alpine and trunk-valley glaciers. A synchronous advance implies that the coeval climate was significantly wetter and warmer than in the high-polar state. (GO-063-O)

Holocene paleoenvironment change along the Antarctic Peninsula: A test of the bipolar/solar signal. *Eugene Domack, Hamilton College.* During this multidisciplinary, multi-institutional project, we will work to elucidate the detailed climate history of the Antarctic Peninsula during the Holocene epoch (the last 10,000 years). The Holocene is an important, but often overlooked, portion of the antarctic paleoclimatic record because natural variability in Holocene climate on timescales of decades to millennia can be evaluated as a model for our present "interglacial" world.

Our project builds on over 10 years of prior investigation into the depositional processes, productivity patterns, and climate regime of the Antarctic Peninsula. This previous work identified key locations that contain ultra-high-resolution records of past climatic variation. These data indicate that solar cycles operating on multicentury and millennial timescales are important regulators of meltwater production and paleoproductivity. These marine records can be correlated with ice-core records in Greenland and Antarctica.

We will study sediment dispersal patterns across the Palmer Deep region. The objective is to understand the present links between the modern climatic and oceanographic systems and sediment distribution. In particular, additional information is needed regarding the influence of sea ice on the distribution of both biogenic and terrigenous sediment distribution. Sediment samples will be collected with a variety of grab sampling and coring devices. Two additional objectives are the deployment of sediment traps in front of the Muller Ice Shelf in Lallemand Fjord and seismic reflection work in conjunction with site augmentation. The goal of sediment-trap work is to address whether sand transport and deposition adjacent to the ice shelf calving line results from meltwater or aeolian processes. In addition, the relationship between sea-ice conditions and primary productivity will be investigated. The collection of a short series of seismic lines across the Palmer Deep basins will fully resolve the question of depth to acoustic basement. (GO-072-A)

Dry valleys seismograph project. *Bob Reynolds, U.S. Geological Survey.* The dry valleys seismograph project was established in cooperation with the New Zealand Antarctic Program to record broadband, high-dynamic-range digital seismic data at a remote site removed from the environmental and anthropogenic noise on Ross Island. The Wright Valley offers one of the few locations on the continent where bedrock can be accessed directly. The station consists of a triaxial broadband borehole seismometer at 100 meters depth and a vertical short-period instrument at 30 meters depth. These data are digitized at the remote location and then are radio-frequency telemetered via repeaters on Mount Newell and Crater Hill, eventually to the recording computer located in the Hatherton Laboratory at Scott Base. Although archived at Scott Base for backup purposes, the data do not stop flowing at this point. The data pass via a point-to-point protocol link to the Internet at McMurdo Station and then on to the Albuquerque Seismological Laboratory for distribution to the seismological community. This data set has beautifully complemented the data from the other seismic stations that the Albuquerque Seismological Laboratory operates on the antarctic continent at Amundsen–Scott South Pole Station, Palmer Station, and the Australian station, Casey. (GO-078-O)

Global positioning system measurements of crustal motion in Antarctica. *Barclay Kamb, California Institute of Technology.* We will establish a global positioning system (GPS) geodetic network in the Transantarctic Mountains of Antarctica to measure vertical and horizontal crustal velocities. The vertical crustal velocities measured by GPS reflect the viscoelastic response of the solid Earth to antarctic deglaciation. Data from this GPS network will be used to test models of late Pleistocene–early Holocene versus late Holocene deglaciation of Antarctica. These data will also constrain the length of time over which the antarctic ice sheet disintegrated and the distribution of the peak glacial load. A mid-Holocene deglaciation model produces a predicted uplift pattern near the Transantarctic Mountains that can be measured by high-precision GPS geodetic measurements within a time span of 4 years.

Horizontal deformation induced by rebound will also be measured. These data will also help constrain present-day changes in antarctic ice mass by monitoring the elastic defor-

mation of the lithosphere resulting from ongoing glacial loading and unloading. The lithospheric response to ongoing ice-mass changes is predicted to be an order of magnitude less than the viscoelastic response to late Pleistocene–Holocene deglaciation. Tectonic uplift rates are also predicted to be very small compared to the predicted rebound signal for this region. Baselines across faults in the Transantarctic Mountains may capture coseismic motion, if an earthquake were to occur, or aseismic slip.

During the 1998–1999 field season, we will visit existing autonomous GPS station (AGS) sites at Mount Coates and Mount Cox to perform maintenance, upgrades, and repairs. We will also perform geodetic surveys at Mount Coates and Mount Cox to assess site stability and to ensure recovery of the site in case the original pin is damaged or unstable. Finally, we will search for areas that would be suitable for future sites in the AGS network, and we may install a new AGS this season.

The AGS network sends daily data reports to McMurdo Station. The network is designed to be a permanent installation that will continue to monitor motion in the region beyond the term of this project. Advanced processing techniques have been employed to increase the accuracy of the crustal velocity measurements, especially for the vertical component. These include orbit modeling, troposphere correction, ionosphere correction, and extraction of annual and seasonal solid Earth and ocean tidal signals. (GO-082-O)

Mechanism and timing of west antarctic ice sheet retreat at the end of the last glacial maximum. *John B. Anderson, Rice University.* We will continue a long-term investigation of the continental shelf sediments to examine the configuration of the west antarctic ice sheet during the last glacial maximum, the events and mechanisms involved in its retreat, and the timing of retreat. Our project involves

- characterizing variations in the ice-sheet grounding zone in a latitudinal transect extending from Ross Sea to Bransfield Basin,
- reconstructing conditions at the ice/bed interface before and after ice-sheet retreat, and
- radiometrically dating ice-sheet retreat along this transect.

Detailed seafloor imagery (multibeam and deep-tow side-scan sonar), high-resolution seismic reflection profiles, and sediment cores will be used to map and characterize prior grounding zones.

Of particular concern are features that indicate the amount and organization (channelization) of basal meltwater and the extent of bed deformation that occurred in different ice streams. The timing of ice-sheet retreat provides information about the link between Northern and Southern Hemisphere ice expansion and the role of eustasy in ice-sheet decoupling. Our research should lead to better predictive models to determine which ice streams are most unstable and likely, therefore, to serve as "weak links" in the long-term behavior of west antarctic ice sheet. (GO-083-O)

Scotia Arc GPS Project (SCARP). *Lawrence A. Lawver, Ian W. Dalziel, and Frederick W. Taylor, University of Texas at Austin.* Antarctica, Earth's most isolated continent, is surrounded by actively spreading ridges except in the South American sector. The motion of South America with respect to Antarctica is latitudinal and left-lateral at approximately 22 millimeters per year and is distributed along the boundaries of the intervening Scotia Plate. A prominent but discontinuous bathymetric high, known as the Scotia Ridge surrounds the Scotia Plate on three sides, and includes some continental material detached from the South America and Antarctica, but its eastern closure is a volcanically and seismically active group of is-

lands, the South Sandwich arc, that is separated from the Scotia Plate by a vigorously spreading back-arc ridge. The entire east-closing, locally emergent bathymetric feature joining the two continents is known as the Scotia Arc.

The D-shaped Sandwich Plate and arc appear to be moving rapidly east with respect to both South America and Antarctica, thereby for the first time introducing a subduction system into the otherwise rift-bounded South Atlantic Ocean basin. During this Scotia Arc GPS Project (SCARP), we will use the global positioning system (GPS) to measure the plate motions between South America, Antarctica, and Africa, and around the Scotia Arc using multimodal occupation strategy (MOST). We will set up permanent GPS receivers at a small number of sites in South America and Antarctica and use additional receivers to position numerous stations relative to this continuously operating network. Two seasonally occupied stations in the South Sandwich Islands will be tied to permanent GPS sites in South America, Antarctica, and Africa and to intervening stations in the Falkland, South Georgia, and South Orkney Islands that will be occupied occasionally by our British collaborators.

During the initial 3 years, the South Sandwich Arc motion will be easily resolved, and using roving stations in the Antarctic Peninsula–South Shetland Islands area, it should be possible to determine if extension is occurring across Bransfield Strait. We will also construct a relatively dense subnetwork in Patagonia/Tierra del Fuego and a moderately dense subnetwork in the Antarctic Peninsula.

The objectives of SCARP are to determine

- the relative motions of the Antarctic, South American, Scotia, and South Sandwich plates;
- strain partitioning within the South America–Scotia Plate boundary zone, Tierra del Fuego;
- the rate of extension across the volcanically active Bransfield trough and the present rate of uplift or subsidence of the extinct South Shetland Islands volcanic arc; and
- with our British colleagues, the rate of roll-back of the South Sandwich Trench in a South American-African framework. (GO-087-O)

Logistics support for global seismic station at the South Pole. *Rhett Butler, Incorporated Research Institution for Seismology*. With logistics support from the National Science Foundation, we will install, maintain, and operate IRIS seismic equipment at Amundsen–Scott South Pole Station and at Palmer Station, Antarctica.

The Incorporated Research Institution for Seismology (IRIS) is a consortium of research institutions created to implement critically needed national facilities for support of seismological research on the Earth's interior in the coming quarter century. With a membership of 57 universities, IRIS includes nearly all U.S. universities that have seismological research programs.

IRIS has developed a 10-year plan for the implementation of a global seismographic network (GSN) of about 100 broadband, digital, wide-dynamic-range stations that transmit data via satellite in a broadcast mode so that any site on Earth can access the complete global data set, if desired, in real time. The installation of a state-of-the-art, broadband, digital seismic observation for the South Pole is part of an effort by the National Science Foundation to improve seismic instrumentation globally. A modern seismic station at South Pole and Palmer will provide a crucial link in the global seismic network and is essential for seismic studies of the antarctic continent. (GO-090-O and GO-091-O)

A broadband seismic experiment for study of the tectonics and structure of the Antarctic Peninsula and Scotia Sea. *Douglas Wiens and Dapeng Zhao, 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 the recent cessation of volcanism along the South Shetland Trench and onset of volcanism and rifting in the Bransfield Strait, the possible presence of diffuse deformation and/or microplates in the Drake Passage region, and fast back-arc spreading behind the South Sandwich arc.

We constitute the U.S. component of an international effort to study the seismotectonics and seismic structure of the Antarctic Peninsula and Scotia Sea regions using a large-scale deployment of broadband seismographs that began during the 1996–1997 field season. The project will deploy nine broadband PASSCAL seismographs for 2 years in the Antarctic Peninsula region, southernmost Chile, and South Georgia Island. The following questions will be addressed.

- Is there seismological evidence, in the form of either subduction zone earthquakes or seismic structure, for current subduction beneath the Antarctic Peninsula?
- Is there evidence from seismic anisotropy for large-scale mantle flow around South America into the South Atlantic?
- Are regional earthquakes and focal mechanisms consistent with current kinematic Scotia Plate models, which imply compressional deformation in the Drake Passage region?
- What is the deep structure of the South Sandwich subduction zone?
- What is the seismological structure of active back-arc spreading centers in the Bransfield Strait and South Sandwich regions?

Answering these questions will help to constrain important tectonic questions such as the cause of plate motion changes, what processes initiate back-arc spreading, and the relationship between mantle flow and surface tectonics. (GO-097-O)

Study of the structure and tectonics of the South Shetland Trench and Bransfield back-arc using ocean-bottom seismographs. *LeRoy M. Dorman, Scripps Institution of Oceanography.* The South Shetland Arc/Bransfield Strait region presents an intriguing and unique tectonic setting that exhibits slowing of subduction, cessation of island arc volcanism, as well as the apparent onset of back-arc rifting occurring within the last 4 million years. To investigate the seismicity and tectonics of the region, we will use a 5-month deployment of 14 ocean-bottom seismographs (OBSs) to complement and extend a deployment of six broadband land seismic stations that were successfully installed during early 1997. The OBSs include two instruments that have broadband sensors; all have flowmeters for measuring and sampling hydrothermal fluids.

The OBSs will be used to examine many of the characteristics of the Shetland–Bransfield tectonic system, including the following.

- The existence and depth of penetration of a Shetland Slab.
- The possibility of shallow Shetland trench seismicity.
- The mode of deformation along the Bransfield rift.
- The identification of volcanism and hydrothermal activity.
- The possibility that upper mantle structure of the Bransfield is evidence of partial melting. (GO-135-O)

Antarctic network of unattended broadband integrated seismometers (ANUBIS). *Sridhar Anandakrishnan, Pennsylvania State University.* The antarctic crust and mantle composition

and geometry are poorly known. The primary method for studying the crust, upper mantle, and the deeper asthenosphere is interpretation of seismic data, either by "active" methods acquired through use of explosives or by "passive" means, using natural sources and interpreting various earthquake phase arrival times and amplitudes. Integrating passive and active seismology can result in efficient use of resources to produce detailed images of the lithosphere. Our project will develop a passive seismic network for the antarctic interior.

The Antarctic is a gaping hole in the rapidly improving field of global seismic imaging and tomography. On this huge continent, there are only eight broadband seismic observatories. Further, with the exception of South Pole, all of 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 FDSN (Federation of Digital Seismograph Networks) and on the order of 1,000 in national networks not yet integrated into the FDSN.

We will develop and deploy 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 the stations (including the existing peripheral ones) can be used for seismic tomographic analysis to detail lateral variations in these properties. Six 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 five stations will be in West Antarctica and will be powered and heated by wind turbines during the austral winter. (GO-180-O)

Ferrar Large Igneous Province Study (FLIPS). *Philip Kyle, New Mexico Institute of Mining and Technology*. This international collaborative research project will involve the New Mexico Institute of Mining and Technology and the British Antarctic Survey (BAS). The objective is to understand the origin, emplacement, and evolution of antarctic Jurassic (180-million-year-old) basaltic rocks, which formed when the Gondwanaland supercontinent started to disintegrate. We will test a new unified model for this 180-million-year-old magmatic activity in which the magmatism is caused by a single mantle superplume and is a major factor in continental rifting.

In Antarctica, the Jurassic basaltic rocks are divided into two provinces: Ferrar Large Igneous Province (FLIP) and the Dronning Maud Igneous Province (DMIP). (The official U.S. name for Dronning Maud Land is Queen Maud Land. The foreign term will be used for this project because it is a collaboration with BAS.) The origin of the FLIP is problematical and a plume origin has generally been discounted because of its lateral distribution over 3,000 kilometers along the Transantarctic Mountains and also in southern Australia. The FLIP is characterized by unusual geochemical compositions, which have been attributed to their origin from an enriched mantle source. In the model we are investigating, the FLIP magma would have been significantly contaminated in an upper continental crustal magma chamber (probably the Dufek Intrusion) whereas the DMIP has distinctly mantle-like chemical characteristics but still shows some evidence of modification by crustal material.

In this research, we will examine and sample the rocks of the DMIP and rocks of the FLIP in the Theron and Pensacola Mountains and Dronning Maud Land and conduct an integrated study of the age, geochemistry, and

structural relationships of the FLIP and DMIP. Radiometric age determinations will examine the age relationship between the FLIP and DMIP. Models for upper crustal contamination of the FLIP magmas will be tested using isotopic studies and geochemical modeling. Other studies, conducted by our BAS collaborators, include a regional aerogeophysical survey to determine the size and shape of the Dufek Intrusion and a detailed survey to search for a feeder dike system from the body. (GO-182-O)

UNAVCO's global positioning system receiver. *Randolph H. Ware, University Center for Atmospheric Research.* UNAVCO, a consortium of 30 U.S. universities, manages a satellite facility at McMurdo Station and provides equipment and logistical assistance to earth scientists making use of the global positioning system (GPS) for research in crustal dynamics, earthquake, volcano, and global change research. Using GPS, vector baselines between receivers separated by 100 kilometers or more are routinely measured with 1 centimeter (or 100 parts per billion) accuracy. UNAVCO is also able to support researchers in investigations of global, regional, and local crustal motions where maximum accuracy (in the millimeter range) of baseline measurement is required. In addition to supporting researchers in the U.S. Antarctic Program, UNAVCO's equipment and expertise also support operations at McMurdo Station and Taylor Valley.

GPS measurements can be completed using portable equipment in a few hours or less. The ability to make such measurements has found immediate applications in research on global plate tectonics, earthquake mechanics, volcano monitoring, and regional tectonics.

The UNAVCO facility in Boulder, Colorado, offers a complete support program for university-based investigators including

- preseason planning,
- GPS equipment,
- training,
- field support and technical consultation, and
- data processing and archiving.

UNAVCO also represents the academic research community and acts as a central clearinghouse for information on the scientific applications of GPS. As a part of its service to investigators, UNAVCO tests GPS equipment and techniques and works to improve GPS surveying accuracy. (GO-295-O)

Support Office for Aerogeophysical Research (SOAR). *Donald D. Blankenship, University of Texas at Austin.* The function of the Support Office for Aerogeophysical Research (SOAR) is to facilitate aerogeophysical research over continental Antarctica to help researchers understand the dynamic behavior of the ice sheet and the nature of the lithosphere beneath the ice sheet. SOAR supports peer-reviewed research requiring high-precision laser altimetry, gravity, magnetics, and navigational data sets.

SOAR provides information essential to site selection decisions for a west antarctic ice core as well as critical information for selection of locations of over-snow seismic transects. SOAR represents a unique experiment in research support for the U.S. Antarctic Program. It has the potential to revolutionize the conduct of earth science and glaciology research in Antarctica. (GS-098-O)

Glaciology

Recovery and science coordination of an ice core at Siple Dome, Antarctica. *Kendrick Taylor, Desert Research Institute.* Our project, which will recover a 1,000-meter ice core from Siple

Dome, Antarctica, and coordinate a science management office for the scientific program, is part of the West Antarctic Ice Sheet (WAIS) program, which seeks to understand the current behavior of the west antarctic ice sheet and to decipher its past climate history. Siple Dome is located between ice streams C and D and is well situated to investigate coastal climate conditions and the dynamics of the Siple Coast ice streams, which drain the west antarctic ice sheet. The annual accumulation at the site is 7 to 11 centimeters of ice per year, and it is anticipated that annual layers will be identifiable to an age of at least 6,000 years. The length of the usable climate record will extend to at least 80,000 years.

We provide the background for the Siple Dome drilling program, develop the opportunity for individual scientists to work on the ice core, and establish a science coordination office to coordinate the activities of the various organizations involved in the project, including the National Science Foundation (NSF), the Polar Ice Coring Office (PICO), Antarctic Support Associates (ASA), and the National Ice Core Laboratory (NICL). (II-152-O)

Near-surface processes affecting gas exchange: West antarctic ice sheet. *Mary Albert, Cold Regions Research and Engineering Laboratory.* We will examine the physical processes that affect how heat, vapor, and chemical species in air are incorporated into snow and polar firn. The processes include advection, diffusion, and the effects of solar radiation penetration into the snow. An understanding of these processes is important because they control the rate at which reactive and nonreactive chemical species in the atmosphere become incorporated into the snow, firn, and polar ice and, thus, will affect interpretation of polar ice-core data. Currently, the interpretation of polar ice-core data assumes that diffusion controls the rate at which chemical species are incorporated into firn. We will determine whether ventilation, or advection of the species by air movement in the firn, and radiation penetration processes have a significant effect.

Field studies at the two west antarctic ice sheet deep-drilling sites will be conducted to determine the spatial and temporal extent for key parameters and boundary conditions needed to model the advection, conduction, and radiation transmission/absorption processes. An existing multidimensional numerical model is being expanded to simulate the processes and to serve as the basis for ongoing and future work in transport and distribution of reactive chemical species. (II-155-O)

Physical and structural properties of the Siple Dome Core. *Anthony Gow, Cold Regions Research and Engineering Laboratory.* We will investigate the visual stratigraphy, index physical properties, relaxation characteristics, and crystalline structure of ice cores from Siple Dome, West Antarctica. Our investigation will include time-sensitive measurements that must be initiated at the drill site on freshly drilled cores. This need will be especially pressing for cores from the brittle ice zone, which is expected to constitute a significant fraction of the ice core. The brittle zone includes ice in which relaxation, resulting from the release of confining pressure, is maximized and leads to significant changes in the mechanical condition of the core that must be considered in relation to the processing and analysis of ice samples for entrapped gas and chemical studies. This relaxation will be monitored via precision density measurements made initially at the drill site and repeated at intervals back in the United States.

Other studies will include measurement of the annual layering in the core to as great a depth as visual stratigraphy can be deciphered, crystal size measurements as a function of depth and age, c-axis fabric studies, and analysis of the physical properties of any debris-bearing basal ice and its relationship to the underlying bedrock. Only through careful documentation and analysis of these key

properties can we hope to assess accurately the dynamic state of the ice and the age-depth relationships essential to deciphering the paleoclimate record at this location. (II-165-O)

The evolution of a polar ice sheet in East Antarctica. *George Denton, University of Maine at Orono.* We hope to determine the sequence and chronology of events that led to the development of the antarctic ice sheet. A continental-scale ice sheet probably first developed in East Antarctica close to the Eocene-Oligocene boundary under temperate climatic conditions. We hope to learn, from landscape analysis (with a numerical chronology), when (and why) these early temperate conditions gave way to a polar environment in Antarctica.

From previous fieldwork and recent photographic analysis, an extensive relict landscape (older than 17 million years) with landforms and erosional features characteristic of temperate glaciation has been delineated. This relict landscape has been called the *Sessrumnir erosion surface*, and it extends over 3 degrees of latitude and covers almost 10,000 square kilometers in three fault blocks of the Transantarctic Mountains (Convoy, Dry Valleys, and Royal Society). From this relict land surface, we will collect data that record Middle and Early Miocene glacial history and paleoclimate. The results should allow an identification of the transition from temperate to polar conditions. Our work will involve landscape analysis, stratigraphy of glacial deposits, and argon-40/argon-39 dating of volcanic ashfalls. The rates at which erosion is exposing the rock strata (denudation) will come from fission-track analyses and from exposure-age analyses of bedrock surfaces and erratic boulders. The overall results will elucidate the origin and stability of the polar antarctic cryosphere. (IO-156-O)

Basal conditions of ice stream D and related borehole studies of antarctic ice stream mechanics. *Barclay Kamb, California Institute of Technology*. To obtain observational evidence of 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 stream B and C for measurement of the physical conditions and sampling of materials at the base of the ice, where lubrication of the rapid flow is thought to take place. In the 1998–1999 season, the scope of our study will be widened to include ice stream D, situated some 100 kilometers north of C. Several boreholes will be drilled by the hot-water drilling method to measure the basal water pressure, basal water transport, basal melt rate, basal sliding velocity, deformation, and sedimentology including fossil content of subglacial till if present, basal shear strain rate in the ice, and ice temperature profile. Our objective is to find out if the physical conditions and materials observable by borehole geophysics at the base of ice stream D are consistent with those found in ice stream B and point to a common basal mechanism of ice streaming. We will obtain hot-water drilled ice cores to reveal the internal structure of the ice stream for evaluation of the basal shear stress and rock debris content of the ice and for comparison with B and C. (IO-157-O)

Digital imaging for ice core analysis. *Joan J. Fitzpatrick, U.S. Geological Survey, National Ice Core Laboratory*. Over 2 years we will develop the technology and methodology for digitizing photographs and analyzing thin sections from ice cores. Besides applying digital technology to whole-core stratigraphy, we will investigate the use of digital photography, image enhancement and image processing. The thin section analysis will be piloted with samples already in hand from the Taylor Dome ice core. During the 1998-1999 austral summer, we will identify visual characteristics of ice from the West Antarctic Ice Sheet near Siple Dome. As the deep core is recovered it will be cut, sectioned, photographed, and analyzed. The original digital images, along with the original annotated data files, will be distributed to Siple Dome principal investigators to

use in interpreting their own data. All software and hardware acquired for this project will become part of the permanent equipment inventory at the U.S. National Ice Core Laboratory and will be available for use by clients at the facility. (II-160-O)

Internal stratigraphy and basal conditions at the margins of active ice streams of the Siple Coast, Antarctica. *Charles F. Raymond, University of Washington.* To examine the geometry of the internal layering and the presence or absence of thawed zones outside the margins of active ice streams B and E and across the flow band feeding ice stream D, we will use surface-based radio-echo sounding.

Melting in the marginal shear zone and/or on the bed outside an ice stream relates to the amount of support of the ice stream from the sides compared to the bed and the conditions that limit expansion of its width. Radar observations will be extended over the crest of adjacent inter-ice-stream ridges (B/C and D/E) and areas next to the flow band in the onset of D. The purpose is to examine internal layering indicative of the histories of these areas adjacent to ice streams and to determine whether, in the past, ice streams have expanded into these presently stable areas. These goals concerning the physical controls and history of ice-stream width relate to how the discharge of ice streams has changed in the past and could change in the future to affect sea level. (IO-163-O)

Ice dynamics, the flow law, and vertical strain at Siple Dome. *William Harrison, University of Alaska Fairbanks.* Our 3-year project will measure the vertical strain rate as a function of depth at two sites on Siple Dome, Antarctica. Iceflow near a divide such as Siple Dome is unique because it is predominantly vertical. As a consequence, the component of ice deformation in the vertical direction, the *vertical strain rate,* is dominant. Its measurement is, therefore, important for the calibration of dynamic models of iceflow. Two different, relatively new, high-resolution systems for its measurement in hot-water drilled holes will be employed. The iceflow model resulting from the measurements and flow-law determination will be used to interpret the shapes of radar internal layering in terms of the dynamic history and accumulation patterns of Siple Dome over the past 10,000 years. The resulting improved model will also be applied to the interpretation of the thicknesses of the annual layers (to produce annual accumulation rates) and borehole temperatures from the ice core drilled at Siple Dome. The results should permit an improved analysis of the ice core, relative to what was possible at recent coring sites in central Greenland. This is a collaborative project between the University of Alaska, the University of California at San Diego, and the University of Washington. (IO-164-O)

Stress transmission at ice-stream shear margins. *Ian Whillans, Ohio State University.* Our 3-year project will study stress transmission at three ice-stream shear margins. The objectives are

- to determine how much of the motion of the ice streams is controlled from the inter-stream ridges,
- to compare the magnitude of this lateral drag with the driving stress on the ice stream and with ice-stream width, and
- to determine whether lateral drag support is associated with lateral migration of the margin.

The net force per unit ice-stream length transmitted between ridge ice and ice-stream ice will be deduced from measurements of strain rate.

Fieldwork will entail Twin Otter installation of remote camps that will each be occupied for about 12 days during the first season and about 6 days during the second. The Support Office for Aerogeophysical Research in Antarctica (SOAR) facility will conduct aerial sur-

veys to determine ice thickness on the interstream ridges, as well as the ice thickness and surface slope on the ice streams. The field measurements will be complemented by repeat SPOT imagery of ice stream E adjacent to the field site, to allow velocities in the ice-stream side of the margin to be determined. Comparing these velocities to those obtained from the strain-grid surveys will provide an estimate of the amount of softening of the ice in the margins. (IO-169-O)

West Antarctic Glaciology V. *Robert Bindschadler, National Aeronautic and Space Administration.* Our 3-year project is designed to answer two questions of critical importance to understanding the iceflow of the west antarctic ice sheet:

- Are the Ross ice streams (B, D, and E) currently surging?
- What has been the buttressing effect of an enlarging Crary Ice Rise on the flow of ice stream B?

Both questions will be answered based on a combination of data collected on the surface, from the air, and from space. Although many past indications of change in West Antarctica have been based on interpolations and calculations with large uncertainties, these measurements will be direct, making use of rapid and accurate global positioning system data to minimize field logistic requirements. Direct measurement of expected thinning in the upper portion of ice stream D and repeated satellite image measurements at the heads of ice streams B, D, and E to detect the inland migration of the onset area (as is required by sustained surging) will enable a test of a surge hypothesis developed by Bindschadler. The buttressing impact of Crary Ice Rise on ice stream B's flow will be studied by comparing new measurements of ice thickness, surface elevation, and velocity with data collected during the 1950s, 1970s, and 1980s, thus providing a multidecadal time series of change. (IO-173-O)

Late Pleistocene inland west antarctic ice sheet elevations at Mount Takahe. *William C. McIntosh, Thomas I. Wilch, and Nelia W. Dunbar, New Mexico Institute of Mining and Technology.* Our objective is to establish a detailed record of volcanism at Mount Takahe volcano in Marie Byrd Land and provide absolute age and elevation data on inland paleoice levels on the west antarctic ice sheet during the most recent glacial cycle.

Previous work at Mount Takahe documented volcanic deposits located on the lower flanks that were erupted beneath, at, or above the level of the west antarctic ice sheet. These deposits have been dated to between 104,000 and 7,000 years before present and suggest that the inland west antarctic ice sheet was much higher during the last glacial cycle than it is today.

The inland paleoice level can be used to test conflicting hypotheses about the configuration of the west antarctic ice sheet in the late Wisconsin and the role of ice-sheet retreat in global sea-level rise. Well-constrained limits on inland paleoice levels during the past 100,000 years can be compared with global records of climate change to assess the relationship between the west antarctic ice sheet and the climate system. Finally, precisely dated paleoice levels can be used as "hard" input data for numerical models of ice-sheet dynamics. (IO-277-O)

SOAR laser: Calibration and first measurement for ice-sheet change detection. *Ian Whillans, Ohio State University.* During a 3-year study, we will make precise and accurate measurements of the elevation of the antarctic ice sheet to detect ongoing changes in the surface of the ice sheet. The location and pattern of change discovered may be used to deduce the causes of the changes. Suitable equipment for these measurements are part of the Support Office for Aerogeophysical Research in Antarctica (SOAR) facility. We will evaluate the quality and calibrate the measurements to be made by SOAR. Tests will be made both

while the aircraft is parked and during flights over ground-surveyed sites near the aircraft base camp. After the validation and calibration is complete, a limited measurement program to detect time changes in surface elevation of glaciologically interesting sites will be started. At the conclusion of the program, the capability of the SOAR facility to determine surface elevation accurately and precisely will be established. SOAR will then be useful to all investigators who are interested in precision mapping and detection of change in the antarctic ice sheet. (IS-166-O)

Ocean and climate studies

Antarctic Meteorological Research Center: 1996–2000. *Charles R. Stearns and John T. Young, University of Wisconsin at Madison.* The Antarctic Meteorological Research Center (AMRC), one of three research centers in the Science and Engineering Technology Center at McMurdo, is a resource for meteorological research and a test bed for improving operational synoptic forecasting.

The Man-Computer Interactive Data Access System (McIDAS), a versatile computer-based system for organizing, manipulating, and integrating antarctic environmental data, forms the basis of AMRC. It captures the flow of meteorological information from polar-orbiting satellites, automatic weather stations (AWSs), operational station synoptic observations, and research project reports. It also receives environmental data products, such as weather forecasts, from outside Antarctica and acts as a repository for existing archived databases.

Phase I began in the 1992–1993 summer season and consisted of the installation and operation of work stations capable of manipulating and displaying Advanced Very High Resolution Radiometer (AVHRR) data based on the existing satellite imagery acquisition system. This effort was followed by the acquisition and integration of a system that provided data collection, data display and archiving, scientific applications, network communications, and remote-user access.

The McIDAS system, developed at the University of Wisconsin in the mid-1970s, receives meteorological data from various sources: standard synoptic observations, radiosonde profiles, satellite-based visible and infrared imagery, atmospheric profiles inverted from multispectral scanning sensors, and nonstandard data such as thematic ozone mapping spectrometer (TOMS) data, synthetic aperture radar (SAR) sea-ice information, and the AWS network observations. The system automatically registers, calibrates, and locates (by geographical coordinates) the input information and allows a user at a work station to manipulate the database. The manipulations include sectorization, false color, enhancements, brightness stretching, overlays, looping, and differencing and are quite definitely keyed to synoptic meteorological research and weather forecasting. The antarctic system is based primarily on data streams provided by polar orbiters (AVHRR/HRPT and DMSP), since the look angles from geostationary satellites are so extremely low. The full utilization of McIDAS capabilities in producing meteorological data products useful in both forecasting and research will include a data transfer and communications capability to, for example, the Australian Bureau of Meteorology (ABOM), the University of Wisconsin Space Science and Engineering Center (SSEC), the Fleet Numerical Oceanography Center (FNOC) in Monterey, and the European Center for Medium Range Weather Forecasts (ECMRWF) in Reading, U.K. (OO-202-O)

Atmospheric oxygen variability in relation to annual-to-decadal variations in terrestrial and marine ecosystems. *Ralph F. Keeling,*

Scripps Institution of Oceanography. In this project, we will continue measuring the concentration of molecular oxygen and carbon dioxide in air samples. The samples are collected at a series of baseline sites around the world. The data will lead to improved estimates of the net exchange of carbon dioxide with land biota and the oceans, marine photosynthesis rates, and atmospheric mixing rates. These results are needed to improve our understanding of the processes regulating the buildup of carbon dioxide in the atmosphere as well as our understanding of the processes regulating marine and terrestrial ecological functions in relation to various agents of change, especially climate changes. In support of the measurement program, we will develop absolute standards for oxygen in air to ensure stable long-term calibration. We will conduct a survey of the oxidative oxygen/carbon ratios of terrestrial and marine organic carbon to improve the quantitative basis for linking the oxygen and carbon dioxide geochemical cycles. (OO-204-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*. We will collect a year-long suite of air samples at Palmer Station to investigate the seasonal trend of the trace gas concentration. At the Oregon Graduate Center, we will analyze the samples for a number of trace components, especially chlorine- and bromine-containing species. These trace constituents have come from both biogenic and anthropogenic sources, and they have the capacity to alter the Earth's climate and to deplete the ozone layer in the way it has recently been depleted above Antarctica. This work is considered vital for a better understanding of the buildup of trace constituents, particularly those of high-latitude marine origin. (OO-254-O)

South Pole monitoring for climate change. Amundsen–South Pole Station: *David Hofman, Climate Monitoring and Diagnostics Laboratory;* **Palmer Station:** *James T. Peters, Environmental Research Laboratories, National Oceanic and Atmospheric Administration*. The National Oceanic and Atmospheric Administration (NOAA) Climate Monitoring and Diagnostic Laboratory team will continue long-term measurements of trace atmospheric constituents that influence climate and the ozone layer. Four scientists will work at the Amundsen–Scott South Pole Station observatory during the austral summer, and two NOAA personnel will stay over the winter to measure carbon dioxide, methane, carbon monoxide, aerosols, water vapor, surface and stratospheric ozone, chlorofluorocarbons, wind, pressure, air and snow temperatures and atmospheric moisture and other trace constituents from the Atmospheric Research Observatory. These measurements are part of NOAA's effort to determine and assess the long-term buildup of global pollutants in the atmosphere. The measurements will be used for time-series analyses of multiyear data records that focus on

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

We will also determine the rates at which concentrations of these atmospheric constituents change and will examine their sources, sinks, and budgets. Working with climate modelers and diagnosticians, we will use these data to determine how the rates of change of these parameters affect climate, particularly when the data are included in climate model studies. In support of this project, Palmer Station personnel also will collect carbon dioxide samples. (OO-257-O and OO-264-O)

Drake Passage expendable bathythermograph program. *Ray Peterson, University of California.* In this project, we will analyze data from bottom pressure gauges deployed across chokepoints for the southern ocean flow. Bottom pressure gauges were deployed between South Africa and the antarctic coast close to the Greenwich Meridian and at two locations spanning the Antarctic Circumpolar Current (ACC) south of Tasmania. Simultaneously, the British deployed similar instruments in the Drake Passage. The main scientific goal of these deployments was to determine the fluctuations in the transport of the ACC and to relate it to those in the subtropical and subpolar gyres and to the wind field over the southern oceans. (OO-260-O)

Katabatic winds in eastern Antarctica and their interaction with sea ice. *Gerd Wendler, University of Alaska Fairbanks.* Our project is the continuation of an internationally collaborative (U.S.–French–Australian) study of katabatic winds along the coast of East Antarctica. It is based on two lines of automatic weather stations, one from Dumont d'Urville, the French station, inland to Dome C at an altitude of greater than 3,200 meters, the other along the coast. The coastal array includes stations at Cape Denison and Port Martin, which have recorded the highest average surface wind speeds on the globe (a monthly average of 27.8 meters per second). One additional automatic weather station will be installed 15 kilometers inland where model results predict even higher average wind speeds. These winds drive the sea ice offshore and are responsible for extremely high heat fluxes from the ocean to the atmosphere. Satellite-based active microwave imagery (synthetic aperture radar) will be combined with the observed meteorological data to analyze the formation persistence and size of offshore polynyas as a function of wind speed. The effort to produce a numerical model of the regional atmospheric structure will continue, with the incorporation of a more detailed terrain map, and a new mesoscale model developed by our French colleagues. In conjunction with the Australian and Japanese station networks to the west of this study area, this work will allow an assessment of the influence of cyclonic storm systems on the drainage flow along the antarctic coast. (OO-263-O)

Investigation of Sulfur Chemistry in the Antarctica Troposphere (ISCAT). *Douglas D. Davis and Fred L. Eisele,Georgia Institute of Technology.* During this 4-year study, we will examine the sulfur chemistry in the antarctic atmosphere, working at Amundsen–Scott South Pole Station for two field seasons, 1998–1999 and 2000–2001. The study, which includes 10 principal and senior investigators at five institutions with seven additional contributing investigators, has two broad-based goals:

- 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 was selected because at this site, the atmospheric boundary layer presents a homogeneous and relatively simple environment from which to unravel the photochemically driven oxidation chemistry of dimethyl sulfide.

Atmospheric sulfur chemistry is an important component in climate change issues because both naturally (i.e., from volcanic emissions and oceanic phytoplankton production) and anthropogenically emitted sulfur compounds form minute particles in the atmosphere—the so-called *aerosols*—that 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 enhance global cloudiness. On the millennial timescale, the variability and natural background level of atmospheric aerosols can be reconstructed from the preserved paleorecords of sulfur oxi-

dation products in ice cores. It is necessary, however, to understand how the physical and chemical environment of the oxidation process affects the relative concentrations of the oxidation products that become buried in the ice.

This study requires simultaneous observations of a wide-ranging suite of sulfur species such as DMS and its oxidation products: sulfur dioxide, dimethyl sulfoxide, dimethyl sulfone, methane sulfonic acid, and sulfuric acid, as well as photochemically important compounds such as carbon monoxide, nitrous oxide, water vapor, and nonmethane hydrocarbons.

Secondary objectives will be

- to examine interior antarctic air samples for other significant DMS oxidation products such as sulfurous acid and methane sulfinic acid and
- to assess the local variation in hydroxyl and perhydroxyl radicals, a measure of the oxidizing power of the atmosphere.

This study will provide, for the first time, a quantitative picture of exactly which atmospheric sulfur compounds are advected into the antarctic interior and a detailed picture of the sulfur chemistry that is active in the antarctic atmosphere. (OO-270-O)

Operation of an aerosol sampling system at Palmer Station. *Gail dePlannque and Colin G. Sanderson, Environmental Measurements Laboratory, U.S. Department of Energy.* In 1990, a team from the U.S. Department of Energy, Environmental Measurements Laboratory (EML) in New York City, installed a high-volume aerosol sampler, a gamma-ray spectrometer, and satellite data transmission system at Palmer Station. This installation is part of EML's Remote Atmospheric Measurements Program, which is an extension of its worldwide surface air-sampling program. The system transmits data through the National Oceanic and Atmospheric Administration's ARGOS satellite system. The sampling station at Palmer provides significant input for EML's database. (OO-275-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.* 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 Chinese antarctic resupply vessel off Prydz Bay in the Indian Ocean sector. In the austral spring, this region experiences phytoplankton blooms that scientists believe are the result of nutrient transport by the ventilation of intermediate and deep water masses. Researchers believe that each year such blooms are the primary source of particulate organic carbon and biogenic silica flux to the ocean bottom. At this time, however, no data exist on the amount of particulate organic matter that sinks through the water column, leaving the quantitative relationships between production and export largely undefined in this region. The initial phase of our work consists of setting out a time-series sediment-trap mooring at approximately 64°S 73°E to take advantage of the historical data set that CHINARE has obtained in this area over the past decade. The biweekly to monthly trap samples will be analyzed for their organic constituents and, in conjunction with primary productivity observations, will provide the basic data from which export values can be derived.

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 shipboard primary productivity experiments and the supporting hydrographic measurements. The

collaborating American scientists will provide both guidance in making these observations to standards developed for the Joint Global Ocean Flux Study and the hardware for the moored sediment trap. There will be a mutual sharing between the U.S. and Chinese investigators of all samples and data sets, and the data analysis will be carried out jointly. (OO-278-O)

Antarctic automatic weather station program: 1998–2001. *Charles Stearns, University of Wisconsin at Madison.* Our project will maintain and augment, as necessary, the network of nearly 50 automatic weather stations established on the antarctic continent and on several surrounding islands. These weather stations measure surface wind, pressure, temperature, humidity, and in some instances, other atmospheric variables, such as snow accumulation and incident solar radiation, and report these readings via satellite to a number of ground stations. The data are used for operational weather forecasting in support of the U.S. Antarctic Program, for climatological records, and for research purposes. The AWS network, which began as a small-scale program in 1980, has been extremely reliable and has proven indispensable for both forecasting and research purposes. (OO-283-O)

Research on Ocean–Atmosphere Variability and Ecosystem Response in the Ross Sea. *Robert B. Dunbar, Rice University.* This interdisciplinary study, "Research on Ocean, Atmosphere and Ecosystem Response in the Ross Sea" (ROAVERRS), focuses on atmospheric forcing, ocean hydrography, sea-ice dynamics, primary productivity, and pelagic-benthic coupling in the southwestern Ross Sea. The primary goal is to examine how changes in aspects of the polar climate system, in this case wind and temperature, combine to influence marine productivity on a large antarctic continental shelf. In the Ross Sea, katabatic winds and mesocyclones influence the spatial and temporal distribution of sea ice, as well as the upper ocean mixed-layer depth, and thus control primary production in the sea ice and in the open water system. The structure, standing stock, and productivity of bottom-dwelling biological communities are also linked to meteorological processes through interseasonal and interannual variations in horizontal and vertical fluxes of organic carbon produced in the upper ocean.

During this 3-year study, we will investigate links among the atmospheric, oceanic, and biological systems of the southwestern Ross Sea ecosystem. Direct measurements will include

- regional wind and air temperatures derived from automatic weather stations;
- ice cover, ice movement, and sea-surface temperatures derived from a variety of satellite-based sensors;
- hydrographic characteristics of the upper ocean and primary productivity in the ice and in the water derived from research cruises and satellite studies;
- vertical flux of organic material and water movement derived from oceanographic moorings containing sediment traps and current meters; and
- the abundance, distribution, and respiration rates of biological communities on the seafloor, derived from box cores, benthic photographs, and shipboard incubations.

Based on archived meteorological data, we expect that the atmospheric variability during the study period will allow us to monitor changes in air-flow patterns and their influence on oceanographic and biological patterns and to deduce the direct and indirect links, which are the focus of the research. Results from this study will contribute to our knowledge of atmospheric and oceanic forcing of marine ecosystems and lead to a better understanding of marine ecosystem response to climatic variations.

During the 1998–1999 research season, the following researchers will conduct studies as part of the ROAVERRS project:

- Robert B. Dunbar, Rice University (OR-216-A), lead;
- Jacqueline Grebmeier, University of Tennessee (BR-216-E);
- Giacomo R. DiTullio, University of Charleston (BR-272-O);
- James Barry, Monterey Bay Aquarium Research Institute (OR-216-B);
- Michael Lizotte, University of Wisconsin (OR-216-C);
- Michael Van Woert, Office of Naval Research, U.S. Navy (OR-216-D); and
- Amy Leventer, Colgate University (OR-216-F).

Dynamic/thermodynamic processes and their contribution to the sea-ice thickness distribution and radar backscatter in the Ross Sea. *Martin O. Jeffries and Shusun Li, University of Alaska Fairbanks.* We will study the effects of antarctic sea ice in the global climate system through an examination of how the spatial distribution of ice and snow thickness and of open water is reflected in satellite-based synthetic aperture radar (SAR) imagery. The field investigations, which will be carried out from the R/V *Nathaniel B. Palmer* in winter 1998 and summer 1999, will produce observations of the snow and ice distribution; the crystal structure, stable isotopes, salinity and temperature structure of ice cores; and the stratigraphy, grain size, and water content of the snow cover. The SAR images from ERS-2 and RADARSAT will be acquired at the McMurdo ground station and processed at the Alaska SAR Facility. These images will provide information about the large-scale ice-motion field and the small-scale ice-deformation field, both of which contribute to the observed ice-thickness distribution. In addition, a study of the spatial and temporal variation of the backscattered microwave energy will contribute to the development of numerical models that simulate the dynamic and thermodynamic interactions among the sea ice, ocean, and atmosphere. The surface data are vital for the extraction of environmental information from the radar data, and for the ultimate validation of interactive models. (OX-286-O)

Aeronomy and astrophysics

RICE—Radio Ice Cherenkov Experiment. *David Besson, University of Kansas.* Electromagnetic radiation (such as light, x-rays, and gamma rays) cannot escape from inside the most active regions of the Universe, for instance from the nuclei of galaxies, nor can the highest energy gamma rays propagate through intergalactic space because they will be absorbed by the cosmic background infrared photons. Neutrinos, however, can traverse a considerable amount of material unimpeded. If they can be detected in such a way that their arrival direction and energy can be determined, they can be used to study high-density regions and highest energy events of the cosmos.

When an electron-type neutrino does interact in a dielectric medium (such as the deep glacial ice beneath South Pole), it will produce an electron and positron shower that will rapidly radiate away the energy of the original neutrino as electromagnetic radiation. The probability of such interactions increases with increasing energy, so that a detector's sensitivity increases with energy. Thus, a modest-sized (by neutrino detector standards) instrumented volume of ice—about a 100-meter cube—could have an effective volume of a cubic kilometer,

a size deemed necessary to do astronomy. Our project will determine the feasibility of the radio detection of neutrino interactions in ice. (AA-123-O)

AMANDA—Antarctic Muon and Neutrino Detector Array, *Robert Morse, University of Wisconsin*. The primary objective of AMANDA is to discover sources of very-high-energy neutrinos from galactic and extragalactic sources. These neutrinos could be of diffuse origin, coming from the contributions of 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.

The AMANDA array, which consists of photomultiplier tubes embedded between 1 and 2 kilometers deep in the antarctic ice near the South Pole, uses natural ice as a Cherenkov detector for high-energy neutrinos of astrophysical origin that have passed through Earth. Recently, new sources of high-energy gamma rays have been discovered, such as the source Mrk-421 discovered by the CGRO and Mt. Hopkins Observatory. Believed to be copious emitters of high-energy neutrinos, objects like this are what AMANDA has been designed to study. To date, neutrino astronomy has been limited to the detection of solar neutrinos and one brief 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, and as one of the first-generation detectors, AMANDA promises to be a large contributor to this new branch of neutrino astronomy. (AA-130-O)

Antarctic long-duration balloonborne observations of the anistropy of the cosmic microwave background on angular scales of 0.2 to 4 degrees. *Andrew Lange, California Institute of Technology*. The angular intensity distribution on the sky of the cosmic microwave background radiation carries a wealth of information about the early Universe because this radiation started on its journey to us just a few hundred thousand years after the Big Bang. The details of the distribution on angular scales from a few degrees to a few minutes can cleanly discriminate between competing models of the dark matter that makes up most of the gravitationally attracting mass of the Universe. This balloonborne microwave telescope—called *BOOMERANG*—will measure variations on a scale from 12 minutes to 3.6 degrees. BOOMERANG has already been flown for a short flight in the United States and will be flown on a long-duration balloon from McMurdo Station, Antarctica, in December 1998 with an expectation of getting up to 2 weeks of continuous data. (AB-033-O)

Long-Duration Balloon program. *Steven Peterzen, National Scientific Balloon Facility*. 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. These large-volume (804,199-cubic-meter), helium-filled balloons circumnavigate the continent for up to 24 days. For each circumpolar flight, NSBF performs the launch operations, designs and manages the telemetry links, and then terminates and recovers the flight system. During the 1998–1999 field season, the LDB program will support research by Andrew Lange of the California Institute of Technology and David Rust of Johns Hopkins University. (AB-145-O)

An optical investigation of the genesis of solar activity. *David M. Rust, Johns Hopkins University*. The Flare Genesis Experiment will use an 80-centimeter telescope to make images and magnetograms of unprecedented resolution (0.2 arcsec) of the solar photosphere and chromosphere while flying from a high-altitude, long-duration balloon around the antarctic continent. The purpose of the experiment is to further understanding on how the energy stored in the Sun's magnetic fields is converted to energetic events such as flares and coronal mass ejections. This experiment

can be done only from an antarctic balloon (short of building a large, special-purpose spacecraft) for two reasons. First, continual viewing of the Sun is necessary for periods much exceeding a day, and that can be achieved only at polar sites. Second, to achieve the required resolution, the telescope must be above most of the atmosphere, and LDBs can carry the telescope to that height. This project is jointly sponsored by the National Science Foundation, the National Aeronautics and Space Administration, and the Air Force. (AB-146-O)

Center for Astrophysical Research in Antarctica (CARA)—Administration, *Stephan Meyer, University of Chicago.* Infrared and submillimeter astronomy has the potential for answering major questions about the formation of the Universe:

- What are the processes by which stars form from interstellar gas?
- How did the planets form?
- What was the nature of primeval galaxies?
- How was matter and energy distributed in the early Universe?

Because of the cold temperatures and the near absence of water vapor in the atmosphere above the polar plateau, the infrared skies are consistently clearer and darker in Antarctica than anywhere else on Earth. These conditions enable researchers to make measurements that would be extremely difficult or impossible from other sites.

To capitalize on these advantages, in 1991 the University of Chicago and several collaborating institutions established the Center for Astrophysical Research in Antarctica (CARA), which is one of 24 Science and Technology Centers funded by the National Science Foundation. To support its scientific mission, CARA is working to establish an observatory at the South Pole and to investigate the conditions for astronomy at the South Pole and other sites on the polar plateau. Currently, CARA supports research using three major telescope facilities.

- The Astronomical Submillimeter Telescope/Remote Observatory (AST/RO) project uses a 1.7-meter-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-meter-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 to plan for future telescopes and facilities.

Projects and principal investigators included as part of CARA are the following.

- CARA-wide operations and activities (Stephan Meyer, University of Chicago) (AC-132-A).
- The AST/RO project, which will receive new array receivers to permit rapid mapping of chemical species (Antony Stark, Smithsonian Institution) (AC-132-B).
- The SPIREX project, which will be revitalized during the 1998–1999 field season with a state-of-the-art array to make possible wide-field surveys of star formation in our Galaxy and in the Magellanic Clouds at wavelengths between 2 and 5 micrometers (Bob Lowenstein, University of Chicago) (AC-132-C).
- The Advanced Telescopes Project (Bob Lowenstein, University of Chicago) (AC-132-E).

- Activities of the COBRA project related to preparation for deployment of the Viper telescope, a new, 2-meter class telescope that will extend the observations now being made with the 0.75-meter Python telescope to structures in the cosmic microwave background having smaller angular scales (Jeffrey Peterson, Carnegie-Mellon University) (AC-132-F).

Besides making measurements of "seeing" quality using the SPIREX telescope, the Advanced Telescopes Project also supports a number of other efforts including wide-field cameras, a near-infrared sky brightness monitor (in collaboration with the University of New South Wales), and an instrument for monitoring mid-infrared sky brightness and transmission (in collaboration with the National Aeronautics and Space Administration's Goddard Space Flight Center).

The operation of an extremely-low-frequency/very-low-frequency radiometer at Arrival Heights, Antarctica. *A.C. Fraser-Smith, Stanford University.* During the 1998–1999 field season, we will continue to operate an extremely-low-frequency and very-low-frequency (ELF/VLF) radiometer at McMurdo Station, Antarctica, to monitor radio noise from natural sources such as thunderstorms. The Arrival Heights site is one of a network of eight such radiometers operated by Stanford University for the Office of Naval Research. Characterizing the possible sources of radio interference is important for operational purposes. Additionally, because the variations in global noise reflect variations in global thunderstorm activity, they can provide information on global climate change. The antarctic site was chosen about 15 years ago because it is unusually free from manmade electromagnetic interference. The ELF/VLF record of data collected by this project now extends unbroken for more than 10 years. (AO-100-O)

Magnetometer data acquisition at McMurdo and Amundsen–Scott South Pole Stations. *Louis Lanzerotti, AT&T Bell Laboratories, and Alan Wolfe, New York City Technical College.* Magnetometers installed at selected sites in both polar regions 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. We will measure these variations using magnetometers installed at conjugate sites in the Northern and Southern Hemispheres, specifically at McMurdo and Amundsen–Scott South Pole Stations, Antarctica, and at Iqaluit, Northwest Territories, Canada. We are also analyzing these data in association with similar data acquired from several automatic geophysical observatories that are part of the polar experiment network for geophysical upper-atmosphere investigations (PENGUIN) program (AO-112-O). Using these systems, we gather data on the coupling of the interplanetary medium into the dayside magnetosphere, including the magnetospheric cusp region, as well as the causes and propagation of low-frequency hydromagnetic waves in the magnetosphere. Because of unique climatic conditions at the South Pole, we are also able to correlate optical measurements with particle-precipitation measurements and with hydromagnetic-wave phenomena recorded by the magnetometer. (AO-101-O)

An investigation of magnetospheric boundaries using ground-based induction magnetometers operated at manned stations as part of an extensive ground array. *Roger Arnoldy, University of New Hampshire.* We operate an array of induction-coil magnetometers located at high geomagnetic latitudes in the Arctic and Antarctic, and we analyze the data collected. The sites, located at Sondre Stromfjord, Greenland, and Iqaluit, Northwest Territories, Canada, in the Arctic and at Amundsen-Scott South Pole and McMurdo Stations in the Antarctic, complement similar magnetometers in the U.S. and British automatic geophysical observatory (AGO) networks and the MACCS array in Canada. The measurements of magnetic pulsations at these high geomagnetic latitudes are used to study the plasma physics

of some of the important boundaries of the magnetosphere, particularly those surrounding the area through which the solar wind enters the magnetosphere and where the magnetosphere transfers the solar wind's energy to the Earth's atmosphere in the form of aurora and similar phenomena. This project is jointly supported by the U.S. Arctic and Antarctic Programs. (AO-102-O)

Antarctic auroral imaging. *Steven Mende, University of California, Berkeley; Space Sciences Laboratory*. In the past, space satellites have performed detailed exploration of the magnetosphere, and the average distribution of the energetic particle plasma content of the magnetosphere has been mapped. This form of measurement is unsuitable, however, for observing the dynamic behavior of the magnetosphere. Auroral phenomena are produced when particles from the magnetosphere precipitate into the atmosphere causing the atmosphere to fluoresce. Because particles tend to travel along the magnetic field line, the aurora can be regarded as a two-dimensional projection of the three-dimensional magnetospheric regions. Thus, observing the morphology of the aurora and its dynamics provides an important way to study the dynamics of the three-dimensional magnetosphere. This method requires knowledge of which type of auroras represent which energy of precipitation and their connection to the various regions of the magnetosphere.

Amundsen–Scott South Pole Station is uniquely situated for optical observations of polar aurora because during the winter, the aurora can be monitored 24 hours a day unlike most other places, where the sky becomes too bright near local mid-day. An intensified optical, all-sky imager, operating in two parallel wavelength channels—4,278 and 6,300 Ångstroms—will be used to record digital and video images of aurora. These wavelength bands allow us to discriminate between more or less energetic electron auroras and other precipitation. From South Pole Station, we can observe the polar cap and cleft regions by measuring auroral-precipitation patterns and interpreting the results in terms of coordinated observations of magnetic, radio-wave absorption images and high-frequency, coherent-scatter radar measurements. Through this investigation, we hope to learn about the sources and energization mechanisms of auroral particles in the magnetosphere and other forms of energy inputs into the high-latitude atmosphere. (AO-104-O)

A study of very high latitude geomagnetic phenomena. *Vladimir Papitashvili, University of Michigan.* Our project is a continuation of a joint U.S.–Russian program to operate an array of high-latitude automated magnetometers in Antarctica. We will use these instruments to investigate the polar cap current systems in the Earth's magnetosphere. The antarctic continent is uniquely suited to these investigations because it is the only land mass at very high latitudes and is, therefore, an excellent and stable location for an array of magnetometers. These investigations are particularly important to the understanding of the coupling of energy and momentum from the solar wind to the magnetosphere, ionosphere, and upper atmosphere. The data will also be extremely useful for analyses coordinated with a number of satellite-based experiments that are currently in progress or are planned for the near future. The specific tasks to be undertaken include design improvements in the digital geomagnetic data-acquisition systems at Vostok and Mirnyy and the continued operations and maintenance of autonomous stations along the Russian traverse route to Vostok. One improvement will be to add a satellite data-transmission capability at Vostok so that a polar cap magnetic index will be available in near real-time for space weather and research applications. (AO-105-O)

Global thunderstorm activity and its effects on the radiation belts and the lower ionosphere. *Umran Inan, Stanford University*. Very-low-frequency (VLF) radio receivers at Palmer

Station, Antarctica, operated by this project, study ionospheric disturbance caused by global lightning. The principal mode of operation is to measure changes in amplitude and phase of signals received from several distant VLF transmitters. These changes occur in the VLF signals following 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 in turn causes increased ionization in the ionosphere, thus affecting the propagating VLF radio waves. Because the directions to the VLF transmitters are known, it is possible to track remotely the path of the thunderstorms that cause the changes. The Palmer Station receivers are operated in collaboration with the British and Brazilian Antarctic Programs, both of which operate similar receivers. This project contributes to the Global Change Initiative. (AO-106-O)

Study of polar stratospheric clouds by lidar. *Guido Di Donfrancesco, Instituto De Fisica Dell'Atmosfere, Rome, Italy.* In cooperation with the U.S. Antarctic Program and in collaboration with the University of Wyoming (AO-131-O), we will use lidar to study the polar stratospheric clouds (PSCs), their formation, evolution, and other peculiar characteristics. Continuous lidar observations permit studies of PSCs and stratospheric aerosol and the thermal behavior and dynamics of the atmosphere above McMurdo Station. (AO-107-O)

Extremely-low-frequency/very-low-frequency (ELF/VLF) waves at the South Pole. *Umran S. Inan, Stanford University.* Advancing our understanding of the electrodynamic coupling of upper atmospheric regions and refining our quantitative understanding of the energy transport between the magnetosphere and the ionosphere are two important objectives of the U.S. Antarctic Program's automatic geophysical observatory program. Particle precipitation driven by extra-low-frequency/very-low-frequency (ELF/VLF) waves has a part in transporting and accelerating magnetospheric and ionospheric plasmas, processes that result from a variety of physically different wave-particle interactions. Because measuring ELF/VLF waves from multiple sites provides a powerful tool for remote observations of magnetosphere processes, we maintain a system at Amundsen–Scott South Pole Station that measures magnetospheric ELF/VLF phenomena; data from this system are correlated with data from the automatic geophysical observatory system. (AO-108-O)

South Pole Air Shower Experiment–2. *Thomas Gaisser, University of Delaware.* 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. It detects energetic charged particles (mostly electrons), which are produced in the upper atmosphere by cosmic rays. The array also includes a subarray, called *VULCAN*, of nine photodetectors to detect Cherenkov radiation produced by the same showers high in the atmosphere.

Our experiment has several goals, the most important of which is to determine the elemental composition of the primary cosmic rays at energies above approximately 100 teraelectronvolts. To do this, SPASE-2 works in conjunction with the Antarctic Muon and Neutrino Detector Array (AMANDA), which has several hundred optical detectors so deep in the ice sheet that the only products of the cosmic ray interactions that can be seen by AMANDA are muons. The ratio of muons to electrons in a cosmic ray shower depends on the mass of the original primary cosmic ray nucleus. In addition, in showers also detected with VULCAN, two other ratios that also depend on primary mass can be determined. Interpretation of the combined data will lead to a determination of the relative importance of different groups of nuclei in the cosmic radiation in an energy region not accessible to direct measurement. This, in turn, will shed light on the origin and mechanisms of acceleration

of this extremely energetic, naturally occurring radiation. This project is cooperative with the University of Leeds in the United Kingdom. (AO-109-O)

High-latitude antarctic neutral mesospheric and thermospheric dynamics and thermodynamics. *Gonzalo Hernandez, University of Washington.* The temperature and windspeed of the atmosphere can be deduced by measuring the emission spectra of certain trace gases, especially the spectra of those that are confined to fairly narrow altitude regions. We use a Fabry-Perot infrared interferometer located at Amundsen-Scott South Pole Station, Antarctica, to look at the band spectra of several trace species, most importantly the hydroxyl radical (OH), in orthogonal directions. By determining the doppler shift of the lines, researchers can measure the winds. The brightness and line ratios within the bands provide density and temperature information. The OH in the atmosphere is primarily found in a narrow band near 90 kilometers altitude. The fact that the measurements are being made at the axis of rotation of Earth significantly limits the types of planetary waves, thus simplifying the study of the large-scale dynamics of the atmosphere. (AO-110-O)

Riometry in Antarctica and conjugate regions. *Theodore J. Rosenberg and Allan T. Weatherwax, University of Maryland at College Park.* To continue and expand the study of the upper atmosphere, especially auroral phenomena, using photometry and riometric techniques, we have developed a new imaging riometer (relative ionospheric opacity meter) 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 Iqiluit, Northwest Territories, Canada, which is the magnetic conjugate to South Pole. Broadbeam riometers also operate at several frequencies at South Pole, McMurdo, and Iqiluit; auroral photometers operate at South Pole and McMurdo. These instruments constitute a unique network with which to study auroral effects in both magnetic hemispheres simultaneously. (AO-111-O)

Polar experiment network for geophysical upper-atmosphere investigations (PENGUIN). *Theodore Rosenberg, University of Maryland at College Park.* A consortium of U.S. and Japanese scientists will use a network of six automatic geophysical observatories (AGOs), established on the east antarctic polar plateau and equipped with suites of instruments to measure magnetic, auroral, and radiowave phenomena. The AGOs, which are totally autonomous, operate year round and require only annual austral summer service visits. We will use these arrays of instruments, along with measurements made at select manned stations, to study 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 cooperation with conjugate studies performed in the Northern Hemisphere.

The data obtained from AGOs 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. (AO-112-O)

All-sky-camera measurements of the *aurora australis* from Amundsen–Scott South Pole Station. *Masaki Ejiri, National Institute of Polar Research, Japan.* Amundsen–Scott South Pole Station, located at the south geographic pole, is a unique platform from which to undertake measurements of the polar ionosphere. Because of the configuration of the geomagnetic field in the Southern Hemisphere, the station

is situated in such a way that dayside auroras can be viewed for several hours each day. Research has shown that they are caused by precipitation of low-energy particles, which enter the magnetosphere by means of the solar wind. Since 1965, data have been acquired at the South Pole using a film-based, all-sky-camera system. Using advanced technology, we can now digitize photographic images and process large amounts of information automatically. Besides continuing to acquire 35-millimeter photographic images with the all-sky-camera system, U.S. and Japanese researchers will collaborate and use an all-sky-camera processing system developed at Japan's National Institute of Polar Research to analyze data. This system displays data in a geophysical coordinate framework and analyzes images over short and long intervals not possible with individual photographic images. The data will be used to investigate dayside auroral structure, nightside substorm effects, and polar-cap arcs. These studies can also be used to obtain further insight into the physics of the magnetosphere, the convection of plasma in the polar cap, and solar winds in the thermosphere. (AO-117-O)

Solar and heliosphere studies with antarctic cosmic-ray observations. *John Bieber, University of Delaware.* Neutron monitors in Antarctica provide a vital three-dimensional perspective on the anisotropic flux of cosmic rays that continuously bombards Earth. At McMurdo and Amundsen–Scott South Pole Stations, year-round observations will continue for cosmic rays with energies in excess of 1 billion electronvolts. These data will advance our understanding of a variety of fundamental plasma processes occurring on the Sun and in interplanetary space. Neutron-monitor records, which began in 1960 at McMurdo Station and 1964 at South Pole Station, will play a crucial role in efforts to understand the nature and causes of cosmic-ray and solar-terrestrial variations occurring over the 11-year sunspot cycle, the 22-year Hale cycle, and even longer timescales. 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 understand the mechanism by which energetic charged particles scatter in this turbulence. (AO-120-O)

Rayleigh and sodium lidar studies of the troposphere, stratosphere, and mesosphere at McMurdo and Amundsen-Scott South Pole Stations. *Jim Abshire, National Aeronautics and Space Administration, Goddard Space Flight Center.* The automated geophysical observatory (AGO) lidar is an ongoing, National Aeronautics and Space Administration (NASA) funded project to develop and demonstrate a compact, low-power, and autonomous atmospheric lidar for operation in the U.S. Antarctic Program's AGOs deployed to various locations in Antarctica. The primary science mission of AGO lidar is detecting, monitoring, and profiling polar stratospheric clouds (PSCs). These clouds form in the extremely cold polar stratosphere during the austral winter, and a particular type of PSC (type 1) has been implicated in the annual springtime destruction of stratospheric ozone. A secondary science mission is long-term continuous monitoring of atmospheric transmission and backscatter from the surface. These data will be compiled into a database that will provide statistics on atmospheric conditions for the Geoscience Laser Altimeter System (GLAS).

The AGO lidar has redundant laser diode transmitters operating at 670 nanometers, producing 500-milliwatt peak power pulses, at 1- or 4-microsecond pulse lengths, and a pulse-repetition frequency of 4 kilohertz. The backscattered laser light is collected by a 20-centimeter diameter telescope and detected by all-solid-state single-photon counting modules in a cross-polarized detection scheme. Type 1 PSCs will depolarize incident radiation. Because the laser transmitters in AGO lidar produce highly linearly polarized light, it sends back a depolarization signal (up to several percent) in the backscattered light.

The lidar data are archived in the lidar instruments' own flash memory as well as the optical drive provided by the AGO platform. The AGO lidar also contains its own Argos transmitter, which telemeters at least one atmospheric profile per day back to NASA's Goddard Space Flight Center in Greenbelt, Maryland. (AO-126-O)

Rayleigh and sodium lidar studies of the troposphere, stratosphere, and mesosphere at the Amundsen–Scott South Pole Station. *George Papen, University of Illinois.* During the 1998–1999 field season, we will continue to operate a sodium resonance lidar at the South Pole to study the vertical structure and dynamics of the atmosphere from the lower stratosphere to the mesopause. During this third year of the project, an iron resonance lidar will be added and will extend the measurements of the dynamics and temperature structure to 100 kilometers altitude. Additionally, an airglow imaging camera will be used to study the horizontal structure. When used in conjunction with the normal balloonborne radio sondes, which are flown regularly from South Pole, the final complement of instruments will provide extensive data on

- the temperature structure from the surface to 100 kilometers altitude;
- the nature of the polar stratospheric clouds, which are important to ozone chemistry;
- the variability and frequency of occurrence of metallic layers in the mesosphere, which play a role in communications as well as chemistry;
- atmospheric gravity waves; and
- many other phenomena, some of which are unique to the South Pole. (AO-127-O)

High-latitude electromagnetic wave studies using antarctic automatic geophysical observatories. *James LaBelle, Dartmouth College.* At radio frequencies between 0.05 and 5.0 megahertz (MHz), three types of radio phenomena related to auroral origin can be detected: narrowband near 2.8 and 4.2 MHz, broadband noise bursts in the frequency range of 1.4–4.0 MHz, and broadband noise at frequencies below 1 MHz. An accepted physical theory explains the third type, called *auroral hiss*, but the origins of the other two types are unknown. 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, analogous to the way in which solar radio emissions are used to infer the processes taking place in the solar corona. Using low-frequency/middle frequency/high frequency receivers, we hope to collect further clues about these emissions from antarctic auroral zone and polar cap sites, taking advantage of radio-quiet antarctic conditions. The receivers will be installed at Amundsen–Scott South Pole Station, in three U.S. automatic geophysical observatories, and in two British automatic geophysical observatories. (AO-128-O)

***In situ* measurements of polar stratospheric clouds (PSCs) spanning the austral winter and of ozone from late winter to early spring.** *Terry Deshler, University of Wyoming.* The annual stratospheric ozone hole above Antarctica is driven by chlorine compounds that interact on the surfaces of polar stratospheric clouds, which form during the polar winter. Thus, the ozone hole appears in the austral spring, and ozone depletion is much more severe in polar regions than elsewhere. By using balloonborne instruments, we provide detailed information on the actual cloud particles and the distribution of the clouds and the ozone. Our measurements will provide vertical profiles of both the PSCs and ozone, size distributions of the PSC particles, and some information on their composition and physical state (liquid or solid). Our project is enhanced by cooperation with an Italian investigator who operates a lidar system at McMurdo Station. The project contributes to the World Meteorological Organization/UNEP Network for the Detection of Stratospheric Change and the Global Change Initiative. (AO-131-O)

Measurement of stratospheric chlorine monoxide and other trace gases over McMurdo Station in the austral spring. *Robert L. de Zafra, University of New York at Stony Brook.* Chlorine monoxide (ClO) is a product of the destruction of stratospheric ozone by chlorine, which enters the stratosphere as a result of the breakdown of chlorofluorocarbons (CFCs). ClO, as well as other trace stratospheric gases that contribute to the development of the antarctic ozone hole, can be measured from the ground by millimeter-wave receivers, similar to those used for molecular radio astronomy.

We will continue a decade-long series of such measurements made at McMurdo Station to further understand climate dynamics and phenomena but, more important, to provide a cross calibration of the new Network for the Detection of Stratospheric Change (NDSC) ClO microwave instrument, which has recently been installed nearby at New Zealand's Scott Base. Because the NDSC instruments are being installed at a number of sites worldwide, it is important to provide as much correlative information as possible so that the NDSC can be relied upon in the future to monitor the health of the stratosphere. Our goal is to provide as much continuity as possible between measurements made from 1986 to 1998 with the Stony Brook spectrometer at McMurdo Station and the current and future measurements made by the new NDSC instrument at Scott Base. During the 1998–1999 field season, we will also test a second newly rebuilt and improved spectrometer at McMurdo before final installation at Amundsen–Scott South Pole Station in early 1999. This spectrometer will be used concurrently to measure other species photochemically or dynamically linked to chlorine chemistry in the stratosphere. (AO-137-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 energy in the millimeter-wavelength region of the radio spectrum, and each species has its own unique spectrum. The shape of each individual species' spectrum provides information on the temperature and pressure of the gas; thus, one can use the millimeter-wave spectrum of the atmosphere to determine the relative abundances and height distribution of a number of trace species. In our investigation, we will use a millimeter spectroscope to monitor ozone, carbon monoxide, nitrous oxide, nitric acid, water vapor, and nitrogen dioxide above South Pole, Antarctica, over the period of a year. Several of these gases have important roles in the formation of the annual antarctic ozone hole, and others, particularly water vapor and carbon monoxide, can provide information about the dynamics, particularly the vertical transport, of the upper stratosphere and mesosphere. (AO-138-O)

Cosmology from Dome-C in Antarctica. *Lucio Piccirillo, Bartol Research Institute, University of Delaware.* The thermal cosmic microwave background radiation (CMBR) left over from the Big Bang carries the only information available on the distribution of matter in the very early Universe. As part of an international collaboration (the United States, Italy, and France), we will measure the anisotropy of the CMBR from Concordia Station, the new French/Italian station on Dome C in Antarctica. Concordia is one of the highest and coldest sites presently occupied in Antarctica. Because of the extreme cold, the atmosphere contains very little water vapor, making Concordia a potentially superb place from which to make CMBR anisotropy measurements. Evaluation of the site for future use is also a major goal of this project. (AO-140-O)

Ground-based infrared measurements in the Antarctic. *Frank J. Murcray and Ronald Blatherwick, University of Denver.* For this project, we will use an infrared (IR) interferometer to monitor selected trace constituents in the atmosphere above Amundsen–Scott South Pole and McMurdo Stations. The measurements will be made in two modes: absorption and

emission. The absorption mode uses the Sun, shining through the atmosphere, as a source of IR radiation and allows us to measure a number of trace constituents, especially during the local springtime when the antarctic ozone hole is forming. The emission mode, using radiation emitted by the atmospheric gases themselves, is less sensitive than the absorption mode but does allow critical measurements during the long, dark polar night, when the chemistry that sets the stage for the springtime ozone depletion is taking place. The compounds we will measure include hydrogen chloride, nitric acid, chlorofluorocarbon-11 and -12, nitrous oxide, methane, ozone, and chlorine nitrate. Each of these gases has a role in ozone depletion, and several are also important greenhouse gases. This project is jointly funded by the National Science Foundation's Office of Polar Programs and Division of Atmospheric Sciences and also by the National Aeronautic and Space Administration's Office of Earth Sciences and Applications. (AO-148-O)

Antarctic halos and ice crystals. *Walter Tape, University of Alaska Fairbanks.* Our project is an experimental and theoretical study of ice crystals in the antarctic atmosphere and the halos that they produce. For reasons that are not currently known, the antarctic interior experiences more frequent and better developed halos than any other location on Earth. Our objectives are to observe natural halos at Amundsen–Scott South Pole Station and to sample ice crystals to validate computer models of light refraction and reflection in ice crystals. Such models have the potential for the remote sensing of atmospheric conditions. Controlled experiments, such as seeding the atmosphere with dry ice, will produce artificially generated but simple and well-formed single-species crystals. Our research provides a unique mechanism for examining the crystal growth and evolution process in the natural atmosphere. By observing halos through polarizing filters, we will also be able to examine the atmospheric ice-crystal orientation, shape, and size. The results of our project will advance our understanding of why well-formed ice crystals grow in the antarctic atmosphere but are not generally observed elsewhere. (AO-208-O)

Continued study of the Earth's ultra-low-frequency wave environment using induction antennas on the British Antarctic Survey's automatic geophysical observatories in Antarctica. *Mark J. Engebretson, Augsburg College.* Earth's magnetic field undergoes variations on many timescales. The low-amplitude fluctuations that have periods of a few tenths of a second to a few seconds, called *micropulsations,* are the result of motion in the magnetosphere such as waves on the magnetopause or other surfaces. Because most of the magnetosphere is connected to the surface by magnetic field lines that have their footprints at high geomagnetic latitude, the large-scale dynamics of the space environment can best be studied from the polar regions.

Now, an extensive antarctic array of magnetometers supports research in this area. In particular, our team has installed magnetometers in the British Antarctic Survey automatic geophysical observatories and has access to data from other similar instruments. The data gathered will provide additional insight into how solar activity affects Earth's environment as well as humanity's technical systems and will increase the worldwide space data pool. (AO-273-O)

Technical projects

These six specialized technical projects will be supported during 1998-1999:

- **PICO/AMANDA hot water drilling at South Pole Station, Antarctica**; *Karl Kuivinen, University of Nebraska.* (TA-177-O)
- **Polar Ice Coring Office support;** *Karl Kuivinen, University of Nebraska (*TI-150-O)
- **Automatic Geophysical Observatory (AGO)—servicing and installation;** *Ron Rainbow, Antarctic Support Associates* (TO-296-O)
- **Synthetic Aperture Radar project;** *Steve Currier, NASA Wallops Flight Facility (*TO-308-O)
- **McMurdo Sound Metsat Station--Upgrade, maintenance, and antarctic research center operation; and refurbishment of Terascan satellite reception & processing system at Palmer Station;** *Robert Whritner, Scripps Institution of Oceanography* (TO-312-O)
- **UV-monitoring network**; *Charles Booth, Biospherical Instruments, Inc* (TO-513-O)

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