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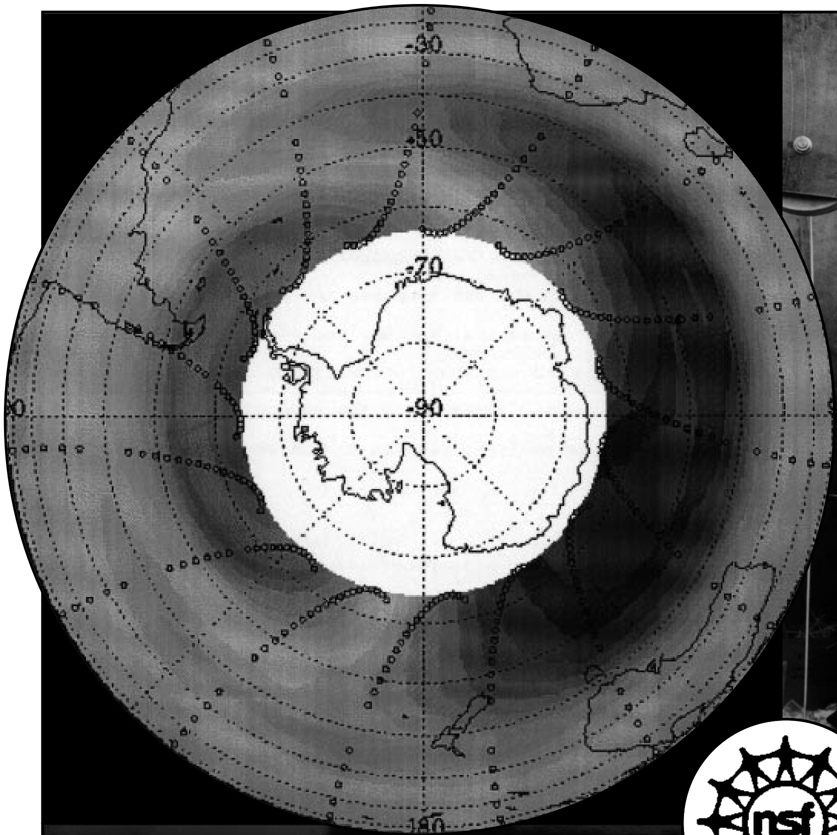

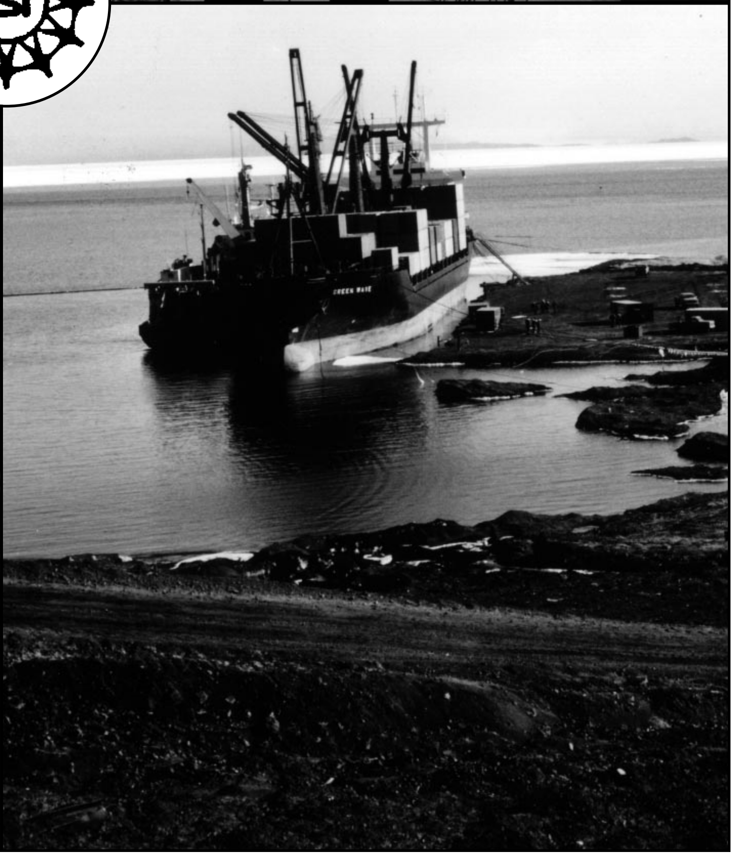

Editor, Winifred Reuning

Antarctic Journal of the United States, established in 1966, reports on U.S. activities in Antarctica, related activities elsewhere, and trends in the U.S. Antarctic Program. The Office of Polar Programs (National Science Foundation, Room 755, 4201 Wilson Boulevard, Arlington, Virginia 22230; telephone 703/306-1031) publishes the journal five times a year (March, June, September, December, and an annual review issue).

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The Director of the National Science Foundation has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this agency.

Contents...

Cover: The seasons of the Antarctic ***(clockwise from upper left)***

Spring: *Since 1985 researchers have monitored annual decrease in the abundance of ozone in the stratosphere above Antarctica. Beginning at onset of the austral spring, the decrease—also known as the "ozone hole"—is brought about primarily by chemical reactions that occur on the surfaces of ice crystals in polar stratospheric clouds as sunlight returns to the Southern Hemisphere.*

Credit: National Oceanic and Atmospheric Administration.

Summer: *During the austral summer, the National Science Foundation supports, as part of the U.S. Antarctic Program, approximately 120 research projects, conducted by more than 600 researchers and technicians, at the three U.S. research stations (McMurdo, Amundsen–Scott South Pole, and Palmer), at field camps in the McMurdo Dry Valleys and in remote areas of the continent, aboard the* Polar Duke *or* Nathaniel B. Palmer, *and in cooperation with other national antarctic programs. Recently, Amundsen–Scott South Pole Station at the geographic South Pole has become a center for astrophysical research, including such projects as the Antarctic Muon and Neutrino Detector Array shown in this photograph.*

Credit: NSF photo by Lynn Simarski.

Fall: *The arrival at McMurdo Station of the cargo ship, which brings supplies and equipment for the next austral summer, heralds the coming winter. The ship also carries waste materials for recycling or disposal back to the United States at the end of each austral summer operating season.*

Credit: NSF photo.

Winter: *Improved satellite communications for tracking ice have extended the ability of* Polar Duke *and* Nathaniel B. Palmer *to operate during the austral winter. While* Polar Duke *operates primarily in the Antarctic Peninsula region,* Nathaniel B. Palmer *regulars conducts winter cruises in the Ross and Weddell Sea regions, as well as along the Peninsula.*

Credit: NSF photo by Kevin Wood, Antarctic Support Associates.

NSF dedicates Martin A. Pomerantz Observatory at South Pole

Astrophysicist Martin A. Pomerantz has been honored in Antarctica with the dedication of an observatory bearing his name at the U.S. Amundsen–Scott South Pole Station. Pomerantz, who has worked in antarctic research since 1959 and conducted experiments at the South Pole since 1964, currently is involved in a helioseismology project to probe the Sun's interior.

Now president-emeritus at the University of Delaware's Bartol Research Institute, Pomerantz has also led research in the fields of submillimeter astronomy, cosmic and gamma rays, and measurement of cosmic background radiation. Pomerantz came to Bartol in 1938 as a research assistant after receiving his A.B. from Syracuse University and M.S. from the University of Pennsylvania. He also holds a Ph.D. from Temple University, an Sc.D from Swarthmore, and an honorary doctorate from the University of Uppsala in Sweden.

In addition to serving as a research fellow, professor, visiting professor, and lecturer both here and abroad, Pomerantz has led a number of National Geographic Expeditions; worked on eight national and international scientific committees; served on the board of trustees for the Franklin Institute; edited the *Journal of the Franklin Institute*; served on the editorial board for *Space Science Reviews*; and participated in five professional associations.

The observatory named in his honor is a two-story elevated structure having 270 square meters of interior space and housing equipment for four projects: the antarctic muon and neutrino detector array (AMANDA), the South Pole Infrared Explorer (SPIREX), the cosmic background radiation anisotropy experiment (COBRA), and the Advanced Telescope Project (ATP). The latter three projects are part of the Center for Astrophysical Research in Antarctica (CARA).

Construction of the observatory took less than a year. During the 1993–1994 austral summer, the observatory was framed up and closed in, and the interior work was completed during the 1994 winter. Located about 1 kilometer from the main South Pole Station, the observatory sits in a region known as the "dark sector," where electromagnetic noise, including light and radio waves, is minimized. Two nearby telescopes, SPIREX and PYTHON, can be controlled from inside the observatory.

National Science Foundation Director Neal Lane conducted the ceremony to name the observatory on 3 December 1995.

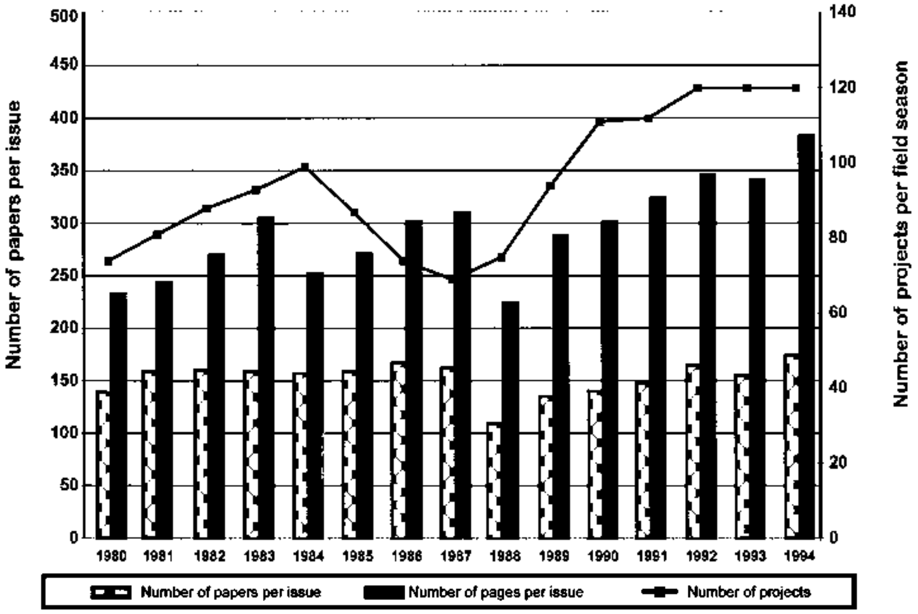
The *Antarctic Journal*, past and future

In January 1966 the National Science Foundation (NSF) and the U.S. Naval Support Force, Antarctica, (NSFA) distributed the first issue of the *Antarctic Journal*. This "new" publication combined two earlier publications—the *Antarctic Report* (NSF) and the *Bulletin of the U.S. Antarctic Projects Officer* (NSFA)—that had been published independently by the two agencies since the International Geophysical Year. The goal of the journal was to provide a common outlet for information on the scientific and logistic aspects of the U.S. effort in Antarctica to a broad audience that includes program participants and interested observers.

Although the content of the journal has remained consistent with the original goals set by NSF, format and frequency have changed a great deal over the last three decades. During its first decade, the journal was published six times a year and had a page count ranging from about 260 to 360 pages per year. In an effort to cut costs, NSF reduced the frequency of publication, in 1976, from six issues a year to four but did not reduce the number pages published during the year. Shortly after this, in 1977, the changing needs and interests of the antarctic science and logistics community caused NSF to again modify the journal's frequency and length, and the journal took on its present appearance—short quarterly issues and a substantially longer fifth issue that reviewed the preliminary results of research projects conducted as part of the U.S. national program in Antarctica.

Over the last 15 years, the U.S. Antarctic Program (USAP) has grown in size and complexity. This growth has had an impact on the *Antarctic Journal*, particularly the annual review issue. As the figure accompanying this article indicates, the growth of the review issue parallels the increase in the number of science projects supported

The growth of the *Antarctic Journal* and of USAP, 1980 -1994



by USAP during the last 15 years. For example, the 1980 review issue included 139 papers and was 233 pages long. In comparison, the 1994 review issue had 174 papers and was 383 pages long; the 1995 review, which is currently in preparation, has approximately 200 papers and will most likely be more than 400 pages long.

In a time of streamlining, increasing material and mailing costs, and decreasing budgets, the journal's growth combined with the increase in the number of people who receive the journal has led the Office of Polar Programs (OPP) to begin investigating ways to control or reduce costs while still meeting the needs of the U.S. antarctic science community. For the 1995 review issue, this meant strictly adhering to the word and illustration limits set out in the guide to authors. We are also looking at ways to use new technology to electronically distribute the journal via the World Wide Web (WWW). This project has already begun: past and current quarterly issues of the journal have been posted to OPP's home page on the NSF Web server. We hope that this effort will not only reduce costs in the future but also will expand the readership of the journal. To view the issues that have already been posted to the WWW go to the NSF home page at www.nsf.gov, select "program areas," followed by "polar programs" and "publications."

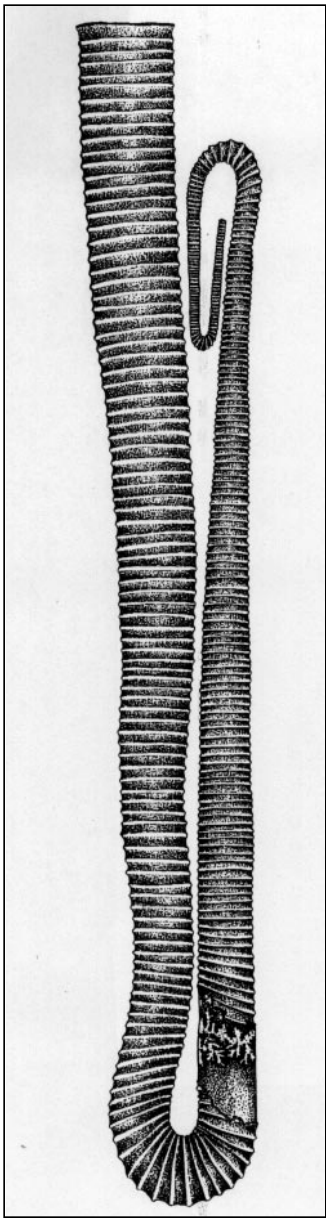
Science news from The Ice: Highlights from the 1994–1995 austral summer

Seymour Island yields the secrets of its past

Paleontologists working with the U.S. Antarctic Program on Seymour Island near the Antarctic Peninsula have discovered fossils of a gigantic mollusk and an oversized ancestor of the modern-day armadillo as well as fish fossils that may provide corroborating evidence for an ancient catastrophic meteorite strike. The island, part of the James Ross Island group, has proved to be a treasure trove of past biodiversity in the southernmost latitudes, so far providing fossils of 800 different species.

No other high-latitude locale can match the geologic record of Seymour Island, one of the few ice-free patches of Antarctica. The island's badlands landscape is a layer cake of sediments and fossils piled up almost continuously over 40 million years, from the late Cretaceous (80 million years ago) to the Eocene (about 37 million years ago). The rocks span the time of mass extinction of life at the boundary of the Cretaceous and Tertiary periods, when the dinosaurs and many other species disappeared, 65 million years ago. The island has also yielded the first mammal fossils found in Antarctica and the oldest penguin fossils known.

A Cretaceous-age hot dog. The new mollusk specimen, which resembles a ribbed firehose curled back on itself in the shape of a giant paper clip, belongs to the ammonites. This group of mollusks—related to the pearly nautilus—became extinct 65 million years ago. Called *Diplomoceras maximum*, the nearly 2-meter-long fossil is the most complete example of this species known, according to William Zinsmeister, paleontologist at Purdue University. Purdue graduate student Anton Oleinik found the fossil which, uncoiled, would stretch more than 4 meters.



Reconstruction of *Diplomoceras maximum* as drawn by Anton Oleinik. If uncoiled, *D. maximum* would stretch to nearly 4 meters.

The animal's fleshy, wormlike body occupied only about half of its shell. "It would have made a nice morsel—a real Cretaceous-era hot dog—for a mosasaur," Zinsmeister said. Mosasaurs—huge marine lizards related to modern monitor lizards such as the Komodo dragon—preyed upon ammonites. A 1-meter-long mosasaur skull, with teeth 7.5 centimeters long, was also found on Seymour Island this year.

D. maximum belongs to an ammonite group called heteromorphs. These ammonites, unlike their hydrodynamically streamlined cousins, took on a wide variety of bizarre and ungainly shell shapes. It was once thought that heteromorphs could live only in isolated areas of the ocean, free from competition. Now it is clear, however, that ammonites such as *D. maximum* were extremely successful, living throughout the world's oceans for millions of years during the Mesozoic Era.

"You might refer to Diplomoceras as the 'Forrest Gump' of the Mesozoic seas," said Zinsmeister. "This creature's success shows that the world doesn't always belong to the sleek and swift."

"The ocean around the Antarctic Peninsula 65 million years ago was probably a nice place to be," Zinsmeister continued. Temperatures there, both on land and sea, were much warmer than today's. "Picture a 'Flintstones' scenario—thick forests on land, with volcanoes puffing away. The oceans around Antarctica teemed with life, ranging from clams and snails to giant marine reptiles like mosasaurs and plesiosaurs."

Fish fossils fuel asteroid impact debate. While working on Seymour Island, Zinsmeister also discovered a bed of fossilized fish bones that may be the first remains of direct victims from the catastrophic event 65 million years ago that wiped out the dinosaurs and 70 percent of the world's species.

The fossil "horizon of death" dates from the boundary of the Cretaceous/Tertiary (K/T) geologic periods 65 million years ago. Covering more than 12 square kilometers of the island, the bone bed rests directly above a layer of iridium, an element that is rare on Earth but is a common signature of meteorite impact. Zinsmeister presented his findings 9 November 1995 at the Geological Society of America meeting in New Orleans.

A widely believed theory holds that a giant asteroid hit the Earth and set off the mass extinctions at the K/T boundary. The impact site most favored by scientists is a large crater in Mexico's Yucatan.

"The fish bones are an exciting discovery that should help us better understand environmental changes at a crucial time in Earth history—the end of the Cretaceous," commented Scott Borg, director of NSF's antarctic geology and geophysics program. "Seymour Island is an important site for understanding what happened on a global scale to the environment at that time. When the sediments containing the fish bones were deposited, the island was located in the far southern latitudes—just like today—and very far from the probable impact site in the Yucatan. The polar region has a very different atmospheric circulation than the tropics or temperate regions, so we can compare the excellent exposures of Seymour Island's K/T fossils to sites of the same age at other latitudes to construct a fuller picture."

In the past, Zinsmeister had argued—based on 20 years of research on late Cretaceous marine fossils in Antarctica—that the southernmost continent's fossil record did not support the asteroid-extinction theory. Even after finding the bed of fish bones, he thinks that the picture may be more complicated and that change was more prolonged than sudden.

"The fossil record in Antarctica suggests that the final extinction event wasn't immediate but, rather, occurred over a period of time up to 500,000 years," he said. "We actually see a decrease in the global diversity of life starting between 8 and 10 million years before the impact."

He points out that two important marine animals—the ammonites and the inoceramid bivalves, a clam relative—began disappearing from the fossil record about 10 million years before the K/T boundary.

"I think the events at the end of the Cretaceous were not due to a single catastrophic event but represent a conjunction of events—climatic change, maybe a period of volcanism, and then, ultimately, a major impact or catastrophic event," he said.

"The reigning idea is that the Earth had a bad day from the impact, but I think it had a series of bad days," Zinsmeister said. "The Earth's biosphere was already stressed to a critical point, and the impact could have pushed it over the edge, causing local catastrophes such as the fish kill in the Antarctic."

A Volkswagen-sized armadillo. Pieces of a bulky relative of the armadillo, known as a glyptodont, were also found during the 1994–1995 research season protruding from Seymour Island's sands. The 40- to 45-million-year-old beast resembled a Volkswagen beetle in size and shape but sported an armored tail, according to vertebrate paleontologist Judd Case of St. Mary's College of California, who found the fossil along with paleontologists Dan Cheney of the Smithsonian Institution and Michael Woodburn and Barry Albright of the University of California at Riverside.

The armored creature lived some 20 million years after the ammonite found by Oleinik, when the Antarctic Peninsula had a cool temperate climate similar to that of the Pacific Northwest. The beast probably wandered along streams, munching lush vegetation along the banks.

Glyptodont remains have been found in North and South America but never this far south. "It's unusually big for this time period, with pieces of its carapace, or shell, ranging in size from a teacup saucer to a dinner plate," Case said.

The glyptodont resembles fossil cousins found in Patagonia but is much larger than others from the same period. It joins fossil marsupials of the time, as well as ungulates or hoofed mammals, and a large, running carnivorous bird—all peculiar to the southern part of South America and Antarctica, and different from contemporary fauna elsewhere in South America.

"Clearly, Patagonia was connected to the Antarctic Peninsula at that time, and somehow cut off biologically from the rest of South America," Case said. Today, the stormy Drake Passage divides South America from Antarctica.

Also on Seymour Island this season, Case and colleagues found pieces of penguin bone that are several million years older than the glyptodont remains. The fossil penguins, the oldest known, stood about as tall as today's Emperor, the largest living penguin. On previous expeditions, they found bones from penguins more than 5 feet tall, the largest ever known.

Clouds and polar ozone depletion

Scientists from the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, are using a new tool to study the very high stratospheric clouds, crucial to the processes creating polar ozone depletion.

Jim Dye, Darrel Baumgardner, Bruce Gandrud, and their co-workers at NCAR have developed an aerosol spectrometer to measure the characteristics of stratospheric aerosols and polar stratospheric clouds. Chlorine compounds react on the surfaces of these particles to release ozone-destroying chlorine molecules. The spectrometer uses a laser to determine the size, concentration, and optical properties of stratospheric particles. From a particle's optical characteristics, researchers can deduce information about its chemical composition.

The spectrometer may also shed light on whether clouds absorb more energy than theory predicts. The instrument will measure haze droplets as small as 0.3 micrometers in diameter; such small droplets have been typically ignored in previous cloud measurements.

Antarctic sea-ice algae display surprise autumn bloom

Algae locked up inside the ice covering the southwestern corner of Antarctica's Weddell Sea undergo an unexpected autumn bloom, according to an article in the 4 November 1995 issue of *Science*. The perennially iced-over region lay beyond the reach of researchers until 1992, when the joint U.S.-Russian Ice Station Weddell 1 set up shop afloat an ice floe to conduct 5 months of investigations. Labyrinthine sea ice, riddled with channels like Swiss cheese, is a nursery ground for krill, the shrimplike mainstay of the southern ocean food web. The unexpected second algal bloom—the first is in spring—furnishes winter food for the krill.

"Virtually no 'biologically active' light reaches the water beneath the ice, so the algae living within the ice may be the only producers of food in that permanently ice-covered area," says Cornelius Sullivan, director of NSF's Office of Polar Programs and coauthor of the paper. "It was a surprise that there was enough light in the antarctic autumn to allow a second bloom." As porous areas of the ice freeze, the process kicks off an exchange between nutrient-depleted brine in the ice and sea water, replenishing the nutrients in the ice. The results suggest that autumnal blooms are an important food source in some areas of sea ice. The paper's lead author is C.H. Fritsen of the University of Southern California, and other authors are V.I. Lytle, University of Tasmania, and S.F. Ackley, U.S. Army Cold Regions Research and Engineering Laboratory.

Antarctic ice drillers pass 3,000-meter depth at Vostok

Ice-core drillers at Russia's Vostok Station, which is situated on the polar plateau of East Antarctica at an elevation of approximately 3,500 meters, recently passed 3,000 meters—a depth at which the ice is about 300,000 years old. Vostok ice cores studied over the past decade by Russian, U.S., and French scientists have yielded unique information about environmental and climatic changes over the last glacial-interglacial period. For example, analyses of air bubbles trapped in the ice confirm that levels of carbon dioxide and methane—gasses critical to greenhouse warming—were higher between, compared to during, glacial times.

The depths of the Vostok core, when extracted, will be much older than the deep cores of the Greenland ice sheet completed several years ago. (Less snow falls in this part of Antarctica every year, so each meter of ice holds more years of snowfall.) NSF supports U.S. scientists who study the ice cores—the deepest available for Antarctica—and provides some logistical support for Vostok Station, which was established by the former Soviet Union more than 37 years ago.

Antarctica's icefields catch many a falling star

As a green, phosphorescent streak momentarily marks the night sky, a low rumble, reminiscent of a train in the distance, announces the arrival to Earth of another meteorite, a rock from space.

Seekers of meteorites, one of the best sources of information about our solar system, have found them in abundance in Antarctica. The annual hunt for antarctic meteorites is like a bargain-priced space mission that lets geologists explore the extraterrestrial worlds without leaving their home planet, according to Ralph Harvey, a planetary geologist at the University of Tennessee. Each year, Harvey leads a team of scientists and assistants into the field. Since Japanese scientists discovered the first concentration of antarctic meteorites, the continent has yielded more than 16,000 finds to U.S. and Japanese researchers.

Meteorites carry clues to how the planets formed and what the early solar system was like. Most are fragments of asteroids, but some are pieces of larger bodies—the moon or even other planets. Scientists believe that several antarctic meteorites came from Mars because the gases trapped in the meteorites are similar to those found in the atmosphere on Mars by the Viking landers.

Meteorites fall to Earth all the time, and no more seem to land in Antarctica than elsewhere on the planet, so why is Antarctica the motherlode of meteorites, supplying an estimated one-third to one-half of the world's scientific samples? "There's no exotic reason, like the ozone hole forming a gateway for debris from space," laughs Harvey. In fact, one reason is that the frigid antarctic climate preserves the space rocks. An antarctic meteorite that landed hundreds of thousands of years ago looks "fresh," whereas a meteorite landing in warmer latitudes breaks down into soil within a few hundred years.

The movement of Antarctica's ice also concentrates meteorites in particular "hot spots." Like a conveyor belt, the ice moves the meteorites along until the flow is blocked by mountains or an obstruction in the glacier's bed. Old ice is pushed upward from below, where it then remains for long periods, while winds relentlessly scour the ice surface free of snow, causing meteorites to accumulate.

"These are ideal places to hunt for things that fall from the sky," Harvey says. "Terrestrial rocks are rare, so any stone you find on ice is probably a meteorite." Every year, he and his field team, along with their snowmobiles, are dropped off by airplane in a remote but promising spot, often pinpointed earlier from the air. "Once we start our traverse, that special feeling of leaving everything behind sets in," Harvey says. His team camps for 6 weeks out on the ice sheet, sometimes forced to huddle inside tents for days as storms rage outside. Where samples prove abundant, the scientists search systematically, lining up snowmobiles about 30 meters apart and driving slowly in parallel, scanning for rocks.

Many meteorites are covered by a black, burned-looking, frothy crust, acquired from their fiery journey through the Earth's atmosphere. If the crust has weathered away, the meteorites are often polished to a glossy sheen, which catches the experienced eye. Each rock is picked

A note to *recipients* of the *Antarctic Journal of the United States*

This volume (30, issue numbers 1 through 4) of the *Antarctic Journal* is a compilation of materials that were scheduled to be published in the 1995 quarterly issues. The two regular features of each issue—"Foundation awards of funds for antarctic projects" and "Weather at U.S. stations"—cover full-year periods. Awards are listed for 1 September 1994 through 31 August 1995; weather (from stations forwarding information) is recorded for November 1994 through October 1995.

We are publishing this single volume to correct scheduling problems that have occurred over the last 18 months and to help ensure that future issues will be published in a timely fashion. The 1995 review issue (volume 30, number 5) and the March 1996 quarterly issue (volume 31, number 1) are currently in production. We regret any inconvenience that scheduling problems may have caused and hope that readers will find the material contained in this volume interesting and useful.

up with forceps and sealed in a specially cleaned nylon bag. The season's take is kept frozen until it arrives at the Johnson Space Center in Houston, Texas. If a sample were to thaw earlier, water could enter, rusting and dissolving the minerals the meteorite contains.

A rock from Mars that Harvey is currently studying—"my favorite Martian," as he calls it—was found in Antarctica's Allan Hills. It contains carbonate, an unusual mineral for a meteorite. "The carbonate might have been deposited by fluids traveling through the Martian crust—an explanation with staggering implications for what Mars is like," Harvey says. "We know that at some time in the past, Mars had an active system of rivers, and today we see polar caps, vapor clouds, and frost on the planet's surface. But we don't know what kinds of fluids these are, or how warm Mars was in the past. Carbonates left by these fluids can tell us how warm and wet Mars might actually have been."

After six field seasons in Antarctica, working with meteorites has transformed Harvey's view of Earth. "I now look at our planet as a giant wrecking ball crashing through the Universe, sampling whatever happens into its path," he says. "Antarctic meteorites are providing new and exciting ideas about our solar system."

Based on material by Lynn Simarski, Public Affairs Specialist, NSF, Office of Legislative and Public Affairs.

Pegasus: A glacial-ice runway for wheeled flight operations at McMurdo Station

The U.S. Antarctic Program (USAP) relies heavily on aircraft support between Christchurch, New Zealand, and McMurdo Station. The austral summer field season begins in early October when the smooth annual sea ice in McMurdo Sound is thick enough to support heavy aircraft. Wheeled C-130 Hercules, C-141 Starlifters, and C-5 Galaxy airplanes operate routinely from this runway until mid-December when near-melting air temperatures and intense 24-hour-per-day sunshine combine to deteriorate the sea-ice surface and force abandonment of the runway.

For the remainder of the season, which ends in late February, flight operations are shifted to a semi-permanent, groomed skiway located on a deep snow field on the Ross Ice Shelf (figure 1). Only airplanes with very low-ground-pressure tires or those that are ski-equipped can operate from this skiway because of its low bearing strength. The USAP uses specialized LC-130 Hercules (equipped with both skis and wheels) to satisfy the logistics needs of the more than 1,000 people using McMurdo Station as a support base at this time of year. Only nine LC-130s exist; five are under the control of the USAP. Demand for these few airplanes has typically been so great that a backlog of personnel and crucial cargo often has occurred. This backlog severely constrains the USAP from the middle to the end of the season.

In 1989, the Cold Regions Research and Engineering Laboratory (CRREL) initiated a study to determine how a runway on the Ross Ice Shelf near McMurdo Station could be created. The proposed glacial-ice runway had to be capable of supporting heavy wheeled aircraft during the period after the sea ice deteriorated. Using historical records and air photos, the study group chose a site 13 kilometers south of McMurdo Station in an area that has a thin, but permanent and complete, snow cover. The snow at the site is underlain by a contiguous mass of glacial ice about 30 meters (m) thick.

Runway construction

During the 1991–1992 field season, the snow cover was stripped from a surveyed 3,000- by 90-m area to expose the undulating ice surface. Large ice blisters were rough graded, and low areas were filled by flood water from a portable snow melter. In August 1992, following the austral winter, accumulated winter snow was removed, and a survey of the ice surface was used to establish the desired grade for the runway to minimize construction. A laser-guided grader (figure 2) with a specially built chisel-tool blade (figure 3) was used to level the ice surface to a high standard for smoothness. A high-capacity snowblower was used to remove the graded ice (figure 4). Grading and clearing were completed by the end of October 1992.

Protection during peak solar period

In December and the first half of January, warm air temperatures predominate (–7°C to +1°C), and exposed glacial ice often experiences enough heating due to absorbed radiation to cause melting. Melting usually occurs slightly below the surface of the ice. When melt pools form, they are generally large and widespread enough to render a runway useless before complete refreezing in March or later.

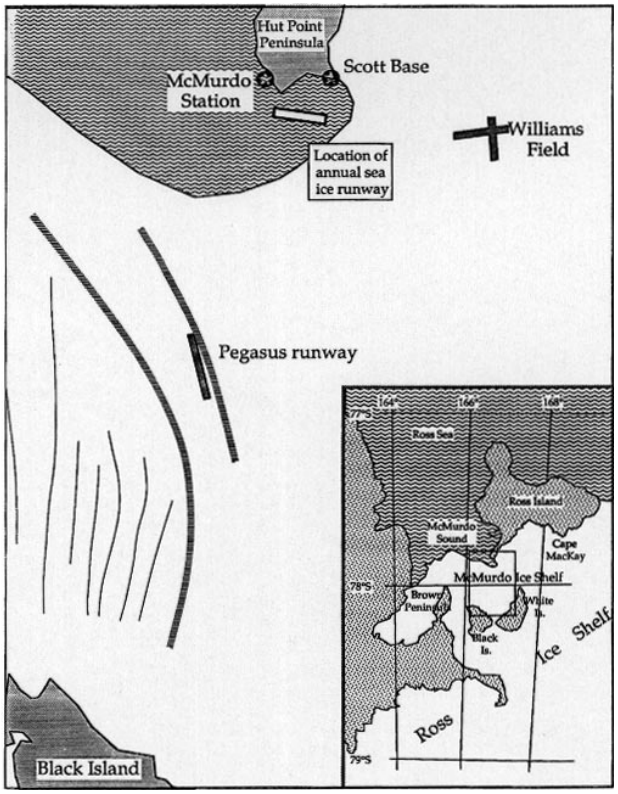


Figure 1. Map of McMurdo Station area showing location of airfields.

Figure 2. Laser-controlled grader used to level natural ice surface for runway.

To protect against melting, the graded ice surface was covered with a 25-centimeter (cm) layer of snow. During the construction phase (1992–1993), material from along the sides of the runway was blown back onto the graded ice surface to provide protection. During subsequent seasons, snow present on the runway following the winter provided the source for this cover. The protective snow cover must be in place by the end of November, just before the peak of the austral summer.

Throughout December and the first week of January, the snow cover required compaction (accomplished with heavy, rubber-tired rollers) to increase its ability to attenuate penetrating solar radiation. Planing and dragging were also done to provide a highly reflective, porous surface. Measurements of air, snow, and subsurface ice-temperature profiles, together with the intensity of the incoming solar radiation, were used to monitor snow-cover performance and to govern snow maintenance activities.

Sometime between 7 and 15 January, the air temperature in the McMurdo Station region begins its downward trend. Within several days of the onset of cooling, the average daily air temperature drops below the highest temperature measured within the ice for that day. With the annual cooling trend thus established, the protective snow cover could be stripped from the runway.

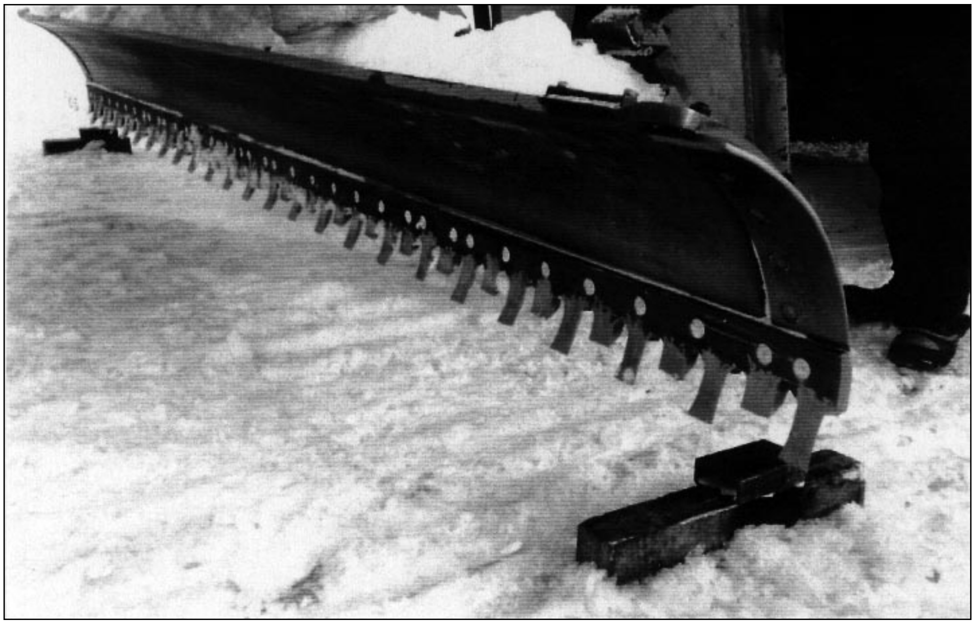


Figure 3. Custom-built grader blade for leveling glacial ice.

Certification of runway strength

In preparation for wheeled aircraft operations, the integrity of the runway was tested with a proof cart. The cart, which replicates the main landing gear of a C-130 or C-141, has a flat deck for ballast to simulate the load, plus a factor of safety, on the aircraft's main landing gear (figure 5). The runway was tracked with the proof cart along its entire length, plus overrun areas at either end. Tire tracks were placed no more than 1 m apart.

During proof testing for C-130 aircraft in January 1993, approximately 30 weak spots were found. In these locations, the ice failed by crumbling, leaving a slight depression in the surface. Excavation of failed points revealed that they had an average size of 2.8 square meters and were 15–45 cm deep. In nearly every case, failure points were associated with a thin (2.5- to 6-millimeter) gap below the ice surface. This gap was most likely caused during refreezing of melt pools that were known to have been present at this site during the 1991–1992 field season when initial construction activities exposed the ice surface and melt pools formed.

Each failure point was excavated, and all of the fractured ice around the edges was dislodged. The ice chunks were broken into fist-sized pieces and packed into the cavity. Cold water was used to flood the cavity, making an ice bath that froze completely within 48 hours. Numerous patched spots were re-tested, and all were found to be sound. On 1 February 1993, the runway was certified for operation of wheeled Hercules aircraft.

During the following season (1993–1994), the proof cart, reconfigured to duplicate C-141 main landing gear, was ballasted to a load of 174,300 kilograms (kg), approximately 25 percent greater than the maximum take-off load on the main landing gear. The tires were inflated to 1,800 kilopascals (kPa), compared to the 1,375-kPa maximum pressure for the C-141.

Proof testing of the runway for C-141 aircraft was completed immediately after the protective snow cover was stripped away on 10 January. No ice failures occurred. After 2 days of proof testing, the runway was dragged and planed to provide an extremely smooth operating surface. The runway was certified for both C-130 and C-141 aircraft and opened for air operations.

Test flights and operations

Before wheeled aircraft could operate on the runway, flight tests were performed to determine the high-speed characteristics and surface traction of the runway. On 6 February 1993, an LC-130 operating on wheels performed a series of landing, taxi, steering, braking, and take-off tests. All test flight results were deemed excellent by the flight crew, and no ill effects were noted on the runway surface.

Full flight operations began from the glacial-ice runway on 8 February 1993. LC-130 aircraft were used to fly cargo from McMurdo Station to Amundsen–Scott South Pole Station allowing an extra 3,600 kg of payload by taking off on wheels. LC-130s operating on wheels and a standard C-130 (figure 6) also used the runway to fly passengers to Christchurch. This change made it possible to increase the number of passengers carried on each flight to 30–50, compared to the usual 15–30 when the plane used skis for take off. The runway was closely inspected following each of the first 15 flights. No damage or wear could be detected, and no ice failures occurred.

In preparation for the 1994 flight season, an LC-130 was again used to certify runway integrity. On 25 January 1994, a wheeled landing, high-speed taxi test, braking test, and a take-off were completed. The flight crew reported that the runway had a superb operating surface, stating that the surface was smoother than most of the concrete runways from which they operate.

Figure 4. Large-capacity snowblower used to remove snow and graded ice from runway.

Figure 5. Proof cart configured and ballasted for C-141 aircraft proof testing.

Figure 6. C-130 Hercules performing routine operations from the glacial-ice runway.

The 1994 operating season began on 26 January and extended through 27 February. Numerous LC-130 flights (on wheels) were operated in supplying the South Pole, and a conventional C-130 was operated between Christchurch and McMurdo Station on an every-other-day basis starting on 1 February. In total, more than 55 flights were operated.

On 7 February 1994, a C-141 flew from Christchurch to McMurdo Station, marking the first-ever C-141 landing on glacial ice. Two to 7 cm of processed snow covered the runway surface, and the C-141's small, high-pressure tires appeared to displace the snow only where more than 5 cm was present or where prior C-130 wheel tracks existed. The C-141 taxied and com-

Figure 7. C-141 completing take-off after successful tests on the glacial-ice runway.

pleted turn-around without difficulty. The C-141 pilot and his crew indicated extreme satisfaction with the runway.

The C-141 was fueled and loaded with three pallets of priority science cargo. Fifty-four passengers boarded and the C-141, at a weight of 127,100 kg, proceeded with take-off, pulling clear of the runway at the 1,500-meter mark (figure 7). The runway suffered no damage from the C-141 operation.

Conclusions

The McMurdo Station glacial-ice runway was developed over a 5-year period and now provides access to heavy wheeled aircraft for much of the austral summer field season. Benefits of the runway include reduced wear and tear on airframes, more efficient use of aircraft and flight crews, less wasted time by science and support personnel, enhanced morale, assurance of stocking South Pole before station closings, increased efficiency for cargo handlers, and timely station close-out. Access by much of the world's aircraft and the potential for winter flights are also gained.

To date, about 78 flights have operated from the glacial-ice runway yielding a savings of 39 flights. This translates to a cost savings of close to 2 million dollars.

The successful completion of this project was the result of cooperation, interest, and hard work by many organizations and agencies including Antarctic Support Associates, the U.S. Navy, and the U.S. Air Force.

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The Arctic and Antarctic Research Center: Support for research during 1994–1995

Since 1988, the Arctic and Antarctic Research Center (AARC) at the Scripps Institution of Oceanography (SIO) has maintained viable satellite data collection facilities for the polar regions and has ensured that full-resolution satellite data of the greatest possible geographic and temporal coverage are available to the research community, both for real-time polar operations and retrospective research purposes (Van Woert et al. 1992). In October 1994, the AARC became part of the California Space Institute, one of the research divisions of SIO. As of mid-1995, the AARC received both high-resolution picture telemetry (HRPT) from the National Oceanic and Atmospheric Administration (NOAA) polar orbiters and Defense Meteorology Satellite Program (DMSP) telemetry from the U.S. Air Force polar orbiters from two land-based, antarctic sites (McMurdo and Palmer Stations) and from the U.S. Coast Guard icebreakers *Polar Sea* and *Polar Star* when these ships are operating north or south of 50° latitude. These four satellite-tracking facilities, as well as the AARC image-processing laboratory at SIO, are based on the TeraScan hardware and software manufactured by the SeaSpace Corporation of San Diego, California, although AARC usually supports scientific users who do not themselves possess the TeraScan software. The table lists the total number of HRPT and DMSP overpasses in the AARC archive that cover part of the antarctic continent and/or the southern oceans. Between the two land-based sites, geographic coverage of the continent is nearly complete with some gaps on the Indian Ocean side. As of 1995, AARC was recording 10 HRPT and 10 DMSP satellite overpasses per day from each land-based site.

In addition to providing the historical archive outlined in the table, AARC offers real-time services in three ways. With the TeraScan software at each shipboard or land-based site, a researcher in the field is able to work with the data using any of the standard TeraScan functions and also his or her own algorithms because the TeraScan software allows export of data to other formats. Real-time services are also available at the AARC image-processing laboratory at SIO via the T1 line out of McMurdo Station. On any given day, a user at SIO can readily access the most recent 24–36 hours of satellite imagery (NOAA or DMSP) tracked by the antenna at McMurdo Station. If additional recent data are required by a user at

The number of HRPT and DMSP overpasses covering high southern latitudes archived at the AARC as of 18 July 1995

Year	HRPT	DMSP
1985	46	0
1986	78	0
1987	123	0
1988	594	0
1989	598	0
1990	1,512	0
1991	2,854	1,133
1992	3,645	1,873
1993	3,987	2,513
1994	4,930	5,166
1995	3,708	3,638

SIO (say, within the past week), a user can request over the Internet that the system operator at McMurdo place a recent archive tape in the drive, so that this data also may or can be transmitted to SIO over the T1 line. A third real-time service involves Japanese geostationary satellite (GMS) data tracked by a TeraScan facility at the University of Hawaii. These data are sent to McMurdo on a daily basis so that the operator can composite these geostationary data with current NOAA or DMSP data. The AARC facility at SIO can process the raw telemetry into numerous geophysical and mathematical products of interest to many disciplines.

The AARC's direct involvement with research has encompassed a wide variety of disciplines, including atmospheric science (20 percent of AARC users as of early 1995), polar oceanography (9 percent), sea-ice research (23 percent), glaciology (9 percent), geophysics (9 percent), polar biology (18 percent), and space science (12 percent). An example of AARC support for biological research is illustrated in figure 1, where collared emperor penguins have been tracked by ARGOS telemetry, and where this tracking is merged with advanced very high resolution radiometer (AVHRR) 1–2-kilometer (km) resolution, clear-sky images, to discern sea-ice conditions associated with the animals' migratory and feeding habits. Throughout 1994–1995, the AARC has provided regular sea-ice mapping support to research cruises of the *Nathaniel B. Palmer* (figure 2), using the 85.5-gigahertz channels of the DMSP SSM/I sensor (Lomax, Lubin, and Whritner 1995). This algorithm offers twice the spatial resolution (12 km) of the standard National Aeronautics and Space Administration (NASA) Team algorithm (30 km, Cavalieri et al. 1991) and, hence, more accurate identification of the ice edge and polynyas. The AARC has also provided the *Nathaniel B. Palmer* with standard NASA Team algorithm sea-ice products, which have proven useful for strategic planning purposes.

During early 1995, AARC began several efforts to improve its overall capability. First, a three-way collaboration commenced under the auspices of the National Science Foundation's Office of Polar Programs (OPP) to create an OPP meteorological data service in conjunction with the

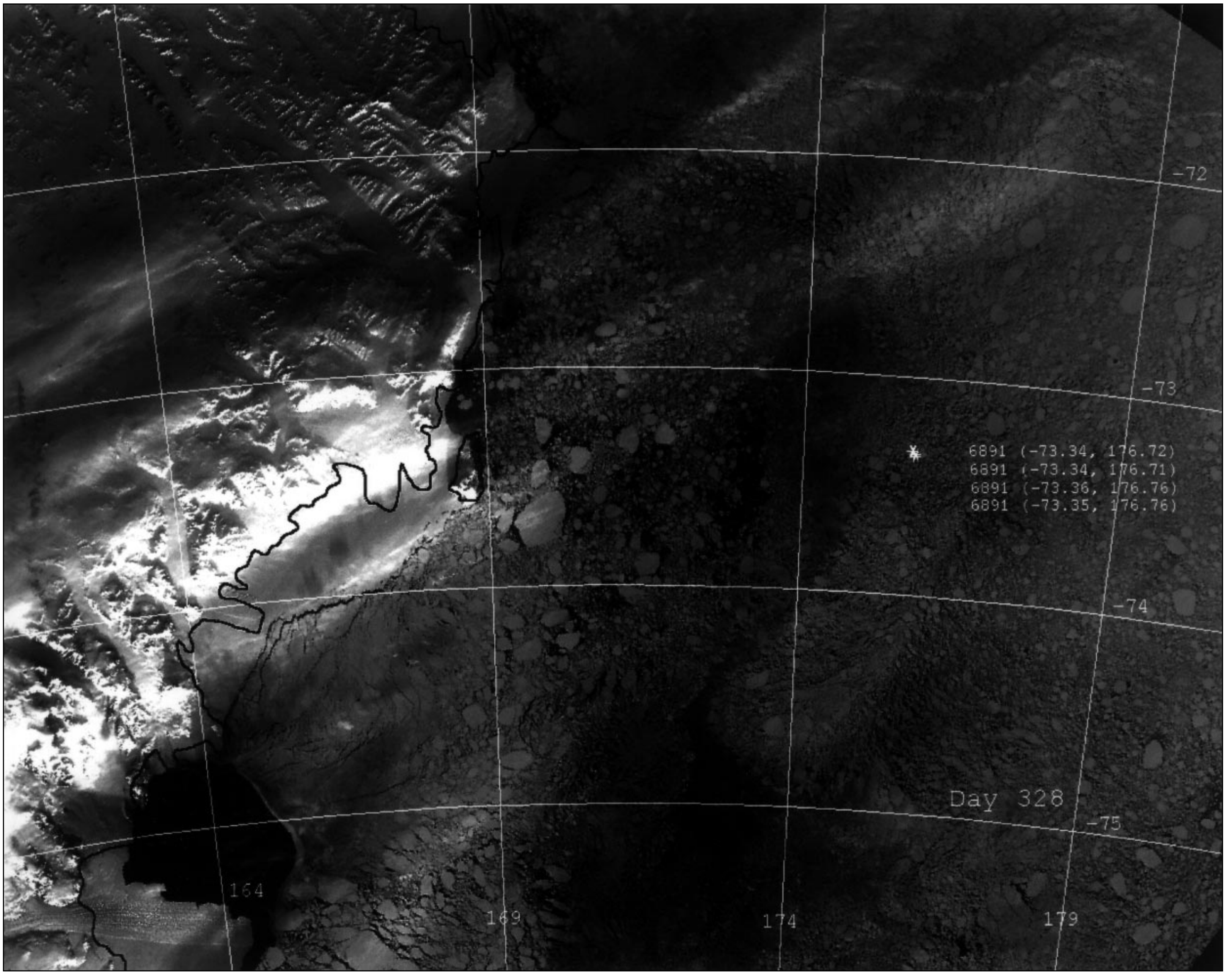

Figure 1. Example of HRPT support given by the AARC to the ecological research program of Gerald Kooyman at the Scripps Institution of Oceanography. This clear-sky AVHRR image was obtained on 23 November 1992 and shows the structure of the ice floes in the Ross Sea at 2-km spatial resolution. The cluster of points east of the center of the image indicates the location of the tracked emperor penguins.

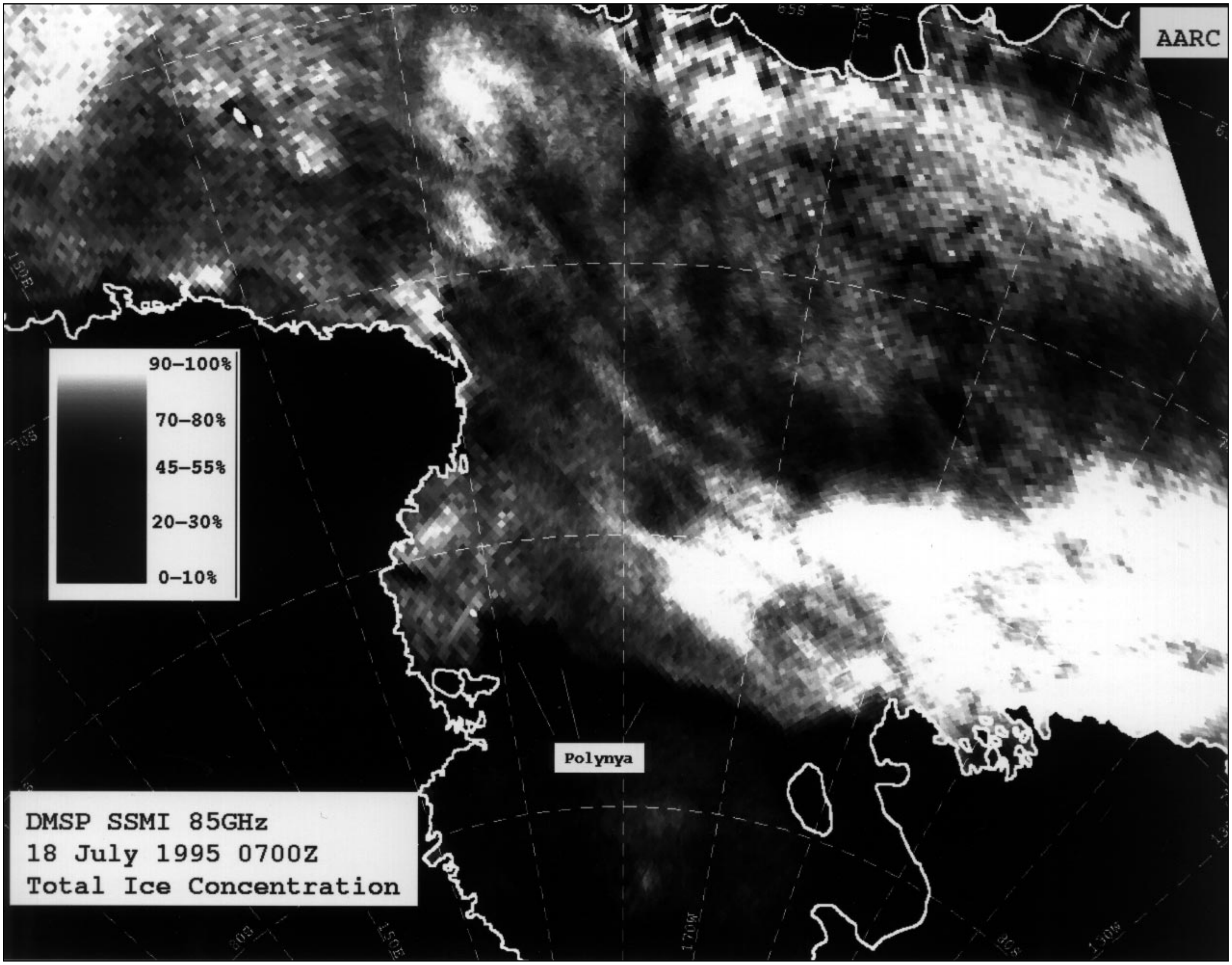

Figure 2. Example of a total sea-ice concentration product provided by the AARC to the *Nathaniel B. Palmer* at sea. The ice concentration is mapped at 12-km spatial resolution using the 85.5-gigahertz channels of the SSM/I instrument aboard the U.S. Air Force polar orbiters.

National Snow and Ice Data Center (NSIDC) at the University of Colorado and the Antarctic Meteorology Research Center (AMRC) at the University of Wisconsin. This OPP data service will eventually feature transparent interaction with users over the World Wide Web. Second, AARC has begun copying the entire satellite data archive for storage and distribution at NSIDC, to facilitate wider usage of the data by the large community of polar researchers who routinely work with NSIDC. Third, AARC is copying the entire archive onto modern 4-millimeter magnetic media in Hewlett-Packard compression format, both to safeguard the archive and to provide greater speed in accessing older data (although the AARC will retain the ability to provide data in 8-millimeter format). The AARC can be reached on the World Wide Web at http://arcane.ucsd.edu, and in 1996, the entire data catalog will be accessible in this manner. The AARC's mandate is to provide satellite data and support with interpretation to interested researchers at no cost to the user, although for large data requests we usually ask that a user cover the cost of magnetic media.

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Microbial ecosystems in Antarctica: Is protection necessary?

In the McMurdo Dry Valleys and other continental locations in Antarctica, ecological systems are composed entirely of microbial life forms. Increased human presence over recent years in these areas has raised concern that these unique microbial systems may be at risk and that human interference with microbial ecosystems may, in turn, affect scientific research. The purpose of this paper is to provide a brief overview of the information available on microbial ecosystems in continental Antarctica and to discuss the potential need for implementing policies for preserving these systems. The focus of the discussion is on microbial systems inhabiting soil and rock surfaces in terrestrial areas away from marine influence.

Microbial ecology of terrestrial Antarctica

Most microbial species isolated from antarctic soils do not possess special adaptations to the local environmental conditions. Rather, most represent cold- and desiccation-tolerant species that may also be found in more temperate zones (Vincent 1988). There is some indication, however, that isolates collected in Antarctica may be capable of growing at lower temperatures than isolates of the same species collected in more temperate locations (e.g., Latter and Heal 1971; Line 1988). In the McMurdo Dry Valleys, microbial abundance and distribution in soils have been related to climate (e.g., Cameron 1972a, pp. 195–260; Horowitz, Cameron, and Hubbard 1972), suitable substrate (e.g., Boyd, Staley, and Boyd 1966, pp. 125–159; Cameron and Benoit 1970; Cameron et al. 1971; Cameron 1972b; Cameron and Ford 1974), and discontinuous inputs of nutrients and energy (Draggan 1993). The current consensus is that abundance and distribution are dictated by a favorable complex of microclimate factors and the physical characteristics and composition of the soil.

Scientists have identified various natural pathways for the introduction of microbes to Antarctica. In coastal regions, microbes may be dispersed by sea spray or via the activities of penguins, skuas, seals, and other animals. In the McMurdo Dry Valleys and other sites isolated from marine influence, microorganisms are more likely to be introduced via high-altitude air-streams. Over the past century, however, introduction has been greatly enhanced by humanborne inocula on food, field gear, and wastes (Lipps 1978). Horses and dogs brought to the continent in the past also contributed microorganisms to the environment. Several studies have found viable microbial contamination introduced by early antarctic expeditions. Meyer, Morrow, and Wyss (1962, 1963), for example, found organisms that had remained viable for over 50 years under ambient antarctic conditions in materials brought to Cape Royds by Shackleton and to Cape Evans by Scott. The long-term survival of these organisms underscores the importance of minimizing wastes of all types.

A number of baseline microbial studies have been conducted in relatively undisturbed areas of the McMurdo Dry Valley region (e.g., Cameron et al. 1970; Cameron and Ford 1974; Parker et al. 1977, 1982; Parker, Howard, and Allnutt 1978, pp. 211–251). Small numbers of viable soilborne microbes were found at virtually every location examined, including the southernmost site (87°21'S). Assessment of microbial contamination around McMurdo Station and various field camps was initiated in the early 1960s (e.g., Boyd and Boyd 1963a, 1963b). Microbial contamination studies have also been conducted at Japanese (e.g., Miwa 1975, 1976; Toyoda et al. 1986) and Russian bases (e.g., Abyzov, Rusanov, and Smagin 1986).

In the late 1970s, Friedmann and his associates began a series of studies on cryptoendolithic microorganisms (e.g., Friedmann and Ocampo-Friedmann 1976; Friedmann 1982; Meyer et al. 1988; Nienow and Friedmann 1993). By occupying niches within the interstitial spaces beneath the surface of sandstones and other porous rocks, these organisms have adapted to the extreme environmental conditions found in the interior of Antarctica. Because of their unique habitat, these organisms are considered endemic and are unlikely to be displaced by microorganisms imported by humans.

Many problems have been identified with techniques used during the early microbial studies in Antarctica. Use of different growth media and incubation temperatures have yielded cell counts that vary by an order of magnitude or more (e.g., Line 1988; Parker et al. 1977, 1982). A review of some of the technical problems associated with field microbiology in Antarctica is provided by Wynn-Williams (1979), and the problems associated with the culture techniques used during early studies are discussed by Vishniac (1993).

Despite the problems associated with accurate assessment, some general conclusions may be drawn (Vishniac 1993). First, although accurate quantification is difficult, microbial populations of soils in Antarctica are low but are *not* zero. Second, data from early studies should not be extrapolated spatially, even over small scales, and interpretation of early data sets should be kept within the context of the specific study conducted. Except in areas influenced by humans, microbial "systems" in terrestrial Antarctica exhibit a general lack of community development and more closely resemble loose assemblages of species. The unique cryptoendolithic communities provide a notable exception.

Impacts to microbial systems—Are they occurring?

In a series of publications, Cameron and associates concluded that human activities have altered microbial ecosystems in Antarctica at least on a small scale. These conclusions were based on observations in the McMurdo Dry Valleys and at McMurdo Station, where alterations (Cameron, Morelli, and Johnson 1972) or complete elimination (Cameron et al. 1974) of the endemic microbial communities were suspected. These perturbations were attributed to the establishment of semipermanent field camps, the use of motorized land vehicles and helicopters, and the establishment of repositories for materials and supplies at former field camps. Despite these claims, it remains uncertain whether introduced species have the capacity to displace or to modify existing microbial assemblages on anything but a local scale (Vincent 1988).

Cameron (1972a, pp. 195–260) described human-induced perturbations to the microbial systems of Antarctica as falling into three distinct categories:

- *Disruption of competitive interactions.* The long-term introduction of cold- and desiccation-tolerant species from temperate environments may alter competitive interactions between microbial species.
- *Microbial enhancement.* The number and/or diversity of species in microbial communities may be altered through, for example, disruption of substrate. This disruption could result in the release of nutrients and dormant organisms from lower depths (Cameron and Morelli 1974) or could interfere with thermal balance and/or light regimes (Wynn-Williams 1990), thereby altering the microbial communities without importing exogenous organisms.
- *Habitat destruction.* Microbial systems may be inadvertently destroyed by damaging or eliminating habitat. This could include physical destruction of the habitat, contamination with toxic substances, or competition from introduced species.

To this original list compiled by Cameron, a fourth category may be added:

- *Altered gene pool.* Interchange of bacterial plasmids between indigenous microbes and those introduced by humans may result in alteration of the microbial gene pool, as has been observed with antarctic microbes in experimental settings (Kobori, Sullivan, and Shizuya 1984; Siebert and Hirsch 1988).

Conclusions

Historically, concerns regarding human impacts to microbial systems have focused on the introduction of non-native biota. Although competition between imported species and native microbial assemblages may represent a potential problem on a local scale, it is unlikely to pose more than a minimal threat in continental Antarctica. The presence of viable, exotic microorganisms in laboratory cultures of antarctic soils does not necessarily mean that these organisms have become part of the local system, because dormant survival in a cold, dry, nutrient-poor environment is much less demanding than growth and reproduction (Vishniac 1993). Those species and strains introduced from temperate regions that are capable of growing in Antarctica would likely be at a severe competitive disadvantage with similar indigenous strains. This distinction between biota that are viable but incapable of growth and those that are fully capable of completing their life cycles under ambient conditions was not generally made during early microbial studies in Antarctica.

Exotic species are most likely to survive in Antarctica if they are introduced along with suitable substrate materials, and organic waste materials of all types are capable of harboring such inocula. One scenario for potential future impact to microbial systems involves the potential accelerated rates of decomposition of organic waste materials following changes in climatic conditions. Decomposition in Antarctica is an extremely slow process due primarily to the ambient environmental conditions. Should climatic conditions change, however, so that temperatures and/or precipitation levels increase, decomposition rates could increase substantially in areas where large quantities of organic substrates have accumulated, mediated by organisms introduced along with these materials. Such an increase could dramatically alter nutrient cycles within these areas.

Although not generally designed with microbial pollution in mind, recent changes in U.S. Antarctic Program policies regarding the accumulation and disposal of waste materials have decreased the potential for entry of temperate-zone microbes to U.S. research stations. Not only are most waste materials generated by the U.S. program in Antarctica now recycled or retrograded, but also some of the waste materials accumulated at bases and field camps during previous decades are also being removed from the continent. Human wastes are routinely removed from field camps. Treaty provisions imposed during recent years banning the import of horses and dogs also help to decrease the rates at which microbes are introduced. Despite these policies, however, the mere presence of permanent research and logistical support bases such as McMurdo Station will provide an ongoing pathway for introduction of a variety of exotic microbial species. Field camps and transportation also are sources of inocula that may influence microbial systems on a small scale.

Considerable uncertainty remains regarding the degree to which special habitats are being destroyed by human activities. For example, the extent to which the minute physical structures on the surfaces of sandstones and other rocks—structures that provide the unique habitat for cryptoendolithic communities in the McMurdo Dry Valley area—are being damaged by human activities is not known. Information is also lacking regarding the length of time required for these communities to recover following damage by humans.

The requirements of the Agreed Measures for the Conservation of Antarctic Flora and Fauna, a provision of the Antarctic Treaty, were enacted in 1978 by the U.S. Congress in the form of the Antarctic Conservation Act (ACA), Public Law 95-541. This was done to ensure that species that are not native to the Antarctic Treaty Area are not *deliberately* introduced. Although microbiota continue to be introduced by humans, their introduction is the indirect result of other activities and cannot, therefore, be considered “deliberate.” Because the native microbial assemblages found in many of the ice-free areas of continental Antarctica represent unique systems, however, the Antarctic Conservation Act *could* be interpreted as requiring their protection. From a practical perspective, though, strict measures for preventing the introduction of microbial species would be impractical, because it would be virtually impossible to conduct research in Antarctica without introducing some forms of exogenous microbial life to the region. Such measures would effectively preclude all human activities in Antarctica (Draggan 1993, pp. 603–614).

Given the vastness of Antarctica, human impacts to the microbial assemblages remain small, although they may be significant on a local scale (Cameron 1972c; Fifield 1985). Furthermore, since introduction of microbes cannot be prevented so long as human activities persist, perhaps the best recommendation is that made in Cameron, Honour, and Morelli (1977), who proposed that monitoring of the microbial communities be continued in areas where the potential for human influence is relatively high. This would necessitate the application of better, more standardized techniques and the accurate establishment of baseline conditions and natural variability. Special attention might be given to areas such as the Sites of Special Scientific Interest that are dedicated to the study of microbial ecology.

Finally, discussion of human influences on microbial systems in Antarctica cannot fail to consider the issue of tourism. Projected increases in tourism levels imply the potential for increased amount and diversity of microbial introductions, destruction of microbial habitat, and imported organic materials. Future monitoring of microbial systems in Antarctica should attempt to assess baseline levels for areas that will likely receive increased tourism pressure.

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Sea-ice development in the Ross, Amundsen, and Bellingshausen Seas revealed by analysis of ice cores in late winter 1993 and 1994

Analysis of ice cores reveals the structure of sea ice, and from the structure of the sea ice, researchers can determine the thermodynamic processes (freezing and melting) and dynamic processes (atmospheric and oceanic forcing) that contribute to the development of the sea-ice cover and the ice-thickness distribution. In addition, ice cores provide ice-property data, such as salinity and temperature, and information on air-ice-ocean interactions and sea-ice development.

Quite extensive studies have been done of first-year and multiyear sea-ice structure, properties, and processes in the Weddell Sea (e.g., Gow et al. 1982; Lange et al. 1989; Eicken 1992). In August and September 1993, we made the first comprehensive investigation of first-year sea-ice development in the Bellingshausen and eastern Amundsen Seas (Jeffries et al. 1994; Worby et al. 1994). In September and October 1994, we investigated first-year sea-ice development in the western Amundsen and eastern Ross Seas. This article presents the results of the 1994 investigation and compares them with the 1993 results. Both data sets were obtained in late winter aboard the R/V *Nathaniel B. Palmer*. The 1993 and 1994 cruise tracks and sampling locations are illustrated in figure 1.

In 1994, a total length of 120 meters (m) of ice core was obtained from 26 first-year ice floes. Half of this length was used for structural analysis and identification of ice-growth processes, and half was used for salinity and temperature analysis. The number of pairs of cores (one for structure, the other for salinity and temperature) obtained at sites on the ice-thickness transects on each ice floe varied between one and five depending on the ice thickness. Three pairs of cores were obtained at most floes. The length of individual cores ranged from 0.05 to 4.23 m with an average of 0.84 m. These values are similar to those in 1993 (Jeffries et al. 1994), consistent with the similarity between the ice-thickness distributions each year (Jeffries et al., *Antarctic Journal*, in this issue).

Three ice types were observed in most floes: columnar ice of congelation origin, granular ice of frazil origin, and granular ice of snow-ice origin. Frazil ice represents growth associated with wind- and wave-induced turbulence, whereas congelation ice grows under calmer conditions. Snow ice forms by the freezing of slush at the surface of floes that have been flooded by sea water. A fourth category, cavities, is noted during ice-core drilling. Cavities contain a mixture of sea water and snow-ice crystals and occur between the blocks and slabs of ice that are rafted and ridged during deformation events. Although a cavity is not strictly ice, it is a part of the total ice thickness and, therefore, included in the interpretation of the ice-core data.

Figure 2 illustrates the distribution of the three ice types in five cores from a single floe. They comprise 44.9 percent frazil, 41.7 percent congelation, and 13.4 percent snow ice. Some of the cores include numerous layers of different ice types. This is typical of most floes. The structural complexity in individual cores and the spatial variability of ice types over short distances illustrate the dynamic and rapidly changing nature of the environment in which floes develop. The entire set of cores obtained during the 1994 cruise comprises 58.7 percent frazil, 28.7 percent congelation, 9 percent snow ice, and 3.6 percent cavities. The 1993 cores comprise 65.1 percent, 25.5 percent, 3 percent, and 5.5 percent of these ice types, respectively, plus 0.9 percent fragmented ice. These values are similar to those observed in the Weddell Sea (Gow et al. 1982; Lange et al. 1989) and in the pack ice off East Antarctica (Allison and Worby 1994) and illustrate that the turbulent conditions that favor frazil ice growth and deformation (the origin of the cavities) are more common than the calmer conditions that favor congelation-ice growth and that the relative contributions of the three ice types to antarctic sea-ice development are spatially and temporally consistent.

One of the significant differences between the 1993 and 1994 data sets is the appreciably larger amount of snow ice in 1994. The final determination of the amount of snow ice awaits the results of stable isotope analysis of the ice samples, but the greater amount of snow ice in 1994 is consistent with the frequent observations of sea-water flooding of floes. For example, 92 of the 102 holes (90 percent) drilled in the floe illustrated in figure 2 had

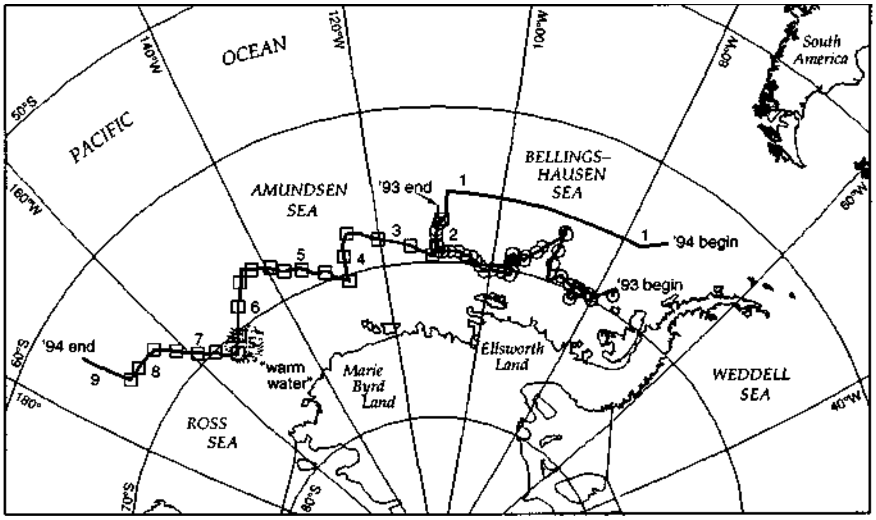

Figure 1. Map of the Bellingshausen, Amundsen, and Ross Seas showing the cruise tracks of the R/V *Nathaniel B. Palmer* in the pack ice in August and September 1993 and September and October 1994. The locations of floes from which ice cores and snow- and ice-thickness data were obtained are identified by open circles (1993) and open squares (1994). Both cruises were from east to west. The beginning and ending points are at the ice edge. The 1994 cruise track is divided into legs numbered 1–9.

a negative freeboard. During the course of the cruise, 2,227 holes were drilled in 23 different floes and 1,135 (51 percent) of those had a negative freeboard (Jeffries et al., *Antarctic Journal,* in this issue). The ice surface can flood because of a number of processes including ice loading during ridging and rafting and snow loading when the weight of snow overcomes the buoyancy of the ice. The greater amount of flooding and snow-ice formation in 1994 may reflect the roughly 1-month later sampling period and, consequently, the greater snow accumulation (Jeffries et al., *Antarctic Journal,* in this issue). The greater snow accumulation meant increased snow load and flooding in 1994 and a longer period for flooded areas to freeze and form snow ice.

Salinity and temperature measurements were made at the same depth at 0.1-m intervals in each core. Composite salinity and temperature profiles were compiled by binning all the values for a given depth and calculating a mean and standard-deviation temperature value for that depth. The composite salinity and temperature profiles for three different ice-thickness categories are shown in figure 3. The profiles for each year demonstrate considerable similarity. Ice temperatures increase as ice thickness increases. In ice more than 1-m thick (figure 3*C*), a significant proportion of the ice is isothermal near the melting point (above 2°C). The salinity profiles in each thickness category are characterized by high values in the upper layers and a trend to low values at the base of the ice (figure 3*D, F*). In 1994, in ice more than 1-m thick, the salinity is an almost constant 6–6.5‰ in the uppermost 0.4 m of ice—constituting a much thicker layer of very saline ice than in 1993 (figure 3*F*). Each year, in ice more than 1.0-m thick (figure 3*F*), the profiles have an S shape, but the 1994 profile is a roughly 180° out of phase with the 1993 profile. Regardless of ice thickness, the salinity variations in individual ice cores are generally independent of any structural complexity below the snow-ice layers.

The increase in ice temperatures as ice thickness increases can be attributed primarily to the insulating effects of the snow cover. Ice thickness is a proxy for age, and in general, the thicker the ice, the greater its age and, thus, the longer the time for snow to accumulate. Thicker snow offers better insulation from the cold air temperatures; hence, the thicker ice is warmer than thinner ice.

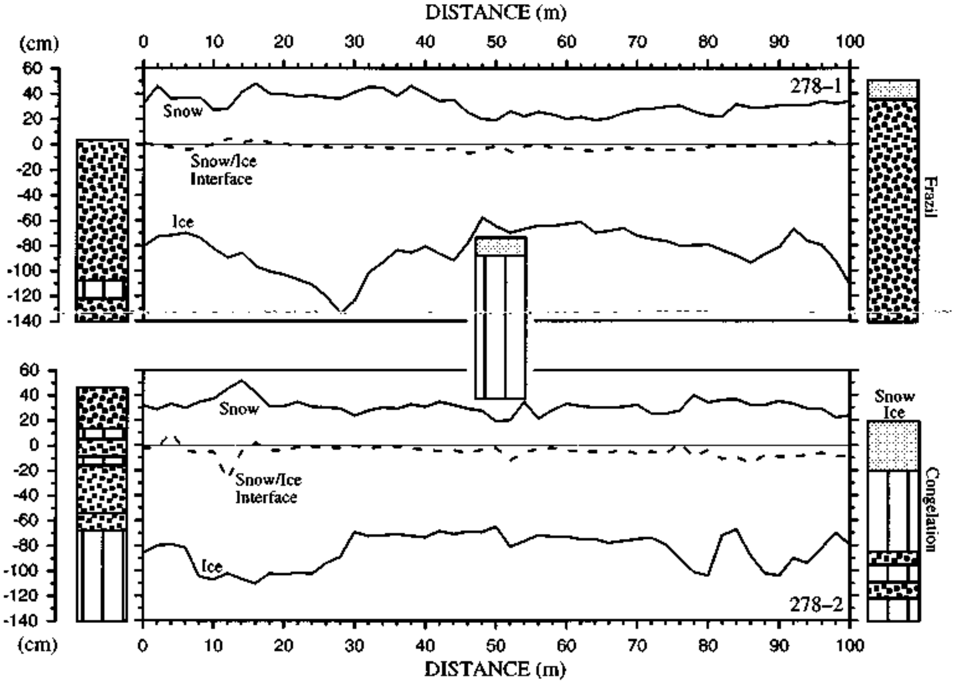

Figure 2. Ice- and snow-thickness profiles along two 100-m long transects oriented perpendicular to one another and crossing at 50 m. The thin horizontal line at 0 m represents the waterline. The dashed line represents the snow–ice interface; any point on this line has a negative freeboard, that is, it is flooded with sea water. The structure profiles of five ice cores obtained at the ends and the intersection of each transect are also shown. The vertical scale of the core profiles is twice that of the ice- and snow-thickness profiles.

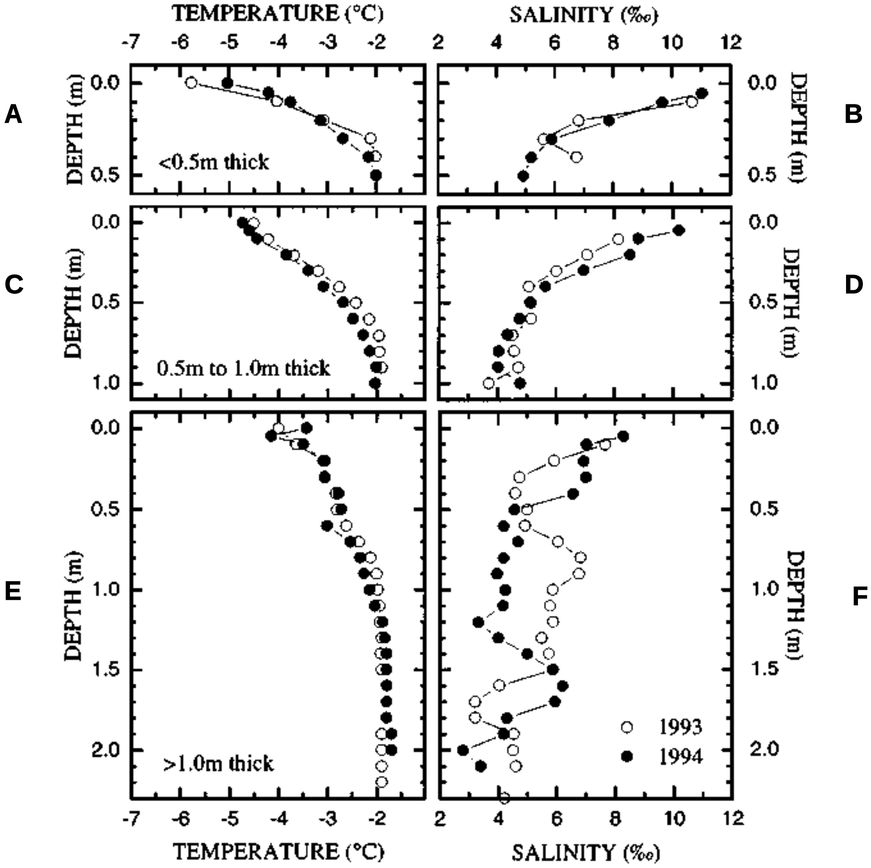

Figure 3. Composite salinity and temperature profiles in three first-year sea-ice thickness categories in 1993 (Bellingshausen and eastern Amundsen Seas) and 1994 (western Amundsen and eastern Ross Seas).

The very high salinity values observed in the upper ice layers have been reported also in Weddell Sea ice and attributed to sea-water flooding and the formation of snow ice (Eicken 1992). The more extensive flooding and larger amount of snow ice observed in the 1994 cores might explain the particularly thick upper layer of 6–6.5‰ salinity ice in cores that are more than 1 m long (figure 3*F*).

The temperature gradients in the ice are sufficient to allow gravity drainage and, thus, desalination of the lower ice layers—hence, the trend to lower salinity values at the base of the ice. In ice that is more than 1 m thick, the nearly isothermal lower part of the ice is probably in, or close to being in, thermal equilibrium with the underlying sea water. Vertical brine exchange between the ice and the underlying sea water affected by the gravity drainage of cold, dense brine and its replacement by warmer, less-dense sea water would account for the high ice temperatures. These temperatures will increase the porosity of the ice and enhance the brine exchange.

The poor correlation between ice salinity and structure is probably also enhanced by the high ice temperatures and resultant gravity drainage of brine across structural boundaries in the multilayered floes. The S shape (figure 3*F*) may be a stable salinity profile representing thick first-year ice in Antarctica. The 180° phase shift between the 1993 and 1994 profiles may be due to a combination of the more extensive sea-water flooding and larger amount of snow ice contributing to a thicker high salinity surface layer, the greater age of the 1994 ice, and therefore, a more prolonged period of desalination.

The structure and growth processes, as well as the temperature and salinity variations in first-year ice in late winter in the Ross, Amundsen, and Bellingshausen Seas have been documented. Although the data were obtained at a slightly different times in different geographic areas, the many similarities between both data sets indicate that the sea-ice processes and the conditions of ice development have no significant spatial differences on an annual basis in this sector of the southern oceans. This finding is consistent with the results of the investigation of the snow and ice-thickness distribution in the same area in 1993 and 1994 (Jeffries et al., *Antarctic Journal*, in this issue).

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Sea-ice– and snow–thickness distributions in late winter 1993 and 1994 in the Ross, Amundsen, and Bellingshausen Seas

The sea-ice–thickness distribution is determined by studying a combination of thermodynamic processes related to freezing and melting and dynamic processes related to atmospheric and oceanic forcing. The extent to which the sea-ice cover modifies atmosphere-ocean interactions and exchanges of heat, mass, momentum, and even regional and global climate variability is dependent on the thickness of the sea ice and its snow cover. Ice and snow thickness are not easily measured by remote means (e.g., from space), so in Antarctica, it is necessary to rely on direct measurements made during research vessel cruises in the ice pack. The relative infrequency of such cruises results in large gaps in our knowledge of the spatial and temporal variability of antarctic sea-ice– and snow–thickness distribution.

Much of the current knowledge of antarctic sea-ice and snow thickness is based on studies of the Weddell Sea ice cover (Wadhams, Lange, and Ackley 1987; Lange and Eicken 1991) and, to a lesser extent, the pack ice off East Antarctica (Allison and Worby 1994). The sea-ice– and snow–thickness distributions in the Bellingshausen and eastern Amundsen Seas were studied for the first time during August and September 1993 (Worby et al. 1994). The first investigation of the sea-ice– and snow–thickness distribution in the western Amundsen and eastern Ross Seas was made in September and October 1994. This article presents the results of the 1994 study and compares the data with the 1993 measurements.

The 1993 and 1994 cruise tracks of the R/V *Nathaniel B. Palmer* are shown in Jeffries et al. (*Antarctic Journal*, in this issue, figure 1). The data presented here are only

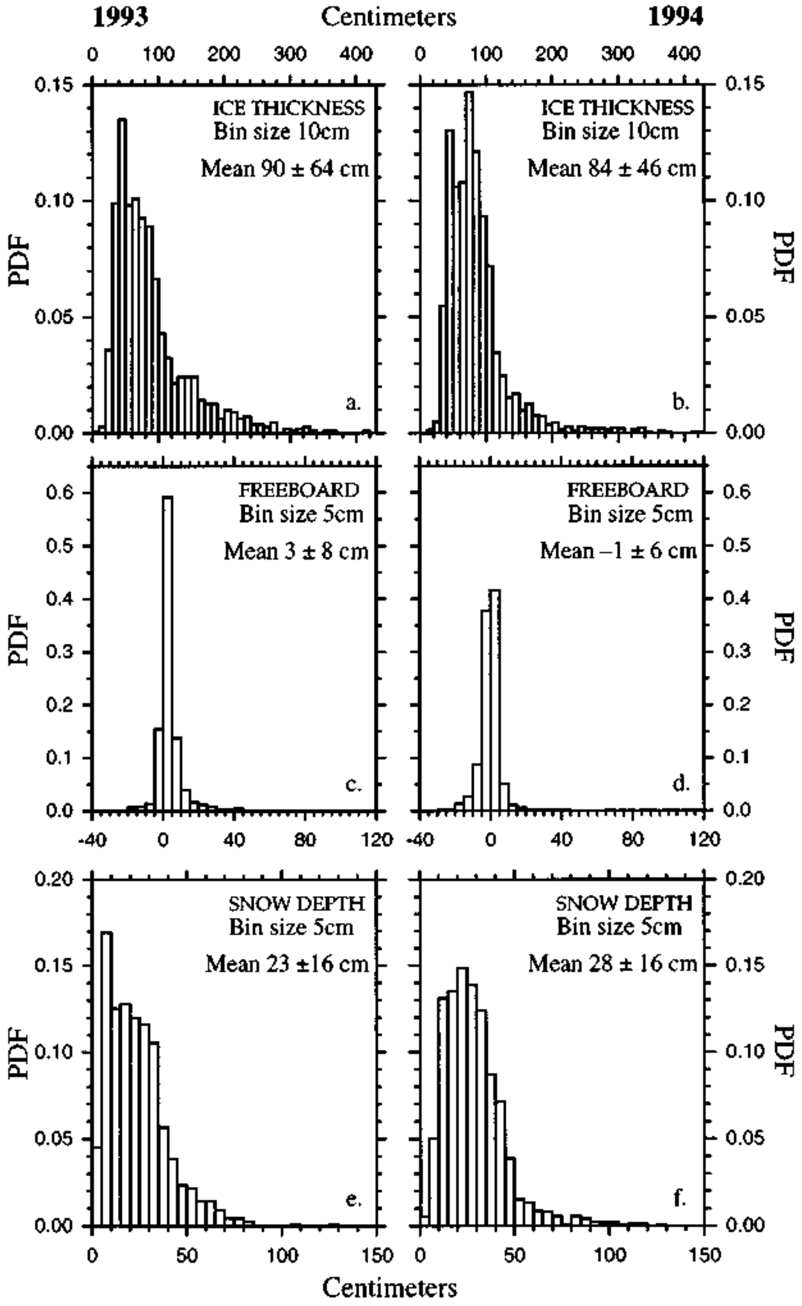

Figure 1. Probability density distributions (PDFs) for set A data acquired by drilling along 100-m-long transects across floes in 1993 (left side, 1,113 measurements) and 1994 (right side, 2,227 measurements). Each bar indicates the probability that a particular thickness or freeboard value will fall in that bin.

for the area south of 67°S and only for first-year ice because the ship was unable to penetrate the multiyear ice pack near the coast. Two sets of sea-ice– and snow–thickness data for 1994 are discussed:

- Set A comprises 2,227 direct measurements made at equidistant intervals [2 meters (m)] along forty-three 100-m long transects on 23 different floes (two transects oriented perpendicular to one another were laid out on most floes).
- Set B comprises 9,125 ship-based estimates (25 per hour) of the ice and snow thickness of individual floes tipped on their sides by the passing of the ship.

The 1993 set A and set B data are described in Worby et al. (1994).

As a result of differences in observational techniques between the data sets, some components of the ice pack are better represented in one data set than in the other. The thin-ice component of the pack is underrepresented in set A because of the hazards of drilling thickness transects across thin ice. Large pressure ridges are not well represented in set B because they are broken up by the ship. Overall, however, the thin ice is better represented in set B, and ridges are better represented in set A, making a combination of these data a useful descriptor of ice conditions within the pack. Set A contains detailed information on individual floes, whereas set B gives more continuous geographic coverage of the entire ice pack.

The ice-thickness distributions for the 1993 and 1994 set A data are very similar in appearance (figure 1*A*, *B*). The dominant ice-thickness categories in both years are between 0.3 m and 1 m, accounting for 70 percent (1993) and 76 percent (1994) of the ice sampled. The 1994 mean thickness value is slightly lower than the 1993 value, primarily because we did not sample as many very thick ridges (greater than 4 m) in 1994. The lower standard deviation value in 1994 is due to a combination of the smaller amount of very thin (less than or equal to 0.3 m) thin and very thick (greater than 4 m) ice that was sampled. Nevertheless, each year the standard deviation values are high relative to the mean value, reflecting the large variability of ice thickness. This variability is a feature of most floe-thickness profiles, which also show that the underside of the ice has a much more pronounced topography than the upper surface (*see* figure 1 in Jeffries et al., *Antarctic Journal*, this issue). This is common in Antarctica, where sea ice frequently deforms by rafting, a process that leads to considerable deformation of the underside of floes but only minimal disturbance at the surface.

As with the ice-thickness distributions, the 1993 and 1994 snow-thickness distributions are similar (figure 1*E*, *F*). In both years, 93–94 percent of the snow was 1 m thick. The mean snow-thickness value is greater in 1994 than in 1993. Because the 1994 observations were made roughly 1 month later than those in 1993, the deeper snow cover in 1994 might reflect the longer period of time available for snow accumulation.

The greatest difference between each year is in the freeboard data (figure 1*C*, *D*). The freeboard is the position of the ice surface relative to sea level. The 1994 data show a negative freeboard, i.e., the ice surface was flooded with sea water, at 51 percent of the drill holes, compared with only 18 percent in 1993. In 1993, however, 59 percent of the freeboard observations were in the 0–5-centimeter (cm) range, an indication of strong flooding potential. A number of processes cause the ice surface to be depressed below sea level and to flood with sea water, including ice loading during ridging and rafting as well as snow loading when the weight of snow overcomes the buoyancy of the ice. Both processes probably account for the extensive flooding observed in 1994; flooding was evident on the flanks of ridges (*see* figure 1 in Jeffries et al., *Antarctic Journal*, in this issue), and the greater amount of snow on the thinner ice cover in 1994 would promote snow loading. The freezing of the snow/sea-water slush that has occurred after flooding leads to snow-ice formation and the growth of floes by the addition of a layer of snow ice at the top surface rather than the bottom. The observation of significantly more snow ice in ice cores analyzed in 1994 than in those analyzed 1993 (Jeffries et al., *Antarctic Journal*, in this issue) is consistent with the widespread flooding observed along the ice-thickness transects.

The ice-thickness distributions for set B are shown in figure 2*A*, *B*. Aside from the fact that these data do not provide a good representation of thick ice in ridges, similarities between set A and set B are evident, e.g, in both years, most of the data fall within a narrow range of values (90 percent of the ice is between 0.4 m and 0.8 m thick in set B), and the amount of thicker ice, i.e., greater 0.8 m thick, in set B is lower in 1994 than in 1993. The major difference between the 2 years is the greater amount of ice 0.3 m thick observed in 1994. Ice of this thickness is younger than the thicker ice and owes its origin primarily to growth in leads created by divergent motion within the ice pack. Subsequent deformation of this ice by rafting and ridging contributes to the thicker ice categories. The greater amount of thin ice in 1994 might, therefore, be evidence that less deformation of the thin ice had occurred in 1994 than in 1993. The smaller amount of ice in the thicker categories of set A supports this hypothesis.

The set B snow-thickness distributions are quite different (figure 2*C*, *D*). In 1994, 90 percent of the data occur in the 0.3-m categories, whereas in 1993 the same amount of data occur in the 0.1- to 0.4-m categories. The thinner snow cover in 1994 can be attributed to the greater amount of thin, young ice which had had a shorter time to accumulate snow.

Because the set B data provide more continuous areal coverage, they can be used to investigate spatial variability of snow and ice thickness within the ice pack. In 1994, in a region bounded by longitudes 147–153°W and more than 69.5°S at the southern end of leg 6 (*see* figure 1 in Jeffries et al., *Antarctic Journal*, in this issue), a noticeably lower concentration of the thicker ice categories (greater than 0.3 m) and a greater amount of open water were recorded by visual estimation of the general ice conditions than were observed during the entire cruise south of 67°S. This difference is illustrated in figure 3, which shows that according to the set B data, the ice at the southern end of leg 6 was thinner than in legs 6 and 7 combined and thinner than in the equivalent southern portion of leg 7. Physical oceanographic measurements made during the same cruise indicate that in this southern region of leg 6, the mixed layer was thinner than was observed during the entire cruise and that the mixed-layer water temperatures were above the *in situ* freezing point, quite possibly due to warm-water upwelling in the Ross Sea Gyre (H. Hellmer and S. Jacobs, personal communications, 1994 and 1995). The reduced ice concentration and thinner ice cover in this region can be accounted for by this oceanographic phenomenon, an illustration of the important role the ocean plays in affecting sea-ice processes and the ice-thickness distribution.

The thickness distributions of first-year sea ice and snow in 1993 and 1994 in the Ross, Amundsen, and Bellingshausen Seas have been documented. The bulk of the ice is between 0.3 and 1.0 m thick, an indication that in general the processes and conditions of ice development were similar each year. This conclusion is corroborated by the ice-structure data (Jeffries et al., *Antarctic Journal*, in this issue). Ice development is dominated by dynamic processes, but the data do suggest that deformation of the very thin (less than 0.3-m) ice categories may have been less in 1994 compared with 1993. The largest difference between the 2 years is the more extensive sea-water flooding observed in 1994, perhaps due to the 1-month delay in making the observations, during which time addi-

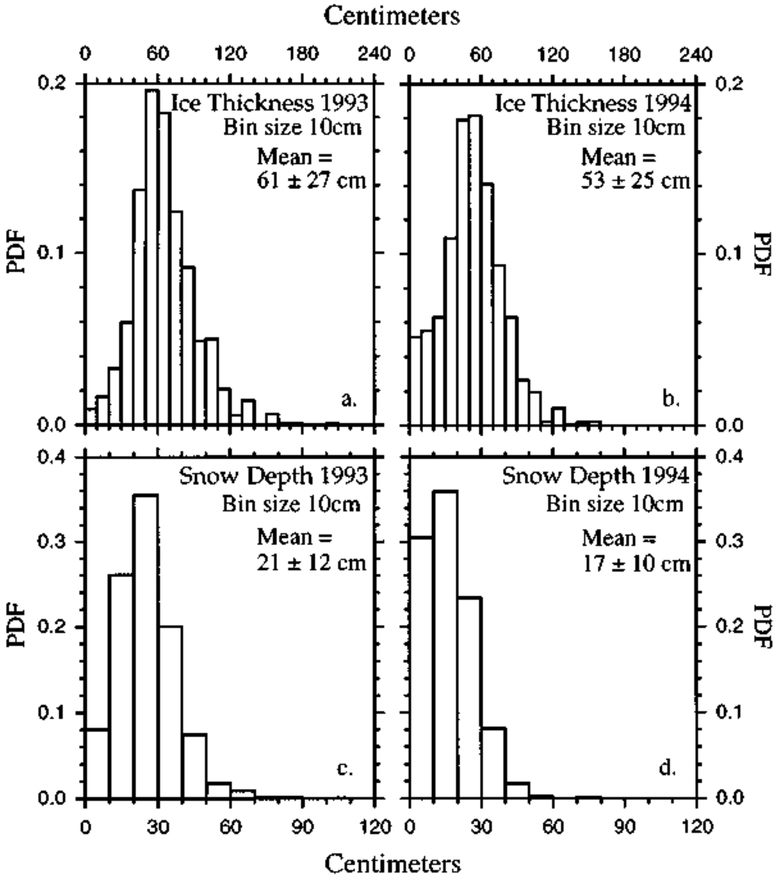

Figure 2. Probability density distributions for set B data acquired from the ship's bridge as floes were tipped on their sides by the passing of the ship in 1993 (4,071 measurements) and 1994 (9,125 measurements). Only data obtained south of 67°S are included in each probability density distribution.

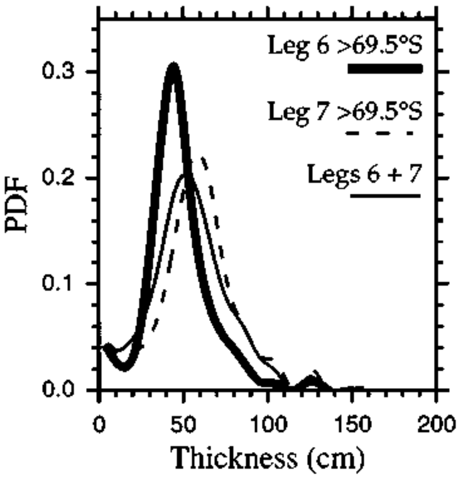

Figure 3. Probability density distributions of set B ice-thickness data illustrate the occurrence of thinner ice at the southern end of leg 6 compared to legs 6 and 7 combined and the equivalent southern portion of leg 7.

tional snow accumulated and formed a greater load on the ice. The large flooding potential in the 1993 set A freeboard data might have been realized later in the season after we completed our study.

This research was supported by National Science Foundation (NSF) grants OPP 91-17721 and OPP 93-16767. Jaña's participation in the cruise was made possible by NSF and Instituto Antartico Chileno. McCullars participated in the cruise under the auspices of the NSF Young Scholars Program. The data would not have been acquired without the enthusiastic and dedicated assistance of the following individuals: Ute Adolphs, Dave Crane, Stephanie Cushing, Rob Massom, Kim Morris, Janet Nonelly, Marjorie Porter, Bernard Rabus, Jane Stevens, and Matthew Sturm (project personnel) and Barney Kane, Rod McCabe, Doyle Nicodemus, Russ Nilson, Buzz Scott, and Bill Young (Antarctic Support Associates personnel). We all offer our sincere thanks to Captain J. Borkowski, the officers, and crew of the R/V *Nathaniel B. Palmer* for their support and assistance throughout an enjoyable voyage.

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A description of the snow cover on the winter sea ice of the Amundsen and Ross Seas

Antarctic sea ice is generally covered by snow, which is an excellent natural insulator. The snow has a significant impact on the temperature of the ice, its brine volume, salinity, and the rate at which it loses heat during the winter. As a result, the snow affects how fast the ice thickens by sea-water freezing. It also loads the ice and, when sufficiently thick, causes it to be depressed below the snow surface. This loading leads to salt-water inundation of the snow-ice interface and, when this salt water freezes, the accretion of snow ice at the base of the snow pack. The blanket of snow on the sea ice has great spatial and temporal variability. Understanding the role of the antarctic sea ice in the global climate requires understanding the snow cover.

Combined snow and sea-ice studies were conducted from the R/V *Nathaniel B. Palmer* in the pack ice of the Amundsen and Ross Seas between 10 September and 21 October 1994. At 26 ice-floe stations, two parallel 100-meter (m) lines, 5 m apart, were established. Along the first line, snow depth, sea-ice thickness, and freeboard measurements were made at 2-m intervals (Jeffries, Jaña, et al., *Antarctic Journal*, in this issue). Snow stratigraphy and texture were measured at 6 to 10 locations along this line. On the parallel line, snow depth and the temperature of the snow-ice interface were measured every meter. A 3-m-long trench was excavated in a location of typical snow depth. The stratigraphy of the trench wall was described and continuous vertical profiles [in 3-centimeter (cm) increments] of density, salinity, grain size, hardness, and temperature were measured at one or more locations in the trench. Boxed snow samples were taken from the trench to the cold rooms on the ship, where snow grain-size distribution was determined by sieving (Sturm 1991), snow thermal conductivity was determined using a needle probe apparatus (Sturm and Johnson 1992), and air permeability was measured using a double-walled permeameter (Chacho and Johnson 1987). In all, measurements were made in 139 snow pits and 21 trenches (mean depth: 32.4 cm). In total, 2,400 measurements of snow depth and snow-ice interface temperatures were made.

In general, the snow cover comprised four distinctly different types of snow:

- soft or moderately hard fine-grained snow layers;
- depth hoar layers;
- icy layers, melt-clusters, and percolation columns; and
- new or recent snow.

The icy features exhibited textures suggestive of formation during high winds. Surprisingly, all four types of snow were often found together. This textural assemblage is unusual because the four types require distinctly different environmental conditions to form. Soft and moderately hard fine-grained snow layers are deposited during periods of low to moderate winds and tem-

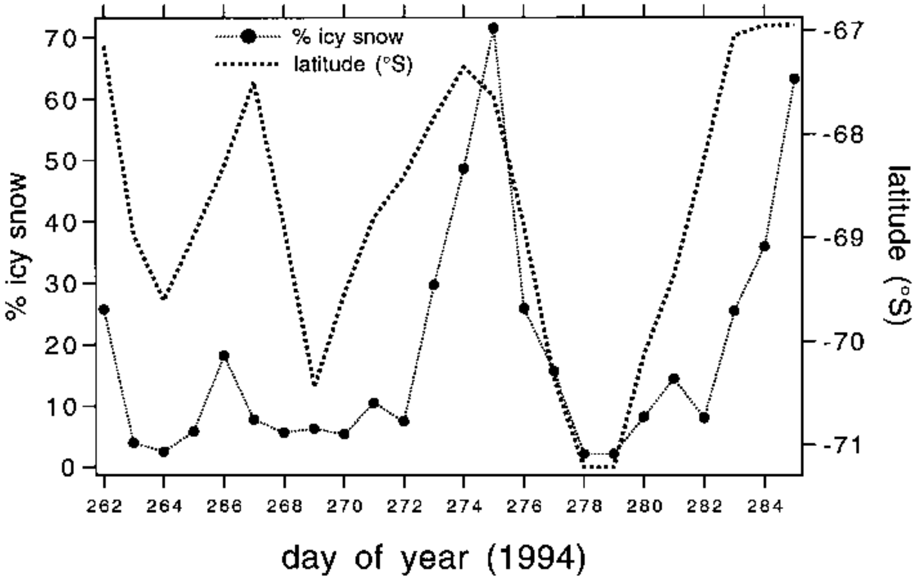

Figure 1. Percentage of snow cover exhibiting icy textures as a function of time. The ship's track was from east to west with north-south zig-zags. See Jeffries, Cushing, and Porter (*Antarctic Journal*, in this issue) for cruise track.

peratures and will metamorphose into quite different snow if conditions change. Depth hoar results from kinetic crystal growth due to strong vertical temperature gradients in the snow (Trabant and Benson 1972; Akitaya 1974; Colbeck 1987). On sea ice, strong vertical temperature gradients occur during periods of prolonged cold. Icy features are due to rain on snow and/or above-freezing temperatures followed by refreezing episodes. Combined, the textural features suggest that the snow cover was deposited by weather systems that alternated between periods of clear cold with little wind and periods of warm and wet (even rainy) conditions with very strong winds. Similar winter conditions had prevailed in the Bellingshausen Sea in 1993 (Jeffries et al. 1994).

The degree of iciness (percentage of total snow cover consisting of ice lenses, layers, percolation columns, and melt-grain clusters) varied in a systematic manner across the cruise area. Iciness increased with decreasing latitude and increasing proximity to the ice edge (figure 1; for cruise track, *see* Jeffries, Cushing, and Porter, *Antarctic Journal*, in this issue). At the most southerly stations, the percentage of iciness remained nearly constant (2 to 10 percent) as the ship traversed west, but over the same amount of westward travel, the degree of iciness increased at the northern stations by a factor of 4 or 5.

On individual floes, two distinct snow regimes were found: drifted snow in and about pressure ridges (*ridge snow*) and a thinner snow with surface dunes and/or sastrugi (*floe snow*) overlying the flat parts of each floe. This pattern is consistent with findings from other sectors of Antarctica (Wadhams, Lange, and Ackley 1987; Eicken et al. 1994). Ridge snow was confined to a strip 20 to 40 m wide centered on ridges. Few ridges (5–10 percent areal coverage) were present, so ridge snow covered only a small fraction of the region. Snow depth across ridges showed a consistent pattern (figure 2): the depth increased as the ridge was approached, reached a maximum 1 to 2 m either side of the ridge crest, then decreased rapidly to a minimum (often no snow) at the crest. This pattern suggests that drift deposition occurred on both sides of the ridges examined and implies variable wind directions and/or rotation of floes with respect to the wind. In the Weddell Sea, Eicken et al. (1994) found snow drifts to lie primarily on one side of pressure ridges.

Floe snow (the thinner snow not near pressure ridges) exhibited strong lateral variability. Layers pinched and swelled; they had undulating upper surfaces suggesting deposition as sastrugi or low dunes. Marked lateral variations in density and grain size occurred within layers. Meltwater percolation and wicking of sea water from the snow-ice interface produced ice lenses, zones of coarse-grained snow, and percolation columns irregularly distributed both laterally and vertically in the snow cover, adding to the heterogeneity. Because of this heterogeneity, little or no relationship between the snow depth and the thickness of a particular type of strata was evident.

Nubbly ice layers (ice layers with 1- to 2-cm-high ice nubs or bumps covering their surface) were commonly observed at snow layer boundaries. These layers were 2 to 10 millimeters (mm) thick. Between two and six layers were present at most stations (typical snow depth: 25 to 65 cm), and a sequence of three closely spaced nubbly ice layers was traced from station 262 to station 274, a distance of more than 1,000 kilometers. One nubbly ice layer was

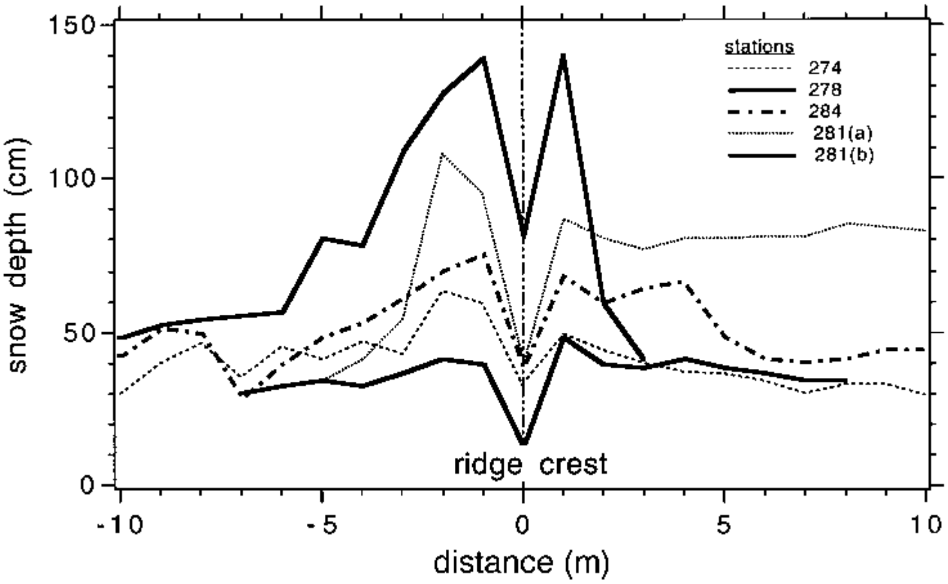

Figure 2. Snow depth across five pressure ridges. Note thin snow at ridge crest and characteristic pattern adjacent to ridge.

observed forming when freezing rain was driven onto a cold snow surface during a period of high wind (wind speed: more than 15 meters per second; air temperature: 2°C). The surface was cold enough that in some locations, droplets froze, whereas in other locations they caused a small amount of snow melt before freezing. This produced a continuous icy crust with many small bumps or nubs that grew into the wind.

Four other types of wet-snow features (rounded crystal forms, capillary ice columns, saline ice layers, and slush) we observed can be linked directly to salt-water flooding at the base of the snow. Measurements confirmed that these features were saline, in some cases with salinities as high as 60 parts per thousand. The measurements also indicated that some sea water had entered the snow pack on virtually every floe visited. In some cases, only minor amounts of water must have been introduced and subsequently drained back, leaving depth hoar crystals with rounded edges as a result of minimization of surface free energy in the presence of liquid water (Colbeck 1986). This rounding gave the snow a gray cast. In other cases, large quantities of water had saturated the base of the snow turning it to slush. Above some slush layers, sea water had been wicked upward in capillary columns as much as 15 cm. At snow-layer boundaries, this water collected and often spread laterally forming highly saline ice lenses and layers perched above less saline and less icy snow.

Where salt-water flooding was minimal, grain-size profiles in the snow showed a maximum at the base of the snow and decreased with height (figure 3). The large grain size at the base was the result of depth hoar growth. Occasionally, a new or recent surface layer of snow, consisting of relatively large, unbroken stellar crystals, produced a local grain-size maximum at the surface. Locally, extremely large melt grain clusters (up to 2 cm diameter) were associated with the nubbly ice layers previously discussed. Typical grain-size distributions (as determined by sieving) for depth hoar and a soft slab are shown in figure 4.

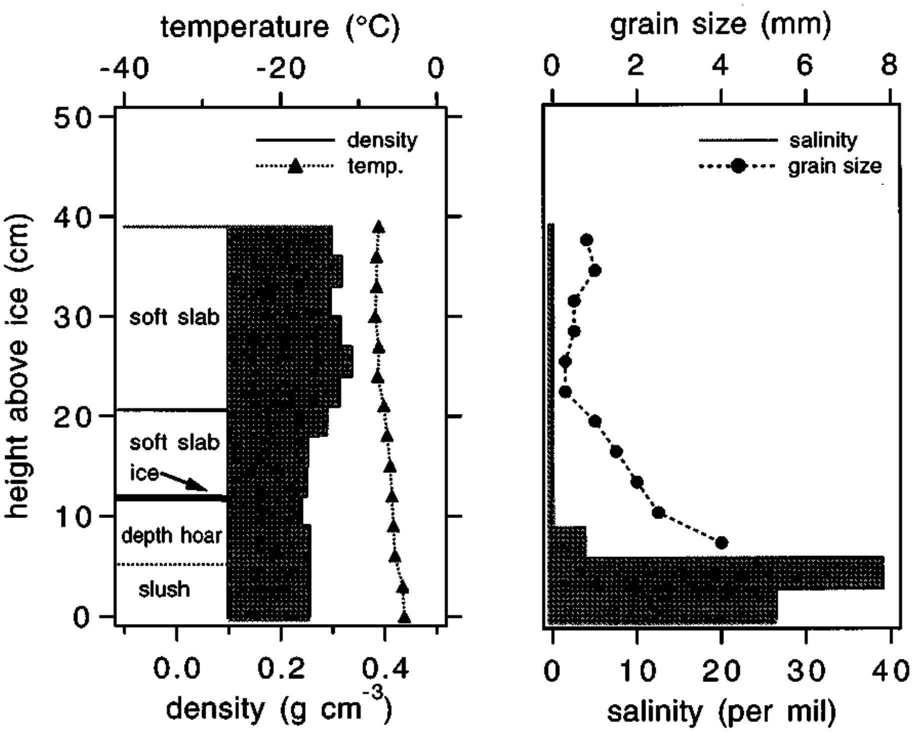

Figure 3. Snow pit diagram showing vertical profiles of density, salinity, grain size, temperature, and stratigraphy (station 278). (g cm^{-3} denotes grams per cubic centimeter.)

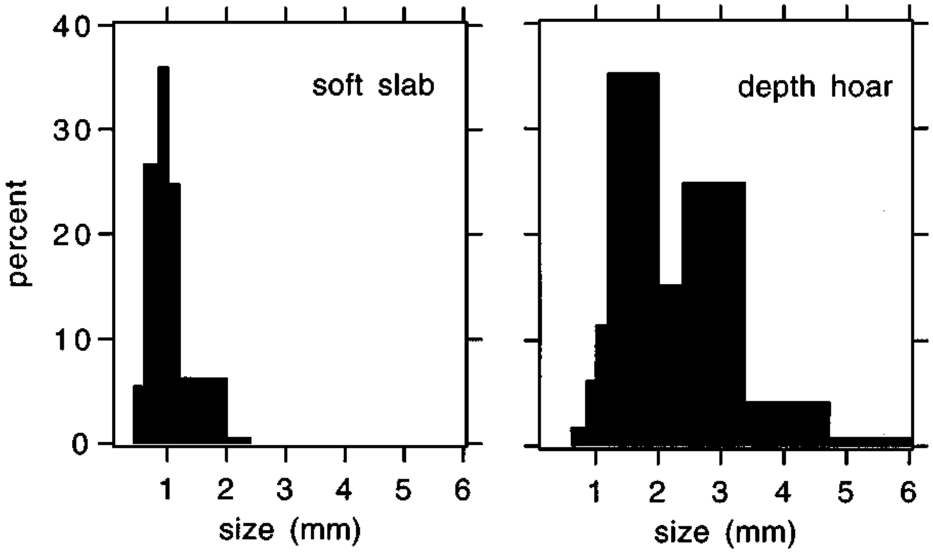

Figure 4. Grain-size distributions determined by sieving for a soft slab and depth hoar (station 268).

Only one snow cover examined had stratigraphic and textural attributes suggestive that it had survived more than 1 year. At station 281, unusually deep snow (more than 100 cm) was encountered overlying sea ice in excess of 2 meters thick. The deep snow cover consisted almost entirely of extremely large depth hoar crystals (greater than 1.5 cm), cemented together by icy zones, percolation columns, and ice layers. Large void spaces (more than 20 cm across) lined with hoar crystals up to 3 cm in length were found throughout the lower layers of the snow. The combination of icy zones and extremely large depth hoar suggests not only that the snow had gone through a summer melt period and become thoroughly wet but also that the remaining snow had had a long period to metamorphose into depth hoar.

Our preliminary interpretation for the development of the snow cover over the cruise sector is that during the austral winter, the weather in the region had alternated between warm, windy maritime cyclones, often accompanied by rain or above-freezing temperatures, and prolonged periods of cold temperatures with little or no wind. The texture and density of the soft and moderate slabs found on the ice floes suggest that most snowfall had occurred during moderately windy conditions. The wind during deposition could not have been excessive, because all observed snow slabs were either soft or only moderately hard. We would expect much harder slabs if the winds were strong during deposition, as is the case for arctic snow covers (Benson and Sturm 1993). We therefore surmise that the main winter deposition of snow on the ice floes did not occur during the windiest weather but perhaps preceded it. The presence of nubbly ice crusts capping most slabs suggests that following periods of deposition, the temperature warmed, sometimes to above freezing, and the wind increased. A hypothetical weather pattern would be as follows:

- snow deposition as a cyclone moved in;
- thawing and surface melt as the cyclone arrived (this stabilized the deposited snow preventing excessive drifting), then
- high winds, sometimes with driving rain, producing the nubbly ice layers.

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C-band radar backscatter from antarctic first-year sea ice: I. *In situ* scatterometer measurements

Spaceborne synthetic aperture radar (SAR) remote sensing offers the opportunity for detailed, year-round studies of polar ocean processes, because active microwave sensors can acquire high-resolution Earth-surface data regardless of light and weather conditions. In recent years, considerable progress has been made in understanding not only the interactions between active microwave systems and arctic sea ice but also the implications for remote sensing of sea-ice properties and processes (e.g., Carsey 1992). Only a few investigations of radar backscatter from antarctic sea ice have been made, and those have been in the Weddell Sea (e.g., Lytle et al. 1993; Drinkwater, Hosseinmostafa, and Gogineni 1995).

In August and September 1993, the R/V *Nathaniel B. Palmer* operated in the Bellingshausen and Amundsen Seas in support of a study of sea-ice geophysics (Jeffries 1994). This included an investigation of *in situ* radar backscatter variability from first-year ice using a scatterometer mounted on the ship and of backscatter variability in SAR images derived from data acquired by the ERS-1 satellite. This article describes some of the results of the *in situ* scatterometer measurements. The spaceborne ERS-1 data are discussed in Morris and Jeffries (*Antarctic Journal*, in this issue).

The scatterometer was mounted on the starboard bridge wing approximately 16 meters above the ice surface. When the ship was stationary, the sea-ice surface was scanned by the radar to obtain backscatter coefficient data ($\sigma°$ expressed in decibels, i.e., dB) as a function of incidence angle. The $\sigma°$ values represent backscatter from a roughly 1 square meter area that is illuminated by the radar. Measurements were made in the C-band (69.8-millimeter wavelength, 5.3-gigahertz frequency) at vertical-vertical polarization (VV, corresponding to the ERS-1 and ERS-2 instruments) and horizontal-horizontal polarization (HH, corresponding to the

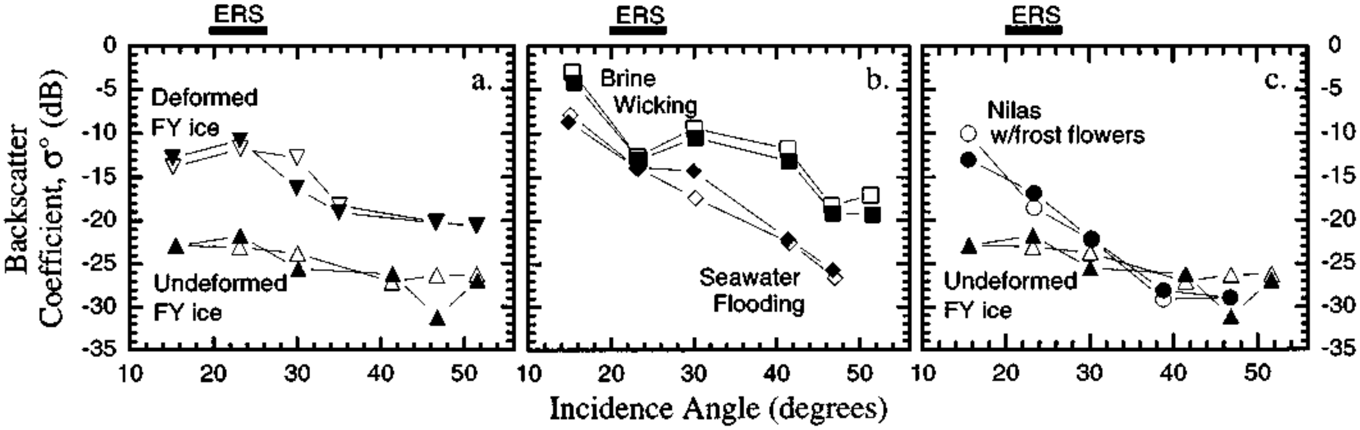

Figure 1. Backscatter as a function of incidence angle for different sea-ice types, states, and processes. Solid symbols represent HH polarization data. Open symbols represent VV polarization data. The bold lines marked ERS at the top edge of each graph show the narrow range of incidence angles for the ERS SAR instruments. In contrast, RADARSAT data will be available across the entire range of incidence angles shown in the graphs.

RADARSAT). In addition to being internally calibrated, the system was calibrated externally using a Luneberg lens placed on the ice after data acquisition was completed at each sampling site. Observations and measurements of snow depth, salinity, and stratigraphy as well as ice temperature and salinity were then made along the line previously scanned by the scatterometer.

Backscatter variability as a function of incidence angle for a variety of ice types and surface conditions is illustrated in figure 1. The effects of ice deformation are shown in figure 1*A*. The undeformed first year (FY) floe comprised 31–36-centimeter (cm) thick ice that had grown undisturbed in a lead. The σ° values for this ice are very close to those of similar ice investigated at C-band (VV) in the Weddell Sea (Drinkwater et al. 1995). The level ice σ° values are considerably lower than those of the deformed FY ice, which comprised cakes that had been severely rafted creating a dense array of surface features with heights of 30–50 cm. Such surface roughness is a source of strong backscatter (Onstott 1992, pp. 73–104).

The effects of sea-water flooding and wetting of the snow cover are illustrated in figure 1*B*. At the flooded site, a 10–14-cm thick slush layer (salinity 23‰) was at the base of the 31–36-cm deep snow cover. At the other site, brine had wicked up from the ice surface into the 3.5–4.0-cm thick snow cover; the wetted snow had a mean salinity of 25‰, and liquid brine would have been present in the snow at the observed snow temperatures of –12° to –8°C. The presence of liquid brine in the snow cover increases both the dielectric constant of the wet snow and the dielectric contrast between wet and dry snow leading to higher σ° values (Lytle et al. 1990, 1993). In this case, the σ° values are as high as those for deformed FY ice (figure 1*A*,*B*).

The backscatter of undeformed, thin FY ice is compared with that of 5-cm thick nilas in figure 1*C*. Although the nilas is younger and more saline (salinity 15.1‰) than the FY ice (mean salinity 6.5±1.1‰) and, thus, might be expected to have lower backscatter values than the FY ice, at incidence angles ≤30°, the nilas has σ° values as high as those from deformed FY ice and from ice having a brine soaked snow cover. This is due to the presence of frost flowers covering 95 percent of the surface of the nilas. The frost flowers represent significant roughness elements on the otherwise smooth nilas surface and are a source of strong backscatter (Grenfell et al. 1992, pp. 291–301).

The data shown in figure 1 represent backscatter variability at different incidence angles during a brief interval at different sites. Figure 2 shows that backscatter at a single site can change significantly as a function of time. The decline in σ° values during 19 September coincides with light snow accumulation as a cold front approached from the northwest, whereas the large increase in backscatter during 20 September occurred as the cold front moved past the ship and temperatures decreased sharply (from –2° to –10°C in 8 hours) and wind speeds reached 30 meters per second. Similar time-dependent backscatter changes have been observed in the Weddell Sea pack ice and are attributed to changes in the state of the snow and ice cover affected by the changing environmental conditions (Drinkwater et al. 1995). The backscatter changes over the course of almost any 8-hour period in figure 2 are greater than those observed during an 8-hour period between ERS-1 SAR image acquisitions during the same cruise (Morris and Jeffries, *Antarctic Journal*, in this issue). Backscatter can remain unchanged if the environmental conditions do not significantly alter the state of the snow and ice cover.

Although some large differences in σ° values at HH and VV polarization are evident in figure 2, the data shown in figure 1 are more typical of most of the sampling sites, i.e., the differences between the two polarizations are quite small at all incidence angles. This indicates that it is unlikely that different criteria will be required for the interpretation of each data

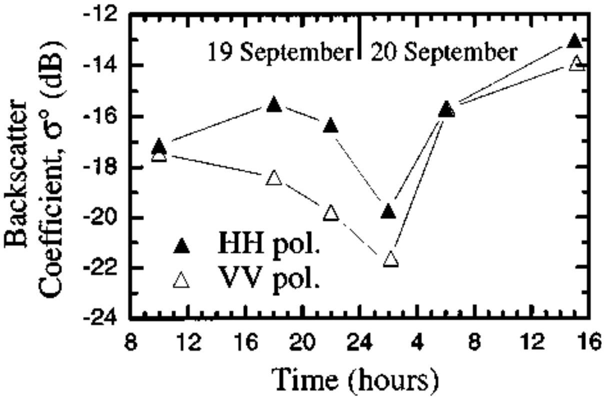

Figure 2. Backscatter at a 23° incidence angle as a function of time at a deformed FY floe (mean thickness 98 cm).

set, and RADARSAT SAR images are likely to provide similar insights into sea-ice surface properties and processes as ERS SAR images. Because RADARSAT will operate in different modes, however, and will have a wider range of incidence angles than the ERS instruments, caution will be required. As the scatterometer data show, a larger range of backscatter will be observed from a given ice type or surface state.

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C-band radar backscatter from antarctic first-year sea ice: II. ERS-1 SAR measurements

Radar backscatter from sea ice is affected by the physical properties of the ice and the physical processes occurring at the ice surface. Because it is known that some of the surface properties and processes of antarctic sea ice differ from those of arctic sea ice (Tucker et al. 1992, pp. 9–28), one would expect the radar backscatter response to differ as well. These potential differences were the subject of an investigation in August and September 1993 when the R/V *Nathaniel B. Palmer* operated in the pack ice of the Bellingshausen and Amundsen Seas. At the time the ship was in the ice, ERS-1 C-band, vertical-vertical (VV) polarized synthetic aperture radar (SAR) data were acquired at the German Antarctic Receiving Station located at O'Higgins Base on the Antarctic Peninsula. Sea-ice backscatter was also investigated using a radar scatterometer mounted on the ship (Jeffries, Chuah, and Morris, *Antarctic Journal*, in this issue). The ERS-1 SAR backscatter variations are the subject of this article.

When possible, the ship was positioned under the satellite path so that local sea-ice conditions could be compared to radar backscatter signatures. Subsequently, backscatter variability was analyzed in 107 images [each covering an area of 100 kilometers (km) by 100 kilometers] from 11 orbits (6 descending and 5 ascending). The orbits were in the area between 72.9°W and 105.6°W and extended from the ice edge to the continent. The images were radiometrically calibrated (Laur et al. 1994) and postprocessed to produce images with a pixel size of 25 meters (m) by 25 m and a spatial resolution of 40 m.

On 29 August, the R/V *Nathaniel B. Palmer* was located at 66.13°S 89.10°W, some 100 km from the ice edge, in a field of floes made up of consolidated pancakes. The ice concentration was 7/10 with 6/10 in the form of 0.6-m thick ice in vast (more than 2,000-m) floes with 40–50 percent areal coverage of 0.5-m high consolidated ridges. The ERS-1 satellite passed over this site twice during an 8-hour period: an ascending pass at 06:21:28.217 Greenwich mean time (GMT) (01:16 local time) and a descending pass at 14:33:08.579 GMT (09:33 local time). Subscenes of the nighttime and daytime images are shown in figure 1. The near uniform gray tones are first-year ice floes, the lighter tones are wind-roughened water, and the darker tones are new ice. Note that the relative positions of the floes changed during the 8-hour period. The backscatter (σ°) of 14 floes common to both images was determined. Each floe was sampled, and σ° (mean and standard deviation) was calculated. The sample size varied according to the size of the ice floe.

The σ° determined for each floe identified in figure 1 is plotted in figure 2. No significant backscatter change is observed during the 8-hour interval between the two data sets (–10.62±0.9 dB at 06:21 vs. –10.56±0.5 dB at 14:33). An increase in wind speed from 4 to 16.5 m per second and a change in wind direction from north-northeast to west-northwest between 2000 on 28 August and 1000 on 29 August accounts for the movement of, and in some cases the break-up of, the ice floes. During this same period, air temperatures decreased from –0.5°C to –3.5°C with temperatures in the upper portion of the snow pack following suit. Snow temperatures at the bottom of the snow pack, however, and ice temperatures near the ice surface remained constant at –4.5°C. Thus, the snow and ice properties at the snow-ice interface remained nominally constant over the 8-hour period, and no

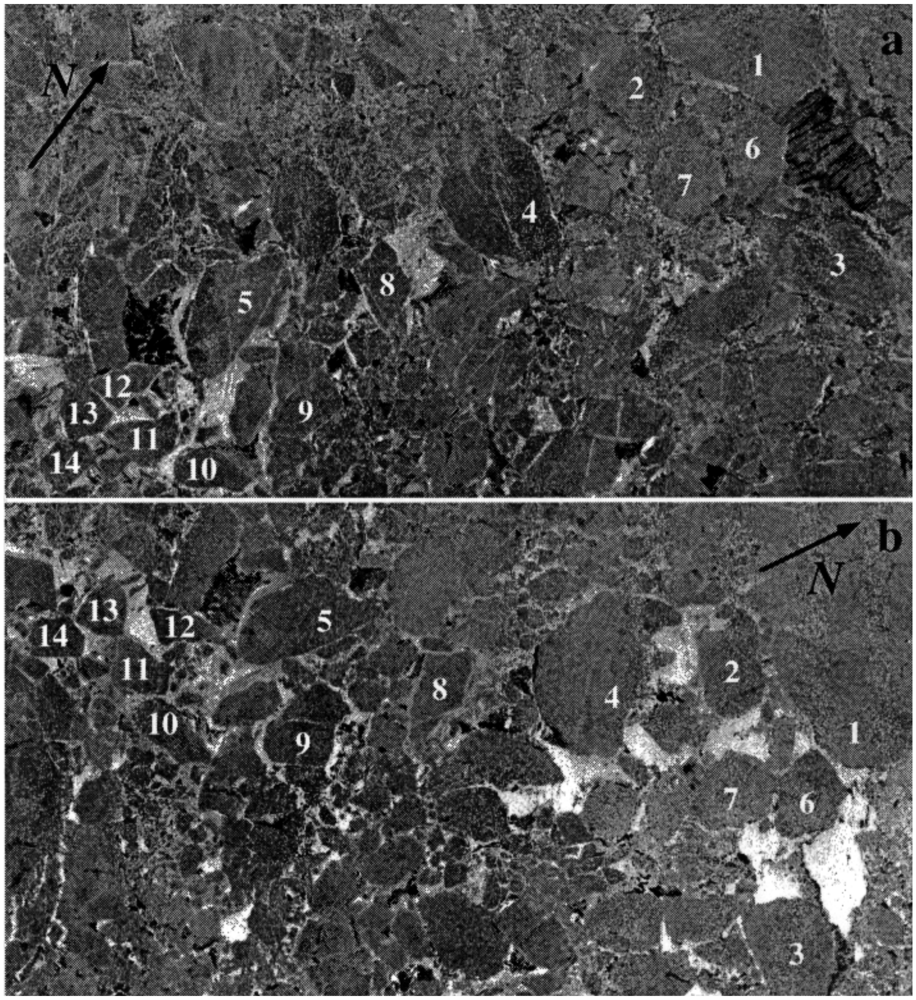

Figure 1. Two radiometrically calibrated ERS-1 SAR subscenes of first-year ice floes approximately 100 km south of the ice edge in the Bellingshausen Sea acquired 8 hours apart on 29 August 1993: orbit 11086, frame 5805 (ascending)—06:21 GMT (*A*); and orbit 11091, frame 4996 (descending)—14:33 GMT (*B*). The gray scale has been manipulated to increase contrast between features within the subscenes, but the gray tones between subscenes remain directly comparable. Each subscene covers an area 67.5 km by 37 km. Pairs of identical floes, from which σ° values were derived, are numbered. The R/V *Nathaniel B. Palmer* is located in floe 1 at 66.13°S 89.10°W in subscene (*A*). SAR scenes are copyright ESA, 1993.

significant change in backscatter return was detected. This lack of change in the ERS-1 SAR backscatter between satellite overpasses contrasts with the significant *in situ* backscatter changes that occurred, on another occasion and at a different location, when a larger temperature decrease and higher windspeeds were noted (Jeffries et al., *Antarctic Journal,* in this issue).

Only a small difference in the floe-to-floe σ° values derived for each floe in each subscene is evident (figure 2). This phenomenon was observed in all of the images that covered the zone between the ice edge and approximately 70°S. Except for leads and icebergs, which are easily distinguishable from the surrounding sea ice in the SAR images, first-year ice has a fairly uniform tone indicating low backscatter variability. In this portion of the Bellingshausen Sea ice cover, designated the annual pack, floes were composed primarily of multiple layers of granular ice of frazil origin, evidence that ice development had been dominated by the rafting of pancakes in the pancake cycle (Jeffries et al. 1994). Rafting results in a relatively rough surface on a decimeter scale. In contrast to the relative uniformity of backscatter in the annual pack ice, a much greater σ° variability was observed in the perennial pack, which extends south from approximately 70°S. Here, spatially complex patterns of σ° variability are indicative of a greater variability in ice types.

Probability density functions of backscatter for first year ice in the annual pack and the perennial pack, what we currently interpret to be heavily deformed ice and new ice, are presented in figure 3. The mean and standard deviation for the first-year ice in the annual and perennial pack are almost identical (–10.1±1.7 dB and –10.4±1.8 dB, respectively). The first-year ice probability density functions and mean σ° values are similar to those reported for rough first-year ice in the Weddell Sea (Drinkwater, Hosseinmostafa, and Gogineni 1995). Unlike Drinkwater et al. (1995), however, we were unable to differentiate between undeformed and deformed first-year ice in the SAR images of the Bellingshausen Sea. The "heavily deformed" ice has a higher σ° value (–8.4±2.6 dB) than the first-year ice whereas the new ice has a very low σ° value (–22.9±0.6 dB). This deformed ice, in what we believe to be rubble fields, has a higher σ° value than the first-year ice because of strong surface scattering and returns to the radar from the angular blocks that constitute the ridges. In contrast, the smooth surface of new ice causes specular reflection away from the radar and, thus, lower σ° values.

The backscatter probability density functions and the mean σ° value for the antarctic first-year ice are significantly dif-

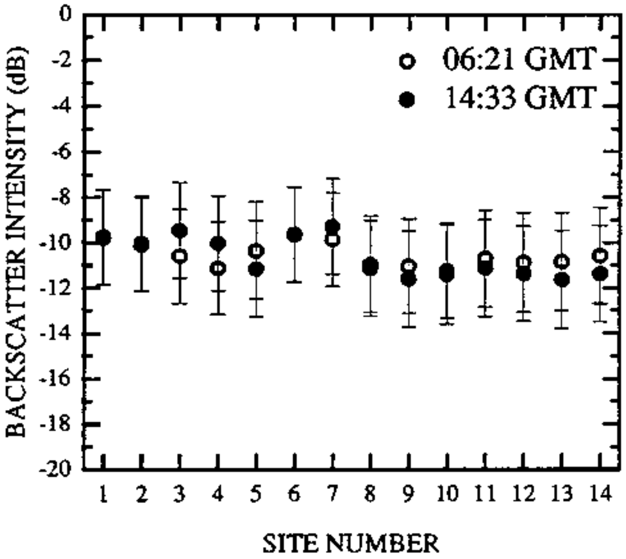

Figure 2. Backscatter mean and standard deviations for the floes identified in figure 1.

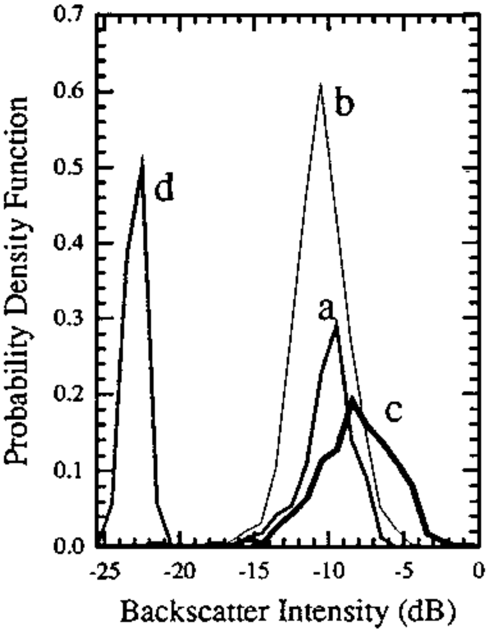

Figure 3. Probability density functions derived from ERS-1 SAR images of the Bellingshausen Sea for outer pack first-year ice (a), inner pack first-year ice (b), highly deformed ice (c), and undeformed new ice (d).

ferent from those reported for deformed arctic first-year ice (–13.58±1.04 dB) by Kwok and Cunningham (1994). The higher σ° values for the antarctic ice may be due, in part, to the widespread occurrence of rafting that leads to a rough ice surface as described above. Overall, from the point of view of active microwave remote sensing, the Bellingshausen Sea ice might have a rougher surface than deformed arctic sea ice and deformation may be more common than in the Weddell Sea. In addition, measurements made during the cruise revealed that as much as 18 percent of the ice surface in the annual pack of the Bellingshausen Sea was flooded with sea water. *In situ* measurements of σ° from flooded antarctic floes indicate that the introduction of sea water at the snow/ice interface creates a strong dielectric discontinuity between the dry and wet snow and results in strong backscatter (Jeffries et al., *Antarctic Journal*, this issue; Lytle et al. 1990, 1993). This might also contribute to the strong first-year ice backscatter observed in the ERS-1 SAR images.

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U.S. support and science personnel winter at three stations

The following lists National Science Foundation (NSF) supported researchers and employees of Antarctic Support Associates (ASA), NSF's support contractor, who wintered at the three U.S. year-round stations—McMurdo, Amundsen–Scott South Pole, and Palmer—during the 1995 austral winter and U.S. Navy Support Force, Antarctica (NSFA) personnel who wintered at McMurdo Station during 1995. The list is arranged by station with names in alphabetical order. For researchers, the title of their research project and the name of the institution to which the NSF grant was awarded are indicated; for employees of ASA and NSFA personnel, positions at the station are included.

McMurdo Station

Able, Patrick H., ASA, boiler mechanic
Akens, Jeffrey S., ASA, crash firefighter
Aldous, Danny M., ASA, operator
Almy, William D., Jr., ASA, electrician
Anderson, Tobi T., ASA, structure firefighter
Auchincloss, William B., IC1, NSFA
Baker, Michael L., ASA, electrician
Belarde, Paul E., ASA, electrician
Bennett, MaiBritt, ASA, administrator
Bennett, William J., ASA, carpenter
Bennett, William M., ASA, materialsperson
Berggren, Allen C., ASA, technician
Bertola, Steven J., ASA, boiler mechanic
Birkmeyer, Louis A., ASA, mechanic
Birkmeyer, Michael E., ASA, senior materialsperson
Bjorkman, Paul E., ASA, plumber
Blachut, Michael J., ASA, refrigeration mechanic
Boone, Esther R., ASA, cook
Bostick, John N., ASA, supervisor
Bracey, Lester P., ASA, cook
Breining, David W., ASA, pipefitter
Brock, Sunny G., ASA, materialsperson
Brown, Larry J., ASA, fuels operator
Brown, Lester C., YN1, NSFA
Brown, Todd D., ASA, carpenter
Callahan, Robert C., ASA, materialsperson
Carroll, Valerie, ASA, administrative coordinator
Carter, Jenifer A., ASA, administrator
Carver, Thomas S., ASA, supervisor
Chambers, Mark L., ET1, NSFA
Chappell, Michael R., ASA, crash firefighter
Cofield, Johnny L., ASA, mechanic
Cortner, Rex M., ASA, operator
Cowman, Jeffrey L., ASA, materialsperson
Crenshaw, John E., ASA, pipefitter
Crossland, Mariah J., ASA, senior materialsperson
Crowley, Andrew T., ASA, help desk specialist

Cully, Timothy J., ASA, supervisor
D'Agostino, Thomas S., HMC, NSFA
Day, James F., ASA, electrician
DeCroce, Tonya L., ASA, administrative assistant
DelGiudice, Marcello A., ASA, mechanic
Delmastro, David D., ASA, painter
Devore, Geoffrey W., DK2, NSFA
Dicks, Ethan, ASA, computer technician
Drake, Robert E., Jr., ASA, sheetmetal worker
Drummond, Stephen S., ASA, captain, crash and fire unit
Dunne, Craig M., ASA, materialsperson
Dunsworth, Franklin L., ASA, plumber foreman
Egeland, Harry A., ASA, mechanic
Eischens, Steen A., ASA, lineman
Enlow, Timothy S., ASA, materialsperson
Epps, Don M., ASA, electrician
Erb, Christopher L., ASA, cook
Evensen, David R., ASA, technician
Fink, Douglas A., ASA, waste management technician
Fliss, Thomas E., ASA, service
Foley, Robert G., ASA, electrician
Foraker, Jay A., ASA, carpenter
Fortson, James L., ASA, senior materialsperson
Freeman, J.B., ASA, construction coordinator
Frontz, Jeffri H., ASA, senior computer technician
Garner, Angela L., AG2, NSFA
Gilliland, Cheryl L., ASA, waste management technician
Gjorstad, Anne C., ASA, baker
Gober, Harold G., ASA, plumber
Gould, Carol V., ASA, materialsperson
Grandchamp, Sandy K., ASA, senior materialsperson
Grant, Kent D., RM2, NSFA
Gulick, Cheryl C., ASA, materialsperson
Hagel, Steven L., ASA, mechanic
Hall, Kimberly G., AC1, NSFA
Hall, Madison W., ASA, utility mechanic
Hancock, Michael J., ASA, MAPCON programmer
Hartford, Michelle K., ASA, painter
Haugland, Heather W., ASA, carpenter helper
Hendricks, Ronald J., ASA, fuels
Herring, Christopher J., ASA, mechanic
Hinson, Lenore F., ASA, cook
Hoagland, Marybeth, ASA, assistant supervisor
Hogan, Alan P., ASA, general field assistant
Hoog, Timothy J., ASA, electrician
Howard, Scott R., ASA, crash firefighter
Howarth, Victoria L., ASA, service
Humbert, Scott E., LT, NSFA
Hunter, Mary E., ASA, clerk
Hyer, Randall N., LT, NSFA
Jung, Christopher R., ASA, structure firefighter
Jurado, Alberto A., ASA, materialsperson
Kaul, Robert J., Jr., ASA, general field assistant
Khoo, David E., ASA, work-order specialist
Kirse, Rudolph L., III, ASA, hazardous waste specialist
Kober, Wendy M., ASA, technician
Koerschen, Jeffrey L., ASA, fire systems technician
Koontz, Benjamin M., ASA, materialsperson
Kraemer, Stephen R., ASA, MAPCON data specialist
Kuder, Shelley D., ASA, quality-control inspector
Kuehn, Bradley E., ASA, sheetmetal foreman
Labelle, Jill, ASA, work order specialist
Larson, Erik C., ASA, service
Layman, William J., Jr., ASA, mechanic
Lester, James K., ASA, mechanic
Longo, Joseph, ASA, science technician
Lopinto, Anthony S., RMC, NSFA
Lopus, Mark T., ASA, materialsperson
Lozano, Robert L., ASA, draftsperson
Maddy, Frank M., ASA, plumber
Marchetti, Peter A., ASA, carpentry shop foreman
Martin, Albert G., III, NSF station manager
Martin, Barbara J., ASA, dispatcher
Martin, David E., ASA, utility mechanic
Martin, Marvin E., ASA, mechanic
Mattila, Edward G., ASA, mechanic
McCarton, James J.., ASA, preventive maintenance
McIntyre, Jon J., ASA, utility mechanic
McLean, Russel R., ASA, carpenter
McPhail, Glen D., MS1, NSFA
Melton, Mark R., ASA, lead structure firefighter
Mendoza, Enrique, AGAN, NSFA
Mickelson, James G., ASA, operator
Miller, Anthony J., HM1, NSFA
Miller, Thom W., ASA, carpenter
Milligan, Joseph P., ASA, painter
Minneci, Michael R., ASA, materialsperson
Moody, Niam M., ASA, general field assistant
Moody, Thomas J., ASA, engineering aide
Morin, Pami L., ASA, administrative assistant
Moxon, Chris A., ASA, mechanic
Moxon, Jennifer, ASA, inventory control specialist
Muir, Randy, ASA, clerk
Murphy, Jay K., ASA, mechanic
Murray, David A., ASA, materialsperson
Navarro, Kenneth M., ASA, senior materialsperson
Navas, David, ET2, NSFA
Navas, Susan, ASA, service
Neighbors, Kevin C., ASA, communication technician
Nelson, Catherine M., ASA, materialsperson
Ness, Gerald T., ASA, winter operations supervisor
Nielsen, Daniel W., ASA, electrician
Noring, Kari A. ASA, materialsperson
Noton, Gail M., ASA, supervisor
Nottke, Connie L., ASA, senior materialsperson
O'Brien, Ronald W., ASA, mechanic
Ochs, Daire M., ASA, service
Olsen, Randy L., ASA, construction coordinator
Oxton, Alfred J., ASA, senior communications technician
Palko, Robert H., ASA, computer field engineer
Parr, James C., ASA, operator
Parrott, Christi R., ASA, service
Pennell, Thomas L., satellite communication installation/National Aeronautics and Space Administration
Perales, Richard, ASA, insulator
Perry, Mitchell R., ASA, senior communications technician
Pickering, Jeffrey A., ASA, crash firefighter
Pizano, Rafael, ASA, senior materialsperson
Poehler, Donald L., Sr., ASA, electrical shop foreman
Pomraning, Verne J., ASA, senior materialsperson
Poorman, Russell A., ASA, mechanic
Porter, David L., ASA, senior materialsperson
Prchlik, Richard A., ASA, firefighter
Prochko, Trenton W., ASA, plumber
Propst, Barbara G., ASA, materialsperson
Putrus, Vince A., ASA, lineman
Ramage, Yvonne E., ASA, network administrator

President's Midwinter's Day message 1995

Greetings to the international community of scientists and support personnel wintering in Antarctica on this year's Midwinter's Day.

Science is a limitless frontier. As we explore and extend this frontier, we increase our understanding of the world around us and improve our ability to respond to new challenges. This knowledge is a resource of inestimable value and the key to a brighter future.

As a natural laboratory, Antarctica plays an important role in this process of discovery. Even before people first arrived at its icy threshold, the possibility of the continent's existence fueled the human drive to learn. Since its discovery, many explorers have sought its remote shores, and scientists have worked to uncover the secrets of the continent's past to understand its role in the future. These investigators significantly advanced scientific understanding, opening our eyes to see Antarctica not as an isolated region but as an integral component of the global system.

Extending a tradition of excellence in science and creating valuable cooperative partnerships among individuals and among nations, all of you who work in Antarctica have an exciting opportunity at hand. By conveying to others what you have learned, you can help the public to understand the value of scientific research, to embrace the principles of responsible environmental stewardship, and to help prepare people everywhere for the challenges of the twenty-first century.

On behalf of all Americans, I applaud you for your efforts and wish you much continued success.

—Bill Clinton

Ramirez, Ronald R., ASA, fire inspector
Rasor, John P., ASA, supervisor
Rehmel, Robert S., ASA, communications technician
Reyes, Juan J., ASA, inventory control specialist
Robinson, Daniel B., ASA, mechanic
Rogers, Peggy A., ASA, cook
Rolle, Tyrone M., ETC, NSFA
Root, Cynthia J., ASA, waste management specialist
Rooth, Glenn T., ASA, cook
Ruddell, Bill W., ASA, materialsperson
Ryan, Jeffrey P., ASA, operator
Sale, John H., ASA, field engineer
Sanchez, Bernard J., DP2, NSFA
Schneider, Chad D., ASA, structure firefighter
Schroeder, Scott A., ET2, NSFA
Schwall, Karen Ann, ASA, winter resident manager
Segler, Richard L., ASA, utility mechanic
Self, Corky J., ASA, structure firefighter
Selzler, David L., ASA, mechanic
Semmler, Sundown D., ASA, operator
Shaefer, Toni M., ASA, service
Shapiro, Dean A., ASA, service
Sheid, Elizabeth D., ASA, science technician
Sheid, Robert W., ASA, machinist
Shulander, Sean E., RM3, NSFA
Simonson, Rebecca A., ASA, clerk
Simpson, Robert E., Jr., ASA, technician
Slack, Donnie R., satellite communication installation/National Aeronautics and Space Administration
Smith, Danny W., ASA, technician
Smith, David L., ASA, boiler mechanic
Smith, David R., ASA, technician
Smith, Howard D., ASA
Smith, Jeffrey A., ASA, supervisor
Smith, Scott F., ASA, plumber
Smock, Christine E., ET2, NSFA
Snyder, Frederick R., ASA, lead crash firefigher
Spain, Joseph G., AG1, NSFA
Stacy, Donald R., ASA, operator
Stacy, Judith, ASA, service
Stacy, Sharon A., ASA, materialsperson
Stark, Duane C., ASA, materialsperson
Starling, David C., ASA, senior materialsperson
Starling, Jennifer K., ASA, materialsperson
Steichen, Kevin R., ASA, mechanic
Stockard, Edward R., ASA, mechanic
Stokes, Ralph W., ASA, construction supervisor
Stout, Hope E., ASA, coordinator
Stowell, Roren L., ASA, service
Strom, Melanie R., ASA, hairstylist
Strow, Larry G., ASA, operator
Tackett, Marci R., ASA, cook
Tams, Eileen C., ASA, materials requisition specialist
Taulbee, Jon D., ASA, phone technician
Teetsell, Gary W., ASA, main facility engineer, Crary Science and Engineering Center
Teske, Christopher M., waste management technician
Testin, Andrew P., ASA, technician
Thompson, Cynthia D., RM2, NSFA
Tomczyk, Scott T., ASA, electrician
Trboyevich, Michael B., ASA, carpenter foreman
Trimingham, Terry S., ASA, general field assistant
Tucker, Marvin, PN1, NSFA
Turnbull, Kristopher L., ASA, lineman
Vanmiddlesworth, Eva L., RM1, NSFA
Vinson, Paul T., ASA, hazardous waste specialist
Walton, Debra K., ASA, materialsperson
Western, Diamond J., ASA, preventive maintenance mechanic
Weston, Shelley, ASA, waste management technician
Wetterlin, Diane, ASA, materialsperson
White, Andrea L., ASA, service
White, John B., Jr., ASA, materialsperson
Williams, Gina M., ASA, materialsperson
Williams, Lisa A., ASA, materialsperson
Williams, Samuel F., ASA, operator
Wilson, Mark A., ASA, plumber
Winckler, Andrea C., ASA, service
Wood, Alan B., ASA, service
Younger, Marilyn J., ASA, inventory control specialist
Zilar, Anthony M., HM1, NSFA
Zinke, Lyle D., ASA, technician

Amundsen–Scott South Pole Station

Booth, John F., ASA
Buesser, Emily C., ASA
Chamberlin, Richard A., Jr., "CARA: Antarctic submillimeter telescope and remote sensing observatory (AST/RO)," Smithsonian Astrophysical Observatory, Cambridge, Massachusetts
Charpentier, Paul J., "Rayleigh and sodium lidar studies of the troposphere, stratosphere, and mesosphere of Amundsen–Scott South Pole Station," University of Illinois, Urbana, Illinois
Cleavelin, Christopher L., ASA
Cuddy, Katherine A., ASA
Dunn, Alton G., III, ASA
Freeman, Gary E., ASA
Hampton, Drew D., ASA
Jones, Andrew R., "Probing the solar interior and atmosphere from the geographic South Pole," National Optical Observatory, Tucson, Arizona
Koester, David A., ASA
Lee, Robert E., Jr., ASA
Lloyd, James P., "CARA: South Pole infrared explorer (SPIREX)" University of Chicago, Chicago, Illinois
Logan, Andrew D., ASA
Logan, Diana J., ASA
Lutz, Jeffrey S., ASA
Makarov, Nikolai A., "Planetary waves in the antarctic mesopause region," University of Colorado, Boulder, Colorado
Masterman, Michael F., "Cosmic Background Radiation Anistropy (COBRA)," Carnegie-Mellon University, Pittsburgh, Pennsylvania
McAfee, Billy M., Jr., ASA
McNitt, Katharine A.,, "South Pole monitoring for climate change," National Oceanic and Atmospheric Administration, Climate Monitoring and Diagnostics Laboratory, Boulder, Colorado
Otten, Jeffrey C., "South Pole monitoring for climate change," National Oceanic and Atmospheric Administration, Climate Monitoring and Diagnostics Laboratory, Boulder, Colorado
Parlin, John T., ASA, station manager
Pokrob, Albert G., ASA
Sharp, Kathie A.H., ASA
Smith, Johnny P., ASA
Stathis, Martha K., ASA
Sverdrup, Eileen K., ASA
Tatley, Thomas J., ASA

Palmer Station

Byce, Rick D., ASA
Carlson, Robert D., ASA
Costello, Dennis L., ASA
Dickens, Jordan L., ASA
Grant, Glenn E., ASA
Huckins, Paul G., ASA
Kiyota, Kirk A., ASA, station manager
Lenox, Mary E., ASA
Lewis, Martin E., ASA
Lux, Paul F., ASA
Mahoney, Jacqueline F., ASA
Peterson, Corey J., ASA
Redlon, Matthew D., ASA
Rothermel, Margaret E., ASA
Sadzikowski, Mark R., ASA
Samojla, Mark S., ASA
Shea, Caryl, ASA
Tollefson, Robert B., ASA
Vella, David A., ASA
Williams, Brian L., ASA
Zadra, Dennis F., ASA

Sailor dies from fall at Castle Rock

A second-class petty officer, who was temporarily assigned to Navy Cargo Handling and Port Group Detachment Yankee, died 30 January 1995 as the result of an accidental fall from Castle Rock, a scenic spot 8 kilometers from McMurdo Station. The day of the accident, the man and his hiking partner left McMurdo Station at approximately 1:00 p.m. for Castle Rock, following the well-marked trail that leads from the station to the popular recreational destination. The accident occurred at approximately 3:30 p.m., as the two men were attempting to climb down the steeper, more treacherous face of Castle Rock.

After the accident, the man's hiking partner returned to McMurdo, a traverse that is described as a steep, uphill climb on a snow-packed trail, arriving at approximately 8:00 p.m., to report the incident. A search-and-rescue team was immediately dispatched via a VXE-6 helicopter, and at 9:10 p.m., the victim was recovered from Castle Rock and returned to McMurdo Medical Clinic.

The victim had been assigned to temporary duty to offload a cargo vessel bringing supplies to the station and had been in McMurdo for 3 days. McMurdo personnel report that he had received the outdoor safety lecture required of all residents of the station.

A new committee for the oversight of antarctic research vessels

Antarctic Support Associates (ASA), as the primary contractor to the National Science Foundation for support to the United States Antarctic Program, has established an Antarctic Research Vessel Oversight Committee (ARVOC). This article introduces the committee, describes its charge, provides information regarding antarctic research ships and their capabilities, and advertises an ARVOC-related electronic bulletin board. The latter represents a platform through which the antarctic research community and ARVOC can communicate regarding ship-related matters, such as ship scheduling, equipment acquisitions or needs, and ARVOC agenda items or announcements.

ARVOC's role

ARVOC represents the interdisciplinary scientific interests of the United States Antarctic Program's ice-capable research ships, currently the *Nathaniel B. Palmer* and *Polar Duke*. Specifically, the committee provides recommendations and advice concerning the following:

- acquisition and use of shipboard equipment and instrumentation;
- shipboard computer systems;
- ship scheduling (particularly long-range) issues; and
- staffing, communications, space allocation, and anything else that improves the research capability of the program.

The committee, whose members serve 3-year rotating terms, consists of eight scientists from the research community (table 1), representing most disciplines involved in sea-going polar research programs. All members bring valuable shipboard experience, and most are directly involved with USAP's ships through their research.

The ARVOC will meet formally at least once a year, though initially it will meet more frequently until most of the fundamental issues facing this new committee have been articulated and a plan of action has been formulated and implemented. To date, the committee has met twice: the first time to identify general issues requiring attention; the second, to focus on some of the more urgent issues, such as long-range ship scheduling and establishment of guidelines for equipment acquisition and ship modifications. Future meetings will likewise focus on specific topics.

The two antarctic ice-capable research ships ARVOC oversees, *Polar Duke* and *Nathaniel B. Palmer*, have the capabilities described below (see table 2 for general specifications).

The Polar Duke

An ice-strengthened vessel, 219 feet (65.7 meters) long, the *Polar Duke* operates in the marginal ice zone around the Antarctic Peninsula region where it supports Palmer Station and sea-going research programs. The ship has onboard personal computer facilities including a DOS network.

The *Polar Duke* has three winches for conductivity-temperature-depth (CTD) measurements, hydrographic and trawl/coring capabilities, a stern A-frame, starboard hydro davit and "Hero" platform, and three cranes. Various laboratory vans for radioisotope and environmental work

Table 1. ARVOC membership, affiliations, and contact information

Member	Affiliation	Electronic mail address	Phone number	Fax number
Douglas Martinson (Chair)	Lamont-Doherty Earth Observatory Columbia University	dgm@ldeo.columbia.edu	(914) 365-8830	(914) 365-8736
Martin Jeffries	University of Alaska	martin@dino.gi.alaska.edu	(907) 474-5257	(907) 474-7290
David Karl	SOEST University of Hawaii	dkarl@soest.hawaii.edu	(808) 956-8964	(808) 956-9516
Amy Leventer	Limnological Research Center University of Minnesota	leven004@gold.tc.umn.edu	(612) 624-7005	(612) 625-3819
James Morison	Polar Research Center University of Washington	morison@apl.washington.edu	(206) 543-1394	(206) 543-3521
Carol Raymond	Jet Propulsion Laboratory California Institute of Technology	car@orion.jpl.nasa.gov	(818) 354-8690	(818) 393-5059
Bruce Robison	Monterey Bay Aquarium Research Institute	robr@mbari.org	(408) 647-3721	(408) 649-8587
Ray Weiss	Scripps Institution of Oceanography University of California at San Diego	rfweiss@ucsd.edu	(619) 534-3205	(619) 455-8306


NSF photo by Kevin Wood, Antarctic Support Associates.

Polar Duke, which the National Science Foundation leases through its support contractor Antarctic Support Associates, has supported research throughout the Antarctic Peninsula region and has transported supplies, equipment, and personnel to and from Palmer Station for a decade. This ship, as a result of a major government contract competition, will be replaced shortly by the *Laurence Gould*, a ship currently under construction.

are available as is diving support. MK II and MK V Zodiacs are available for scientific use. The *Polar Duke* is at sea approximately 300 days a year.

The *Polar Duke*, in service for 9 years, is currently operated through a lease to ASA from Reiber, Inc. It will be replaced, upon completion of the lease, by the *Lawrence M. Gould*, a ship that is being built by Edison Chouest Offshore. The replacement ship, to be operated through a 5-year lease to ASA, is scheduled to begin operation in fiscal year 1997. Its scientific instrumentation will come from the *Polar Duke*. General specifications of the replacement vessel are listed in table 2.

The Nathaniel B. Palmer

A recent addition to the fleet, the *Nathaniel B. Palmer* is USAP's research ship with ice-breaking capabilities and provides the United States with a means of exploring the far reaches of the antarctic waters. It sometimes provides vital logistics support to the scientific programs on the antarctic continent and continental margin. The *Nathaniel B. Palmer*, a 308-foot-long (92.4-meter) general-purpose oceanographic ship, can operate anywhere within the antarctic sea-ice fields and can maintain approximately 3 knots in 1-m-thick ice.

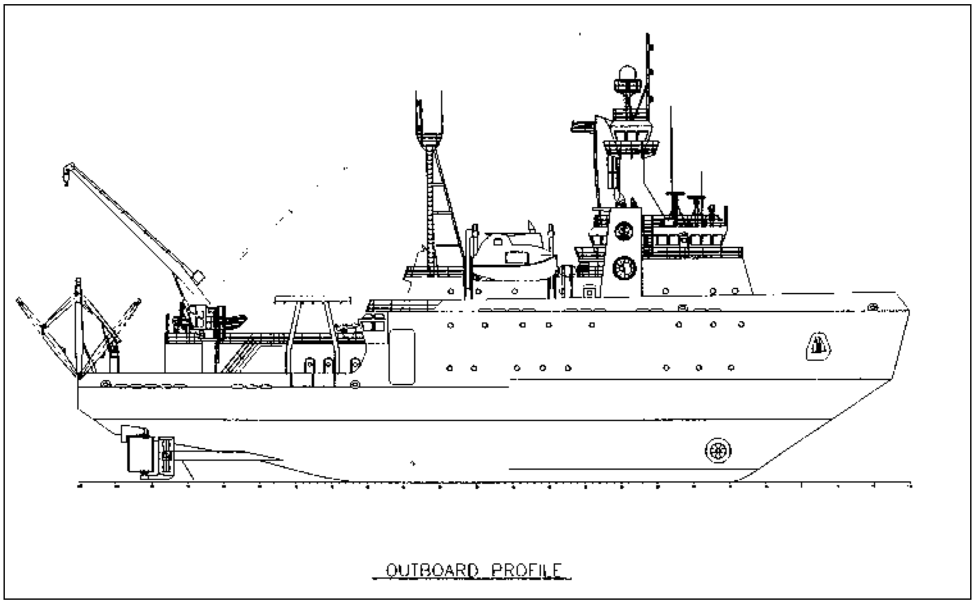
The ship has extensive onboard computer facilities including a local area network with ports in each stateroom. Closed-circuit TVs in each of the staterooms and labs provide views of various ship locations (outboard and winch locations) and extensive real-time data displays (such as ship location, speed, winds, and data traces).

The *Nathaniel B. Palmer* also has a variety of winches for CTD measurements, hydrographic and trawl/coring capabilities, A-frames on the stern and starboard side, a 6-ton hydraulic boom that extends outboard directly from the Baltic Room with a 15-foot (4.5-meter) reach, and several articulated cranes having capacities from 2.5 to 10 tons, capable of servicing forward and aft decks. A general purpose laboratory van and another configured as an isotope lab are available. A 26-foot (7.8-meter) steel boat having forward cabin and aft working deck and two MK V Zodiaks are available for scientific purposes. The ship has a helicopter deck and hangar capable of supporting two small helicopters. The *Nathaniel B. Palmer* is at sea approximately 300 days a year.

The ship had its inaugural cruise in March of 1992 (supporting Ice Station Weddell–1 and sailing through some of the thickest sea ice around Antarctica). It is operated through a 10-year lease to ASA from Edison Chouest Offshore.

The complexities of ship scheduling

Both ships are available for NSF-supported sea-going research programs through the usual method of competitive proposals. Scientists planning sea-going



The *Laurence M. Gould*, shown here in the preliminary design drawing, is scheduled for completion in mid-1997. With over 1,600 square feet of laboratory space, the *Gould* can house 23 scientists (plus 12 in vans) for cruises lasting 75 days. The specifications and planned instrumentation are listed in table 2.

Antarctic explorer and geologist Laurence M. Gould dies at age 98

Laurence McKinley Gould, who was born on his family's farm in Lacota, Michigan, on 22 August 1896, died in a Tucson, Arizona, retirement home on 20 June 1995. Gould served as senior scientist and second in command for Admiral Richard Byrd's first antarctic expedition 1928–1930. That was to be the first of many expeditions Gould would take to Antarctica, kindling his interest in the continent as a haven for science.

During the First Byrd Antarctic Expedition, Byrd and Gould established an exploration base at Little America on the Ross Ice Shelf. Gould and two other men (Bernt Balchen and Harold June) then flew a ski-equipped Fokker Universal monoplane, named "The Virginian," 2 hours east to the newly discovered Rockefeller Mountains in the Queen Maud Range, West Antarctica. Gould's party anchored the Fokker solidly to the ice, but the wind grew so strong that the light, cloth-covered plane was lifted from its moorings into the air, its propeller beating as though it were in flight. One member of the party, who had been in the Fokker keeping a radio schedule when the winds came up, reported looking out and seeing Gould "hanging onto a rope attached to one of the wing tips. He was blown straight out, like a flag." The plane was irreparably damaged by the storm, and Byrd had to rescue the party in a larger plane.

Gould led a second party of five back to the Queen Maud Mountains, this time by sledge, traveling 2,400 kilometers along the route Norwegian Roald Amundsen had taken 17 years earlier in his race to beat Englishman Robert F. Scott to the South Pole. In a cairn named by Amundsen, Gould found one of Amundsen's notes from that historic expedition. Gould's party's primary goal was to explore the Queen Maud Mountains and to set up an advanced base for Byrd's planned flight to the South Pole, and on his mission, Gould was as much a geologist as an explorer. From the Queen Maud Mountains, he radioed back to Byrd,

> No symphony I have ever heard, no work of art before which I have stood in awe gave me quite the thrill I had when I reached out after that strenuous climb [up Mount Fidjtof Nansen] and picked up a rock to find it sandstone. It was just the rock I had come all the way to Antarctica to find…

Gould's 1931 book about that expedition, *Cold: The Record of an Antarctic Sledge Journey*, concludes with a statement that defines his scientific career. "I had rather go back to the Antarctic," he writes, "and find a fossil marsupial than three gold mines."

Over the next three decades, Gould returned to Antarctica frequently, his research and publications contributing significantly to the growing body of antarctic literature. On a 1969 expedition with Grover Murray to the Beardmore Glacier, his party found a vertebrate fossil closely resembling fossils that had just been found in South Africa, providing concrete evidence to support the theory that Africa and Antarctica had once been attached. He radioed Washington that this was "not only the most important fossil ever found in Antarctica, but one of the truly great fossil finds of all time."

Educated at the University of Michigan between 1916 and 1925, Gould first intended to study law but was attracted to geology instead through his close association with Professor William H. Hobbs, in whose home he was given a room in exchange for tending the furnace and the lawn. Gould cites Hobbs's "bouyancy and infectious enthusiasm" for geology as the life-changing influence that moved him from an interest in the law to a love of science. "I probably owe more to Hobbs," Gould wrote in a memorial to the professor, "than to any other person I have known."

In 1926, Gould began teaching geology at the University of Michigan. Six years later, he accepted a teaching position at Carleton College, where he not only founded the Department of Geology and Geography upon his arrival but also served as college president from 1945 to 1962. In his retirement, Gould returned to teaching, this time at the University of Arizona at Tucson. He was remembered by one former student in *The Voice of the Carleton Alumni* as "a scientist fascinated by the pursuit of truth and knowledge" who had "the spirit of the scholar, the soul of the poet and adventurer, and a special ability to communicate his passion for learning to his students."

Gould served in World War I both in the Italian Army and with the American Expeditionary Forces, and during World War II, he took 2 years leave of absence from Carleton College to serve as Chief of the Arctic Branch of the Arctic, Desert, and Tropic Information Center of the U.S. Army Air Corps.

For the International Geophysical Year in 1957–1958, Gould headed the American delegation to the planning meetings for the unprecedented 11-country scientific endeavor. For many years, Gould chaired the Committee on Polar Research of the National Academy of Sciences and headed the Special Committee on Antarctic Research, an international organization that coordinates efforts in Antarctica. His work on these bodies helped smooth the way for the adoption of the international Antarctic Treaty in 1959, which ensures that the antarctic continent and the waters around it will "…continue forever to be used exclusively for peaceful purposes." Gould also served on the National Science Board (1963–1970) and as chairman of the Advisory Panel on Polar Programs of the National Science Foundation (1953–1962).

Gould was the recipient of 24 honorary doctorates and 10 medals and awards. To commemorate his lifelong contributions to south polar scientific exploration, six different physical features in Antarctica have been named for him, and the new research ship commissioned by the National Science Foundation for use in the U.S. Antarctic Program will also bear his name—the *Laurence M. Gould*.

programs, however, are sometimes unaware of competing plans, incompatibilities in regional foci, and opportunities for participation in other cruises. This lack of awareness can reduce operational efficiency, make long-range ship scheduling difficult, increase anxiety in the planning process, and even discourage some scientists from proposing sea-going programs.

In an attempt to achieve a more optimal ship scheduling process, ARVOC hopes to make scheduling accessible to the research community by experimenting with a public, albeit purely voluntary, component. Toward this goal, ARVOC has established a "list-server" and electronic bulletin board to serve as an open forum through which, among other things, planned or desired sea-going programs can be openly aired. ARVOC would like to invite investigators to submit some basic information regarding such programs to the ARVOC bulletin board. The basic information should include

- time and duration of the program (this may be a specific time, or more generally a season or year, and any flexibility in this schedule);
- type of research program;
- general region;
- number of participants involved, required, or desired; and
- whether the program would be a principal user of the ship or could supplement another program (if the former, is room for ancillary programs available? and if so, are specific or general ones needed?).

The group offering the field plan may remain anonymous if it desires.

ARVOC will assimilate this information into a general, evolving schedule representing "expressions of interest" that would be available for examination through the bulletin board. The schedule will clearly distinguish between funded programs (for which the ships are definitely committed) and those still being planned or proposed. *Please note that the bulletin board is an ASA and ARVOC activity and is not part of the NSF funding process. The submission of bulletin board information is in no way a prerequisite for submission of an NSF proposal.* The desire here is simply to keep the sea-going community aware of future plans. It is an effort to coordinate scheduling between programs more efficiently, coordinate regional concentrations, identify major scheduling conflicts or gaps, and encourage individuals to participate in cruises in which ancillary programs can be accommodated.

We recognize the sensitivities that may be involved in attempting such an open forum for ship scheduling. For example, often groups of investigators get together and plan a particular program for which they do not desire outside participation. In an attempt to encourage such groups to publicize their ship plans while protecting their privacy, we do not require that names or discipline be given. We will display any explicitly stated program needs, however, and will help bring together complementary groups or individuals where explicitly stated needs represent an apparent match. We welcome

Table 2. Antarctic research vessel specifications and general instrumentation

Specification/ instrumentation	Nathaniel B. Palmer	Polar Duke	Laurence M. Gould
Year built	1992	1983	Mid-1997
Length (ft)	308	219	230
Beam (ft)	60	43	46
Displacement (lt)	6,800	2,973	3,123
Horsepower (BHP@1000 erpm)	12,700	4,500	5,400
Speed in open ocean (kts)	12	10	12
Speed in ice[a] (kts/m)	~3	~1	~1
Crew	22	13	13
ASA personnel	5	3	3
Science party	32	23	23 (+12 in vans)
Endurance (maximum number of days)	75	75	75
Laboratory space (ft^2)	5,500	1,400	1,637
Communications capability	All vessels: INMARSAT (voice, fax, telex, e-mail); high-frequency and very-high-frequency radio		
Scientific instruments and special facilities[b]	All vessels: Real-time data-acquisition system; sea-water aquaria; deep-sea piston coring systems (standard and jumbo); dredges; Seabird CTD rosette; 5-, 10-, and 30-liter Niskin bottles and 12-liter Go-Flo bottles; wind speed and direction, air temperature monitors; nutrient autoanalyzer; salinometer and fluorometer; SIPPICAN MK 9 digital expendable bathythermograph system; 3.5- and 12-kilohertz sonar; magnetometer; Furuno hull-mounted, sector-scanning sonar; trawls (IKMT, PLANKTON, BLAKE, OTTER); nets; radioisotope vans and dive-support vans; echo sounder		
	Seabeam; magnetic gradiometer; multichannel seismics		
Computers	All vessels: Networked DOS (with Windows) and Macintosh computers		
	SGI workstations with Ethernet backbone		

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[a] Actual speed and endurance is strongly dependent on ice conditions such as snow cover, hardness, and compaction.

[b] Research instrumentation and equipment are also available from Palmer and McMurdo Station laboratories, although availability is dependent on cruise time and station requirements. The ASA SIP forms (available from ASA and on the Web) provide additional instrumentation and equipment specifications and details.

The icebreaking research ship *Nathaniel B. Palmer*, which made its first cruise to Antarctica in February 1991, was constructed by Edison Chouest Company, the same U.S. firm that is building the *Laurence Gould*.

NSF photo by Kevin Wood, Antarctic Support Associates.

suggestions for improving this mechanism and expect that the manner in which it operates will evolve with time and experience.

In addition to ship scheduling, we intend to use the bulletin board for general announcements; to provide minutes of the ARVOC meetings; and to solicit community input to relevant issues, equipment needs, and ship modifications. The equipment and ship modification lists will be compiled and prioritized for continual shipboard improvements; it, too, will be made available through this means.

How to participate

The bulletin board will be a central location on which information of interest will remain posted, and the list-server will be a means through which the "subscribers" can initiate, participate in, or simply monitor, communitywide discussion and debate on any topic of general interest. ARVOC invites all interested parties to contact the list-server and become subscribers. This is done automatically by sending a message to

majordomo@listserv.asa.org

The text of the message should read

subscribe ARVOC

Once this is done, you can send messages to ARVOC at the address

ARVOC@listserv.asa.org

Your message will then be forwarded to all subscribers. Subscribers will also receive messages notifying them of new information posted to the bulletin board, instructions for accessing the bulletin board, and other announcements of interest. If you are interested in instructions regarding use of the bulletin board but do not wish to subscribe to the list-server, please contact Lynne Drew, Administrative Assistant, Marine Science, ASA, at

drewly.asa@asa.org

or (303) 790-8606, for instructions.

In addition to the list-server, ARVOC will attempt to interact openly with the community at public forums to be held at certain national meetings. Besides disseminating general information and soliciting community feedback, ARVOC will also present the ship scheduling information at these meetings allowing investigators an opportunity to interact more openly, if desired, for further coordination.

ARVOC is committed to attaining the best possible antarctic shipboard operations and scientific programs. We welcome all community feedback, suggestions, and criticisms that contribute to this goal.

Douglas G. Martinson, Chairman, Antarctic Research Vessels Oversight Committee

Office of Polar Programs reorganizes

In 1995, NSF's Office of Polar Programs (OPP) reorganized to focus its resources more effectively. The office is now composed of two science sections—the Antarctic and the Arctic Science Sections—each of which is composed of specific research programs and related activities. The third section, the Polar Research Support Section (formerly the Polar Operations Section), provides laboratory, operational, and logistics support for antarctic and arctic science programs.

The Antarctic Science Section continues to support five disciplinary research programs—aeronomy and astrophysics, biology and medicine, ocean and climate systems, glaciology, and geology and geophysics—within the Science Cluster. These five disciplines are integrated with the common goal of fostering research that expands fundamental knowledge of polar regions, uses the special features of Antarctica that make it a platform for exploration of the Universe, and enhances understanding of the continent's role in regional and worldwide problems of scientific importance, such as global climate change. Added to the Antarctic Sciences Section are the Information Cluster and the Environmental Cluster. The latter is responsible for determining what environmental assessments are required, monitoring compliance with the National Environmental Protection Act, and issuing waste and flora and fauna permits required under the Antarctic Conservation Act.

The Arctic Science Section supports disciplinary and interdisciplinary basic research to advance knowledge of fundamental cold-region processes and to enhance regional and global models. The primary goal of this research program is to gain a better understanding of arctic biological, geological, chemical, physical, and sociocultural processes. The Arctic Science Section consists of four programs—Arctic System Science, Arctic Natural Sciences, Arctic Social Sciences, and Arctic Research and Policy.

OPP's research activities can only be executed with a well-developed, safe infrastructure and expert logistics support, based on sound environmental practices. This is the responsibility of the Polar Research Support Section, which focuses OPP's operational and logistic resources through contractors to support science conducted in both polar regions. The section's goal is to improve science support, while using fewer resources, by increasing intelligent systems, improving efficiency, and economizing throughout the program.

The table provided with this article provides names and titles for the staff members of the three sections, as well as the names and titles of those individuals who report directly to OPP's Director, Dr. Cornelius Sullivan.

Office of Polar Programs new organization

Office of the Director	**Phone: (703) 306-1030**
Director	Dr. Cornelius Sullivan
Deputy Director	Dr. Carol Roberts
Budget and Planning Officer	Mrs. Altie Metcalf
Budget Analyst	Mr. Darren Dutterer
Administrative Officer	Mrs. Pawnee Maiden
Office Secretary	Mrs. Brenda Williams
Deputy Secretary	Ms. Regina Williams

Arctic Sciences Section	**Phone: (703) 306-1029**
Section Head	Dr. Thomas Pyle
Head of Interagency Arctic Staff	Mr. Charles Myers
Social Science Program Manager	Dr. Noel Broadbent
Arctic System Science Program Director	Dr. Michael Ledbetter
Associate Program Director	Vacant
Arctic Logistics Support	Mr. Imants Virsniek/Detailee
Arctic Natural Sciences	Mrs. Odile De La Beaujardiere
Senior Program Assistant	Mrs. Simona Gilbert
Program Assistant	Mrs. Natasha Rutledge
Office Automation Clerk	Ms. Tammy Short
Management Intern	Ms. Shanna Draheim

Polar Research Support Section	**Phone: (703) 306-1032**
Section Head	Mr. Erick Chiang
Deputy Section Head	Mr. Dwight Fisher
Associate Managers (Department of Defense)	COL Karl Doll (Air National Guard)[a] LT COL Ade Hudnall (Air National Guard)[a]
Systems Manager	Mr. David Bresnahan
Safety and Health Officer	Dr. Harry Mahar
Safety and Health Specialist	Ms. Gwendolyn Adams
Manager, Specialized Support	Mr. Arthur Brown
Facilities Engineering Project Manager	Mr. Frank Brier
South Pole Engineering Projects Manager	Mr. John Rand[b]
South Pole Construction/Operations and Maintenance Coordinator	Mr. Jerry Marty[c]
Environmental Engineer (Implementation)	Dr. Shih-Cheng Chang
Technology Development Manager	Mr. Patrick Smith
Electronics Systems Coordinator	Mr. Dennis Tupick[d]
Research Support Manager	Mr. Simon Stephenson
Oceans Project Manager	Mr. Al Sutherland
Program Coordination Specialist	Mrs. Kim Fassbender
Fire Protection Engineer	Mr. Douglas Carpenter
Senior Program Assistant	Mrs. Pamela Conyers
Program Assistant	Vacant
Program Assistant	Mrs. Carlena Fooks
Imaging Applications Specialist	Mr. David Beverstock[e]
Air Projects Specialist	Mr. Mike Scheuermann[e]
Program Manager, Naval Antarctica Support Unit Transfer	Dr. Charles Paul
McMurdo Station Manager	Mr. Edward Finn
Antarctic Support Associates Contractor Representative	Mr. George Lake

Antarctic Sciences Section	**Phone: (703) 306-1033**
Section Head	Dr. Dennis Peacock
Biology and Medicine Program Manager	Dr. Polly Penhale
Associate Program Manager (Biology and Medicine)	Dr. Edward Carpenter
Aeronomy and Astrophysics Program Manager	Dr. John Lynch
Ocean and Climate Sciences Program Manager	Dr. Bernhard Lettau
Antarctic Geology and Geophysics Program Manager	Dr. Scott Borg
Glaciology Program Manager	Dr. Julie Palais
Coordinated Science Projects Program Manager	Dr. Jane Dionne
Laboratory and Equipment Manager/Internal Coordinator	Vacant
Environmental Officer	Mrs. Joyce Jatko
Manager, Information Program	Mr. Guy Guthridge
Writer/Editor	Ms. Winifred Reuning
National Environmental Protection Act Compliance Manager	Mr. Robert Cunningham
Associate Compliance Manager	Ms. Kristin Larson
Polar Coordination Specialist	Ms. Nadene Kennedy
Information/Reference Assistant	Mr. David Friscic
Senior Program Assistant	Mrs. Kimiko Bowens-Knox
Program Assistant	Vacant
Program Assistant	Mrs. Tammy Butler
Capital Systems contractor	Ms. Amrita Narayanan

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[a] Military personnel on detail to the National Science Foundation from the Department of Defense.

[b] U.S. Army Cold Regions Research and Engineering Laboratory personnel on detail to the National Science Foundation.

[c] Capital Systems Group personnel for on-site contract support.

[d] Contract support personnel from Jackson-Tulle, Inc.

[e] On-site contract personnel from Antarctic Support Associates.

Foundation awards of funds for antarctic projects, 1 September 1994 to 31 August 1995

Award numbers for all awards initiated by the Office of Polar Programs (OPP) contain the prefix "OPP." However, funding of awards is sometimes shared by two or more antarctic science or support programs within OPP or between OPP antarctic and arctic science or support programs. For these awards, a listing is included under the heading for each OPP program that funded the project. The first amount represents the funds provided by that individual program, and the second amount, in parentheses, is the total award amount. All of these contain the OPP prefix. Additionally, investigators may receive funds for antarctic research from other divisions or offices of the National Science Foundation, as well as from OPP. Awards from the Division of Atmospheric Sciences contain the ATM prefix; awards from the Division of Design, Manufacturing, and Industry Innovation contain the DMI prefix; and awards from the Division of Ocean Sciences contain the OCE prefix. When awards are initiated by another NSF division, the three-letter prefix for that program is included in the award number. As with awards split between OPP programs, antarctic program funds are listed first, and the total amount is listed in parentheses. The numbers 1 through 4 in parentheses following the entries indicate when the award was made: 1, 1 September to 30 November 1994; 2, 1 December 1994 to 28 February 1995; 3, 1 March to 30 May 1995; 4, 1 June to 31 August 1995.

Biology and medicine

Arrigo, Kevin R. University of Maryland, College Park, Maryland. Research on ocean–atmosphere variability and ecosystem: Response in the Ross Sea (ROAVERRS). OPP 94-21496. $0 ($60,850) (4)

Barry, James P. Monterey Bay Aquarium Research Institute, Pacific Grove, California. Research on ocean–atmosphere variability and ecosystem: Responses in the Ross Sea (ROAVERRS). OPP 94-20680. $54,933 ($115,001) (4)

Bowser, Samuel S. Health Research, Inc., Albany, New York. Test morphogenesis in giant antarctic foraminifera. OPP 92-20146. $84,581 (4)

Carpenter, Edward J. State University of New York, Stony Brook, New York. Intergovernment Personnel Act mobility assignment. OPP 95-22577. $143,047 (4)

Davison, Ian. University of Maine, Orono, Maine. Thermal adaptation of polar macroalgae. OPP 94-18033. $128,118 (4)

Day, Thomas A. Arizona State University, Tempe, Arizona. Ozone depletion, ultraviolet-B radiation and vascular plant performance in Antarctica. OPP 93-17019. $73,000 ($233,957) (4)

Delong, Edward F., University of California, Santa Barbara, California. Antarctic marine archaebacteria: Biological properties and ecological significance. OPP 94-18442. $110,395 (3)

Detrich, H. William. Northeastern University, Boston, Massachusetts. Structure, function, and expression of cold-adapted tubulin and microtubule-dependent motors from antarctic fishes. OPP 94-20712. $143,444 ($284,070) (4)

DeVries, Arthur L. University of Illinois at Urbana–Champaign, Urbana, Illinois. The role of antifreeze proteins in freezing avoidance of antarctic fishes. OPP 93-17629. $159,844 ($324,885) (4)

Ducklow, Hugh W. The College of William and Mary, Marine Institute, Gloucester Point, Virginia. Bloom dynamics and food web structure in the Ross Sea: Primary productivity, new production, and bacterial growth. OPP 93-19222. $69,770 ($126,016) (4)

Dunton, Kenneth H. University of Texas, Austin, Texas. Thermal adaptation in polar macroalgae. OPP 94-21764. $169,647 (4)

Eastman, Joseph T. Ohio University, Athens, Ohio. Buoyancy and morphological studies of antarctic Notothenioid fishes. OPP 94-16870. $164,912 (3)

Franklin, Jerry F. University of Washington, Seattle, Washington. Stimulating and facilitating collaborative long-term ecological research: A proposal for continuing support of the Long-Term Ecological Research network office. OPP 95-41893. $89,991 ($1,039,906) (4)

Fraser, William R. Montana State University, Bozeman, Montana. Changes in Adélie penguin populations at Palmer Station: The effects of human disturbance and long-term environmental change. OPP 95-05596. $46,000 ($210,047) (4)

Freckman, Diana W. Colorado State University, Fort Collins, Colorado. The ecology of nematodes in antarctic dry valleys. OPP 94-44469. $3,750 ($13,251) (1)

Friedmann, E. Imre. Florida State University, Tallahassee, Florida. Limits of adaptation and microbial extinction in the antarctic desert. OPP 91-18730. $11,442 ($88,000) (2)

Gautier, Catherine. University of California, Santa Barbara, California. Surface ultraviolet irradiance and photosynthetically available radiation variability over Antarctica. OPP 93-17120. $130,188 (3)

Gerard, Valerie A. State University of New York, Stony Brook, New York. Thermal adaptation in polar macroalgae. OPP 95-21496. $205,858 (4)

Gowing, Marcia M. University of California, Santa Cruz, California. Bloom dynamics and food web structure in the Ross Sea: Role of microzooplankton in controlling production. OPP 93-16035. $164,769 ($382,622) (4)

Green, William J. Miami University, Oxford, Ohio. Microbial and geochemical controls on metal cycling in Lake Vanda. OPP 94-43939. $124,851 (1)

Hall, Michael J. National Oceanic and Atmospheric Administration, Washington, DC. Support for Argos data collection and location system. OPP 95-43519. $23,109 ($479,174) (4)

Hofmann, Eileen E. Old Dominion University, Norfolk, Virginia. Modeling the transport and exchange of krill between the Antarctic Peninsula and South Georgia. OPP 95-25806. $192,149 ($212,149) (4)

Holm-Hansen, Osmund. University of California, San Diego, California. Effects of ozone-related increased ultraviolet-B fluences on photosynthesis, photoadaptation, and viability of phytoplankton in antarctic waters. OPP 92-20150. $43,322 (3)

Holm-Hansen, Osmund. University of California, San Diego, California. U.S–Argentina cooperative research: Ozone-related impact of solar ultraviolet radiation on the marine food chain in Argentine coastal waters. OPP 95-03643. $10,000 ($27,690) (4)

Howes, Brian L. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. Antarctic dry valley lakes: Pathways of organic material production and decomposition. OPP 95-42668. $35,000 (4)

Jeffrey, Wade H. University of West Florida, Pensacola, Florida. Ultraviolet-radiation-induced DNA damage in bacterioplankton in the southern oceans. OPP 94-19037. $140,969 ($278,910) (4)

Kareiva, Peter M. University of Washington, Seattle, Washington. Foraging behavior and the dispersion of pelagic birds. OPP 95-42669. $9,500 (4)

Karl, David M. University of Hawaii–Manoa, Honolulu, Hawaii. Long-Term Ecological Research (LTER) on the antarctic marine ecosystem: Microbiology and carbon flux. OPP 91-18439. $129,760 (2)

Kensley, Brian F. Smithsonian Institution, Washington, DC. Recording of data and sorting of collections from polar regions. OPP 94-40137. $249,999 (1)

Kieber, David J. State University of New York, College of Environmental Science and Forestry, Syracuse, New York. Investigations into the photochemistry of antarctic waters in response to changing ultraviolet radiation fluxes. OPP 93-12767. $91,290 (3)

Koger, Ronald G. Antarctic Support Associates, Englewood, Colorado. Logistics support of operations/research activities related to the U.S. program in Antarctica. OPP 95-42227. $72,500 ($30,098,868) (4)

Kooyman, Gerald L. University of California at San Diego, Scripps Institution of Oceanography, La Jolla, California. Physiology and energetics of king and emperor penguins. OPP 92-19872. $169,117 (4)

Lessard, Evelyn J. University of Washington, Seattle, Washington. Bloom dynamics and foodweb structure in the Ross Sea: Role of microzooplankton in controlling production. OPP 93-15027. $90,064 (3)

Lizotte, Michael P. University of Wisconsin, Oshkosh, Wisconsin. Research on ocean–atmosphere variability and ecosystem response in the Ross Sea (ROAVERRS). OPP 94-20678. $58,109 (4)

Lowenthal, Douglas H. University of Nevada, Desert Research Institute, Reno, Nevada. Particulate matter less than 10 microns in size (PM10) source apportionment at McMurdo Station, Antarctica. OPP 94-17829. $130,000 (4)

Manahan, Donal T. University of Southern California, Los Angeles, California. Metabolic physiology during embryonic and larval development of antarctic echinoderms. OPP 94-20803. $131,317 ($261,612) (4)

Mopper, Kenneth. Washington State University, Pullman, Washington. Photochemistry of antarctic waters in response to changing ultraviolet radiation fluxes. OPP 92-21598. $65,000 (3)

Mullen, Roy R. U.S. Geological Survey, Reston, Virginia. Antarctic surveying and mapping program. OPP 94-43652. $10,000 ($257,849) (1)

Priscu, John C. Montana State University, Bozeman, Mountana. Water-column transformations of nitrogen in a perennially ice-covered antarctic lake. OPP 94-44636. $10,798 (1)

Priscu, John C. Montana State University, Bozeman, Montana. Antarctic lake ice microbial consortia: Origin, distribution, and growth physiology. OPP 94-19413. $199,635 ($381,690) (4)

Reed, H.L. Henry M. Jackson Foundation for the Advancement of Military Medicine, Bethesda, Maryland. The polar T_3 Syndrome: Metabolic and cognitive manifestations, their hormonal regulation, and their impact upon performance. OPP 94-18466. $83,923 ($125,323) (4)

Ross, Robin M. University of California, Santa Barbara, California. Long-term ecological research on the antarctic marine ecosystem: An ice-dominated environment. OPP 90-11927. $600,000 (4)

Schmidt, Thomas M. Michigan State University, East Lansing, Michigan. Microbial and geochemical controls on metal cycling in Lake Vanda. OPP 94-43937. $126,707 (1)

Sidell, Bruce D. University of Maine, Orono, Maine. Adaptations to counter diffusional constraints in muscle of Channichthyid icefishes. OPP 92-20775. $149,582 (3)

Siniff, Donald B. University of Minnesota at the Twin Cities, Minneapolis, Minnesota. Possible linkages between ecosystem measures and the demographics of a Weddell seal population. OPP 94-20818. $140,376 (4)

Smith, Kenneth L. University of California at San Diego, Scripps Institution of Oceanography, La Jolla, California. Seasonal ice cover and its impact on the epipelagic community in the northwestern Weddell Sea: Long timeseries monitoring. OPP 93-15029. $169,742 ($226,322) (3)

Smith, Kenneth L. University of California at San Diego, Scripps Institution of Oceanography, La Jolla, California. Seasonal ice cover and its impact on the epipelagic community in the northwestern Weddell Sea: Long timeseries monitoring. OPP 95-42643. $26,065 ($126,065) (4)

Smith, Raymond C. University of California, Santa Barbara, California. Ozone diminution, ultraviolet radiation, and phytoplankton biology in antarctic waters. OPP 92-20962. $220,235 (2)

Smith, Raymond C. University of California, Santa Barbara, California. Ozone diminution, ultraviolet radiation, and phytoplankton biology in antarctic waters. OPP 95-42706. $14,511 (4)

Spear, Larry B. Point Reyes Bird Observatory, Stinson Beach, California. Studies of southern ocean seabirds in South Pacific waters during winter. OPP 95-26435. $15,000 (4)

Stoecker, Diane K. University of Maryland, Horn Point Laboratory, Cambridge, Maryland. Ecology and physiology of sea-ice brine microalgae. OPP 93-18772. $109,870 ($224,806) (4)

Virginia, Ross A. Dartmouth College, Hanover, New Hampshire. Antarctic dry valley nematode communities: Establishment, function, and response to disturbance. OPP 95-22665. $83,656 (4)

Weathers, Wesley W. University of California, Davis, California. Foraging ecology and reproductive energetics of antarctic petrels. OPP 92-18536. $98,088 (4)

Wharton, Robert A. University of Nevada, Desert Research Institute, Reno, Nevada. McMurdo Dry Valleys: A cold desert ecosystem. OPP 92-11773. $606,088 ($1,182,904) (4)

Marine and terrestrial geology and geophysics

Anderson, John B. Rice University, Houston, Texas. Geologic record of Late Wisconsinan/Holocene ice-sheet advance and retreat from Ross Sea. OPP 91-19683. $115,386 (4)

Anderson, John B. Rice University, Houston, Texas. Geologic record of Late Wisconsinan/Holocene ice-sheet advance and retreat from Ross Sea. OPP 95-43494. $25,319 ($49,319) (4)

Andrews, John T. University of Colorado, Boulder, Colorado. Geological record of Late Wisconsin/Holocene ice-sheet advance and retreat from the Ross Sea. OPP 91-17958 $120,886 (3)

Askin, Rosemary A. Ohio State University, Columbus, Ohio. Quaternary paleoenvironmental evolution of the Larsen Basin, offshore Seymour Island, eastern Antarctic Peninsula. OPP 94-19316. $9,781 (3)

Askin, Rosemary A. Ohio State University, Columbus, Ohio. Permian and Triassic palynostratigraphy of the central Transantarctic Mountains. OPP 94-18093. $144,979 (4)

Barrera, Enriqueta. University of Michigan, Ann Arbor, Michigan. Quaternary paleoenvironmental evolution of the Larsen Basin, offshore Seymour Island, eastern Antarctic Peninsula. OPP 94-22282. $24,040 (3)

Barrera, Enriqueta. University of Michigan, Ann Arbor, Michigan. Quaternary paleoenvironmental evolution of the Larsen Basin, offshore Seymour Island, eastern Antarctic Peninsula. OPP 95-42666. $2,390 (4)

Bartek, Louis R. University of Alabama, Tuscaloosa, Alabama. Glacial marine stratigraphy in the eastern Ross Sea and western Marie Byrd Land, and shallow structure of the west antarctic rift. OPP 93-16710. $59,554 ($156,043) (4)

Bartek, Louis R. University of Alabama, Tuscaloosa, Alabama. Integrated biostratigraphy and high-resolution seismic stratigraphy of the Ross Sea: Implications for Cenozoic eustatic and climatic change. OPP 92-20848. $75,000 (4)

Behrendt, John C. U.S. Geological Survey, Reston, Virginia. Lithospheric controls on the behavior of the west antarctic ice sheet: Corridor Aerogeophysics of the Eastern Ross Transect Zone (CASERTZ). OPP 93-19877. $28,012 (1)

Behrendt, John C. U.S. Geological Survey, Reston, Virginia. Lithospheric controls on the behavior of the west antarctic ice sheet: Corridor Aerogeophysics of the Eastern Ross Transect Zone (CASERTZ/WAIS). OPP 95-43179. $43,524 (4)

Bell, Robin E. Columbia University, New York, New York. Lithospheric controls on the behavior of the west antarctic ice sheet: Corridor Aerogeophysics of the Eastern Ross Transect Zone (CASERTZ). OPP 93-19854. $123,196 (1)

Bell, Robin E. Columbia University, New York, New York. Lithospheric controls on the behavior of the west antarctic ice sheet: Corridor Aerogeophysics of the Eastern Ross Transect Zone (CASERTZ). OPP 93-19854. $132,554 ($286,644) (4)

Benoit, Paul H. University of Arkansas, Fayetteville, Arkansas. Natural thermoluminescence levels in antarctic meteorites and related studies. OPP 94-17851. $106,663 (3)

Bentley, Charles R. University of Wisconsin, Madison, Wisconsin. Seismic refraction/wide-angle reflection investigation of the Byrd Subglacial Basin—Field test. OPP 92-22092. $110,383 (4)

Blankenship, Donald D. University of Texas, Austin, Texas. Lithospheric controls on the behavior of the west antarctic ice sheet: Corridor Aerogeophysics of the Eastern Ross Transect Zone (CASERTZ). OPP 93-19369. $1,402 ($151,402) (1)

Blankenship, Donald D. University of Texas, Austin, Texas. Lithospheric controls on the behavior of the west antarctic ice sheet: Corridor Aerogeophysics of the Eastern Ross Transect Zone (CASERTZ). OPP 93-19369. $4,706 ($336,782) (4)

Blankenship, Donald D. University of Texas, Austin, Texas. Support Office for Aerogeophysical Research (SOAR). OPP 95-43530. $240,000 ($915,000) (4)

Boyce, Joseph. National Aeronautics and Space Administration, Washington, DC. Antarctic meteorite working group. OPP 94-43624. $42,719 (1)

Boyce, Joseph, National Aeronautics and Space Administration, Washington, DC. Antarctic meteorite working group. OPP 95-42696. $14,000 (4)

Cande, Steven C. University of California–San Diego, Scripps Institution of Oceanography, La Jolla, California. Late Cretaceous–Early Tertiary plate interactions in the southwest Pacific. OPP 93-17872. $63,081 (2)

Cande, Steven C. University of California–San Diego, Scripps Institution of Oceanography, La Jolla, California. Late Cretaceous–Early Tertiary plate interactions in the southwest Pacific. OPP 93-17872. $44,988 (2)

Cassidy, William A. Case Western Reserve, Cleveland, Ohio. Antarctic search for meteorites. OPP 91-17558. $91,819 ($183,710) (4)

Dalziel, Ian W. University of Texas, Austin, Texas. Seismic traverse of the Byrd Subglacial Basin—Field test. OPP 92-22121. $211,896 (3)

Dalziel, Ian W. University of Texas, Austin, Texas. Geologic studies in the Shackleton Range, Coats Land, and Queen Maud Land, East Antarctica: A North American connection. OPP 91-17996. $173,499 (3)

Dalziel, Ian W. University of Texas, Austin, Texas. The Bransfield Strait–South Shetland Islands/trench: Structural and stratigraphic evolution of a linked(?) back-arc/fore-arc system. OPP 94-18135. $59,276 (3)

DePaolo, Donald J. University of California, Berkeley, California. Metamorphism and intrusion chronology and tectonic evolution of the central and southern Transantarctic Mountains using samarium-neodymium isotopes. OPP 93-18838. $37,990 (2)

Domack, Eugene W. Hamilton College, Clinton, New York. Undergraduate research initiative: Antarctic marine geology and geophysics. OPP 94-18153. $72,594 (3)

Duebendorfer, Ernest M. Northern Arizona University, Flagstaff, Arizona. The Ellsworth Mountain terrane: Its origin and accretion to East Antarctica. OPP 93-12040. $38,281 (3)

Elliot, David H. Ohio State University, Columbus, Ohio. Jurassic volcanic rocks in the Transantarctic Mountains: Testing a model for continental flood basalt magmatism in Antarctica. OPP 94-20498. $85,413 (3)

Elliot, David H. Ohio State University, Columbus, Ohio. Paleogene strata, Seymour Island, Antarctic Peninsula. OPP 95-08089. $29,000 (3)

Faure, Gunter. Ohio State University, Columbus, Ohio. Age of the last transgression of the east antarctic ice sheet, Transantarctic Mountains, southern Victoria Land. OPP 93-16310. $19,340 ($38,690) (3)

Fitzgerald, Paul. University of Arizona, Tucson, Arizona. Thermochronologic constraints on the formation of the Transantarctic Mountains, Antarctica. OPP 93-16720. $116,669 ($214,823) (4)

Frey, Frederick A. Massachusetts Institution of Technology, Cambridge, Massachusetts. Origin and evolution of the Kerguelen plume: Constraints from studies of the Kerguelen Archipelago. OPP 94-17774. $47,420 (3)

Goodge, John W. Southern Methodist University, Dallas, Texas. Comparative petrologic, structural, and geochronometric investigation of high-grade metamorphic rocks in the Transantarctic Mountains. OPP 92-19818. $49,739 (4)

Grunow, Anne M. Ohio State University, Columbus, Ohio. Establishment of Gondwana Early Paleozoic reference poles and tests for terrane motion. OPP 93-17673. $130,753 (3)

Hallet, Bernard. University of Washington, Seattle, Washington. Patterned ground, McMurdo Dry Valleys, Antarctica: An evaluation of the scientific merit of more than 30-year-old study sites. OPP 95-22215. $41,228 (4)

Hammer, William R. Augustana College, Rock Island, Illinois. Continued research on the vertebrate paleontology of the Upper Fremouw (Early-Middle Triassic) and the Falla Formations (Jurassic), Beardmore Glacier region, Antarctica. OPP 93-15830. $57,416 (3)

Hammer, William R. Augustana College, Rock Island, Illinois. Vertebrate paleontology of the Triassic to Jurassic sedimentary sequence in the Shackleton Glacier regions, Antarctica. OPP 93-15826. $86,722 (3)

Hart, Stanley R. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. Antarctic rift and hot-spot volcanism. OPP 94-19094. $179,758 (3)

Harwood, David M. University of Nebraska, Lincoln, Nebraska. Diatom biostratigraphy and paleoenvironmental history of Cape Roberts project cores. OPP 94-20062. $1 ($17,914) (4)

Harwood, David M. University of Nebraska, Lincoln, Nebraska. Paleobiology and paleoenvironments of pre-glacial(?) Eocene coasts in southern Victoria Land, Antarctica. OPP 93-17901. $59,107 ($100,195) (4)

Hayes, Dennis E. Columbia University, New York, New York. Analysis of circumantarctic ocean basin paleobathymetry and structure. OPP 94-18936. $85,819 (3)

Isbell, John L. University of Wisconsin, Milwaukee, Wisconsin. Stratigraphic and sedimentologic analysis of Permian strata in the Shackleton Glacier area, Antarctica. OPP 94-19962. $139,619 (4)

Jarrard, Richard D. University of Utah, Salt Lake City, Utah. Downhole logging for the Cape Roberts project. OPP 94-18429. $12,125 ($112,033) (4)

Jasper, John P. University of Connecticut, Storrs, Connecticut. Maintenance of preindustrial atmospheric partial pressure of carbon dioxide (pCO_2) levels: Recalibration of a carbon isotopic paleobarometer and pCO_2 mapping of the late Quaternary global ocean. OPP 92-16918. $2,500 ($149,802) (1)

Kennett, James P. University of California, Santa Barbara, California. Cenzoic paleoceanographic and climate development of the antarctic region based on oceanic sediment sequences. OPP 92-18720. $52,663 ($102,663) (2)

Klinkhammer, Gary. Oregon State University, Corvallis, Oregon. A survey of hydrothermal vents in Bransfield Strait, Antarctica. OPP 95-42590. $15,000 (4)

Koger, Ronald G. Antarctic Support Associates, Englewood, Colorado. Logistics support of operations/research activities related to the U.S. program in Antarctica. OPP 95-42227. $26,368 ($30,098,868) (4)

Kyle, Philip R. New Mexico Institution of Mining and Technology, Socorro, New Mexico. Antarctic rift and hot-spot volcanism. OPP 94-19686. $110,242 (3)

Kyle, Philip R. New Mexico Institute of Mining and Technology, Socorro, New Mexico. Mount Erebus Volcano Observatory. OPP 94-19267. $80,093 ($156,482) (4)

Lagoe, Martin B. University of Texas, Austin, Texas. Quaternary paleoclimatic evolution of the Larsen Basin, offshore Seymour Island, eastern Antarctic Peninsula. OPP 94-19232. $55,335 (3)

Lawver, Lawrence A. University of Texas, Austin, Texas. Neotectonic evolution of Antarctic Peninsula/Scotia Sea region: Multibeam, sidescan sonar, seismic, magnetics, and gravity studies. OPP 95-43465. $21,888 ($31,464) (4)

Lerner-Lam, Arthur. Columbia University, New York, New York. Analysis of antarctic broadband PASSCAL seismic data for surface-wave dispersion. OPP 94-18114. $27,000 (4)

Leventer, Amy. University of Minnesota–Twin Cities, Minneapolis, Minnesota. Late Quaternary paleoclimatic history of southern Chile: Evidence from the marine record. OPP 91-18492. $69,100 ($102,807) (1)

Lubin, Philip M. University of California, Santa Barbara, California. Studies of long-duration medium-scale cosmic background radiation anisotropy. OPP 95-42728. $1,684 ($13,500) (3)

Luyendyk, Bruce P. University of California, Santa Barbara, California. Glacial marine stratigraphy in the eastern Ross Sea and western Marie Byrd Land, and shallow structure of the west antarctic rift. OPP 93-16712. $70,090 ($119,838) (4)

Marchant, David R. University of Maine, Orono, Maine. Tephrochronology applied to Late Cenozoic paleoclimate and geomorphic evolution of the central Transantarctic Mountains. OPP 94-18986. $48,242 (3)

Marsh, Bruce D. Johns Hopkins University, Baltimore, Maryland. Three-dimensional magma dynamics in large sills. OPP 94-18513. $109,961 (3)

Miller, Molly F. Vanderbilt University, Nashville, Tennessee. Permian and Triassic biogenic structures in the Shackleton Glacier area, Transantarctic Mountains: Record of nonmarine benthic communities and their response to climate change. OPP 94-17978. $104,579 (3)

Mukasa, Samuel B. University of Michigan, Ann Arbor, Michigan. A neodymium, osmium, lead, and strontium isotopic study of the Dufek Intrusion, Pensacola Mountains, Antarctica: Reassessment of differentiation mechanisms in layered mafic complexes. OPP 92-19012. $106,098 (2)

Mullen, Roy R. U.S. Geological Survey, Reston, Virginia. Antarctic surveying and mapping program. OPP 94-43652. $124,837 ($257,849) (1)

Plasker, James R. U.S. Geological Survey, Reston, Virginia. Antarctic surveying and mapping program. OPP 95-42588. $119,000 ($225,000) (4)

Pospichal, James J. Florida State University, Tallahassee, Florida. Calcareous nanofossil biostratigraphy and paleoenvironmental history of the Cape Roberts project cores. OPP 94-22893. $1 ($37,608) (4)

Rees, Margaret N. University of Nevada, Las Vegas, Nevada. The Ellsworth Mountains terrane: Its origin and accretion to East Antarctica. OPP 92-20395. $110,824 ($210,563) (4)

Retallack, Gregory J. University of Oregon, Eugene, Oregon. Triassic paleosols, paleoclimate, and vegetation of Antarctica. OPP 93-15228. $85,280 (4)

Rowell, Albert J. University of Kansas, Lawrence, Kansas. Antarctic Lithosphere Working Group 1994–1996. OPP 94-20086. $17,061 (1)

Rowell, Albert J. University of Kansas, Lawrence, Kansas. Antarctic Lithosphere Working Group 1994–1996. OPP 94-20086. $17,997 (4)

Scherer, Reed. University of Massachusetts, Amherst, Massachusetts. Diatom biostratigraphy and paleoenvironmental history of Cape Roberts project cores. OPP 94-22894. $1 ($25,592) (4)

Shimizu, Nobumichi. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. Origin and evolution of the Kerguelen plume: Constraints from studies of the Kerguelen Archipelago. OPP 94-17806. $32,580 (3)

Smithson, Scott B. University of Wyoming, Laramie, Wyoming. Seismic refraction wide-angle reflection investigation of the Byrd Subglacial Basin, Antarctica. OPP 92-22428. $51,135 (4)

Stock, Joann M. California Institute of Technology, Pasadena, California. Late Cretaceous–Early Tertiary Plate interactions in the southwest Pacific. OPP 93-17318. $44,632 (3)

Stravers, Jay A. Northern Illinois University, De Kalb, Illinois. Quaternary marine stratigraphy and sedimentology of Chilean fjords and continental shelf, western Patagonia. OPP 91-19194. $25,551 (3)

Taylor, Edith L. Ohio State University, Columbus, Ohio. The Shackleton Glacier area: Floristics, biostratigraphy, and paleoclimate. OPP 93-15353. $30,814 ($101,014) (3)

Taylor, Edith L. University of Kansas, Lawrence, Kansas. The Shackleton Glacier area: Floristics, biostratigraphy, and paleoclimate. OPP 93-15353. $70,200 ($242,995) (4)

Verosub, Kenneth L. University of California, Davis, California. Small grant for exploratory research—Paleomagnetic and mineral magnetic studies in anticipation of the Cape Roberts project. OPP 95-22309. $30,000 (3)

Von Frese, Ralph R. Ohio State University, Columbus, Ohio. Workshop proposal: Antarctic digital magnetic anomaly map (18–19 September 1995). OPP 95-27413. $7,500 (4)

Walker, Nicholas W. Brown University, Providence, Rhode Island. Testing the East Antarctica–Laurentian connection: Ages of detrital zircons from Late Proterozoic Metasediments, Transantarctic Mountains. OPP 94-18621. $28,223 (3)

Walker, Nicholas W. Brown University, Providence, Rhode Island. Comparative petrologic structural and geochronometric investigation of high-grade metamorphic rocks in the Transantarctic Mountains: Nimrod Group and Lanterman Range. OPP 92-19555. $72,173 (4)

Walker, Nicholas W. Brown University, Providence, Rhode Island. Testing the East Antarctica–Laurentian connection: Ages of detrital zircons from Late Proterozoic metasediments, Transantarctic Mountains. OPP 95-42383. $2,259 (4)

Wannamaker, Philip E. University of Utah, Salt Lake City, Utah. Seismic/magnetotelluric traverse of the Byrd Subglacial Basin—Field test. OPP 95-43584. $30,128 ($90,128) (4)

Watkins, David K. University of Nebraska, Lincoln, Nebraska. Calcareous nanofossil biostratigraphy and paleoenvironmental history of Cape Roberts project cores. OPP 94-19770. $1 ($3,387) (4)

Webb, Peter-Noel. Ohio State University, Columbus, Ohio. Workshop—Antarctic Stratigraphic Drilling—Cape Roberts Project. OPP 94-42181. $6,481 (1)

Webb, Peter-Noel. Ohio State University, Columbus, Ohio. Antarctic stratigraphic drilling: Cape Roberts project. OPP 93-17979. $33,571 ($68,805) (4)

Webb, Peter-Noel. Ohio State University, Columbus, Ohio. Cretaceous-Paleogene foraminifera of the Victoria Land Basin (Cape Roberts project). OPP 94-20475. $1 ($30,871) (4)

Webb, Peter-Noel. Ohio State University, Columbus, Ohio. Integrated biostratigraphy and high-resolution seismic stratigraphy of the Ross Sea: Implications for Cenozoic eustatic and climate change. OPP 95-43429. $2,530 (4)

Wilson, Terry J. Ohio State University, Columbus, Ohio. Group travel to Seventh International Symposium on Antarctic Earth Sciences, Siena, Italy. OPP 95-10737. $25,303 (3)

Wilson, Terry J. Ohio State University, Columbus, Ohio. Group travel to Seventh International Symposium on Antarctic Earth Sciences, Siena, Italy. OPP 95-43013. $6,797 (4)

Wilson, Terry J. Ohio State University, Columbus, Ohio. Regional structure of the Antarctic Peninsula derived from ERS-1 synthetic aperture radar mosaic: A study of upper/lower plate interactions during subduction of the Antarctic/Aluk Ridge crest. OPP 95-27550. $24,956 (4)

Wise, Sherwood W. Florida State University, Tallahassee, Florida. Curatorship of antarctic collections. OPP 95-42343. $84,564 (4)

Woodburne, Michael O. University of California, Riverside, California. The geology and paleontology of one Sobral Formation, Seymour Island, Antarctic Peninsula. OPP 93-15831. $77,632 (4)

Zinsmeister, William J. Purdue University, West Lafayette, Indiana. High-resolution biostratigraphic analysis of molluscan fauna across the Cretaceous–Tertiary boundary on Seymour Island, Antarctica. OPP 94-17776. $47,000 (4)

Ocean and climate studies

Ackley, Stephen F. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. Sea-ice measurements during the Anzone Winter Flux Experiment. OPP 95-41672. $77,686 (3)

Andreas, Edgar L. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. Analysis of the atmospheric boundary layer data collected on Ice Station Weddell. OPP 95-41769. $83,620 (4)

Anthes, Richard. University Center for Atmospheric Research (UCAR), Boulder, Colorado. Cooperative agreement: Support of UCAR. OPP 95-43748. $30,182 ($336,933) (4)

Anthes, Richard. University Center for Atmospheric Research (UCAR), Boulder, Colorado. UCAR educational outreach and related activities. OPP 95-42378. $40,000 ($427,184) (4)

Asper, Vernon L. University of Southern Mississippi, Hattiesburg, Mississippi. Collaborative research on bloom dynamics and food web structure in the Ross Sea: Vertical flux of carbon and nitrogen. OPP 93-17598. $83,444 ($173,413) (4)

Bromwich, David H. Ohio State University, Columbus, Ohio. An evaluation of numerical weather prediction in high southern latitudes with first regional observing study of the troposphere (FROST). OPP 94-22104. $37,772 ($75,544) (3)

Bromwich, David H. Ohio State University, Columbus, Ohio. A study of the katabatic wind confluence zone near Siple Coast, West Antarctica. OPP 94-17983. $180,339 (4)

Bromwich, David H. Ohio State University, Columbus, Ohio. Research on ocean–atmosphere variability and ecosystem response in the Ross Sea (ROAVERRS). OPP 94-20681. $64,382 ($134,097) (4)

Carleton, Andrew M. Pennsylvania State University, University Park, University Park, Pennsylvania. Structure and evolution of southern ocean mesocyclones using multiple satellite systems. OPP 92-19446. $42,537 (3)

Carroll, John J. University of California, Davis, California. Model simulations of antarctic katabatic flows. OPP 94-20641. $149,320 (4)

Dunbar, Robert B. Rice University, Houston, Texas. Research on ocean–atmosphere variability and ecosystem response in the Ross Sea (ROAVERRS). OPP 94-19605. $82,501 ($152,203) (4)

Foster, Theodore D. University of California, Santa Cruz, California. Deep water formation off the eastern Wilkes Land coast of Antarctica. OPP 93-17379. $0 ($108,000) (3)

Foster, Theodore D. University of Delaware, Newark, Delaware. Deep water formation off the eastern Wilkes Land coast of Antarctica. OPP 93-17379. $108,000 ($203,000) (4)

Gordon, Arnold L. Columbia University, New York, New York. Ice Station Weddell–1: Physical oceanography data analysis phase. OPP 93-13700. $263,154 (2)

Guest, Peter S. Naval Postgraduate School, Monterey, California. Atmospheric forcing during the ANZONE Winter Flux Experiment (ANZFLUX). OPP 95-42436. $60,092 (4)

Hall, Michael J. National Oceanic and Atmospheric Administration, Washington, DC. Support for Argos data collection and location system. OPP 95-43519. $65,779 ($479,174) (4)

Hansell, Dennis A. Bermuda Biological Station Research, Saint Georges West, Bermuda. Bloom dynamics and food-web structure in the Ross Sea: Dynamics of dissolved organic carbon. OPP 93-17200. $120,057 (3)

Jacobs, Stanley S. Columbia University, New York, New York. Oceanography of the Amundsen and Bellingshausen Seas. OPP 94-18151. $296,807 (3)

Jacobs, Stanley S. Columbia University, New York, New York. Oceanography of the Amundsen and Bellingshausen Seas. OPP 95-42954. $62,464 (4)

Jeffries, Martin O. University of Alaska, Fairbanks, Alaska. The role of snow in antarctic sea-ice development and ocean–atmosphere energy exchange. OPP 93-16767. $201,250 (1)

Jeffries, Martin O. University of Alaska, Fairbanks, Alaska. The role of snow in antarctic sea-ice development and ocean–atmosphere energy exchange. OPP 93-16767. $169,291 (3)

Jeffries, Martin O. University of Alaska, Fairbanks, Alaska. The role of snow in antarctic sea-ice development and ocean–atmosphere energy exchange. OPP 95-42419. $10,000 (4)

Katsaros, Kristina B. University of Washington, Seattle, Washington. Structure and evolution of southern ocean mesocyclones using multiple satellite systems. OPP 92-18810. $60,800 (3)

Ledley, Tamara S. Rice University, Houston, Texas. A study of the sea-ice regimes of the Ross Sea and McMurdo Sound. OPP 93-16633. $100,000 (2)

Lubin, Dan. University of California at San Diego, Scripps Institution of Oceanography, La Jolla, California. The Arctic and Antarctic Research Center: A unique resource for polar science and operations. OPP 94-14276. $20,000 ($192,000) (3)

Martinson, Douglas G. Columbia University, New York, New York. Ice Station Weddell turbulence and mixed-layer data analysis and modeling. OPP 93-16449. $71,691 (3)

Martinson, Douglas G. Columbia University, New York, New York. Modeling deep and bottom water formation along the continental margin of the western Weddell Sea, based on Ice Station Weddell data. OPP 92-20407. $88,250 (3)

Martinson, Douglas G. Columbia University, New York, New York. ANZFLUX (Antarctic Zone Flux Experiment) conductivity-temperature-depth/tracer program. OPP 93-17231. $300,000 ($600,000) (4)

Maslanik, James A. University of Colorado, Boulder, Colorado. Enhancement of sea-ice processes in the Genesis GCM. OPP 94-23506. $12,853 ($64,064) (4)

McPhee, Miles G. McPhee Research, Naches, Washington, Upper ocean turbulent fluxes and mixing in the Weddell Sea. OPP 93-15920. $50,400 (3)

Morison, James H. University of Washington, Seattle, Washington. Ice Station Weddell turbulence and mixed-layer data analysis and modeling. OPP 94-10849. $53,426 (4)

Muench, Robin D. Science Applications International Corporation, San Diego, California. Acoustic Doppler Current Profile and mesoscale current observations in the eastern Weddell Sea: A component of ANZFLUX. OPP 93-15019. $81,574 ($84,753) (2)

Nelson, David M. Oregon State University, Corvallis, Oregon. Bloom dynamics and food-web structure in the Ross Sea: The irradiance/mixing regime and diatom growth in spring. OPP 93-17538. $151,084 ($290,095) (4)

Padman, Laurence. Oregon State University, Corvallis, Oregon. Heat, salt, and momentum fluxes through the pycnocline in the eastern Weddell Sea. OPP 93-17321. $106,764 (3)

Padman, Laurence. Oregon State University, Corvallis, Oregon. Upper-ocean temperature and microstructure in the western Weddell Sea. OPP 93-17319. $99,613 (3)

Schlosser, Peter. Columbia University, New York, New York. Construction of an inlet system for automated tritium measurements by helium isotope mass spectrometry. OCE 94-02110. $34,000 ($113,935) (2)

Shen, Hayley H. Clarkson University, Potsdam, New York. Wave and pancake-ice interactions. OPP 92-19165 $69,580 ($90,000) (2)

Shen, Hayley H. Clarkson University, Potsdam, New York. Wave and pancake-ice interactions. OPP 95-41524. $30,000 (4)

Smethie, William M. Columbia University, New York, New York. Investigation of deep and bottom water formation in the western Weddell Sea from measurement of chlorofluorocarbons on samples collected during the ANZONE project. OPP 93-17166. $74,000 (4)

Stamnes, Knut. University of Alaska, Fairbanks, Alaska. Experimental investigations of the winter cloud/radiation environment of the southern ocean marginal ice zone: A pilot study. OPP 95-23260. $19,392 (4)

Stamnes, Knut. University of Alaska, Fairbanks, Alaska. Nitrite column abundance measurements and trace gas chemistry regulating arctic stratospheric ozone abundance. OPP 93-02348. $3,697 ($87,261) (4)

Stanton, Timothy P. Naval Postgraduate School, Monterey, California. Mixed-layer turbulence measurements during the ANZONE Winter Flux Experiment (ANZFLUX). OPP 95-42492. $75,000 (4)

Stearns, Charles R. University of Wisconsin, Madison, Wisconsin. Antarctic Meteorological Research Center. OPP 92-08864. $56,785 ($421,442) (4)

Stearns, Charles R. University of Wisconsin, Madison, Wisconsin. Continuation for the antarctic automatic weather station climate program 1995–1998. OPP 94-19128. $81,442 ($865,444) (4)

Aeronomy and astrophysics

Anthes, Richard. University Center for Atmospheric Research, Boulder, Colorado.

Cooperative agreement: Support of the National Center for Atmospheric Research. ATM 94-43536. $78,140 ($1,438,369) (1)

Arnoldy, Roger L. University of New Hampshire, Durham, New Hampshire. Continuation support of high-latitude geomagnetic pulsation measurements. OPP 92-17024. $62,140 ($162,140) (3)

Baker, Kile B. Johns Hopkins University, Baltimore, Maryland. Southern Hemisphere Auroral Radar Experiment (SHARE). OPP 92-21343. $21,900 (2)

Baker, Kile B. Johns Hopkins University, Baltimore, Maryland. Multiradar studies of the dynamics of the antarctic ionosphere. OPP 94-21266. $30,000 ($228,300) (4)

Bering, Edgar A. University of Houston, Houston, Texas. Balloonborne studies of the ionosphere and magnetosphere above South Pole. OPP 93-18569. $60,000 (1)

Bieber, John W. Bartol Research Institute, Newark, Delaware. Solar and heliospheric studies with antarctic cosmic-ray observations. OPP 92-19761. $228,348 (2)

Clauer, C. Robert. University of Michigan, Ann Arbor, Michigan. A study of very-high-latitude geomagnetic phenomena. OPP 93-18766. $160,000 (2)

Deshler, Terry L. University of Wyoming, Laramie, Wyoming. Vertical profiles of polar stratospheric clouds, condensation nuclei, ozone, nitric acid, and water vapor in the antarctic winter and spring stratosphere. OPP 93-16774. $383,840 (2)

Engebretson, Mark J. Augsburg College, Minneapolis, Minnesota. Induction antennas for British Antarctic Survey automatic geophysical observatories. OPP 93-16750. $53,888 (2)

Erlandson, Robert E. Johns Hopkins University, Baltimore, Maryland. Comparison of simultaneous ground-satellite observations of electromagnetic ion cyclotron waves. OPP 92-24511. $10,000 ($123,500) (2)

Forbes, Jeffrey M. University of Colorado, Boulder, Colorado. Planetary waves in the antarctic mesopause region. OPP 93-20879. $45,452 (2)

Fritts, David C. University of Colorado, Boulder, Colorado. Correlative midfrequency radar studies of large-scale middle atmospheric dynamics in the Antarctic. OPP 93-19068. $147,179 (2)

Gaisser, Thomas K. Bartol Research Institute, Newark, Delaware. South Pole Air Shower Experiment–2. OPP 93-18754. $186,780 ($534,456) (1)

Gaisser, Thomas K. Bartol Research Institute, Newark, Delaware. South Pole Air Shower Experiment–2. OPP 95-42703. $11,400 (3)

Harper, Doyal A. University of Chicago, Chicago, Illinois. A Center for Astrophysical Research in Antarctica (CARA). OPP 94-43446. $2,850 ($7,305) (1)

Harper, Doyal A. University of Chicago, Chicago, Illinois. A Center for Astrophysical Research in Antarctica (CARA). OPP 95-43163. $1 ($5,325) (4)

Helliwell, Robert A. Stanford University, Stanford, California. Active and passive very-low-frequency wave–particle interaction experiments from Siple Station, Antarctica: Mechanism and diagnostic application. OPP 92-21395. $25,131 ($125,131) (2)

Hernandez, Gonzalo J. University of Washington, Seattle, Washington. High-latitude antarctic neutral mesospheric and thermospheric dynamics and thermodynamics. OPP 93-16163. $130,000 (1)

Hernandez, Gonzalo J. University of Washington, Seattle, Washington. High-latitude antarctic neutral mesospheric and thermospheric dynamics and thermodynamics. OPP 93-16163. $130,000 (2)

Inan, Umran S. Stanford University, Stanford, California. Very-low-frequency remote sensing of thunderstorm and radiation belt coupling to the ionosphere. OPP 93-18596. $90,000 (2)

Jefferies, Stuart M. Bartol Research Institute, Newark, Delaware. Probing the solar interior and atmosphere from the geographic South Pole. OPP 92-19515. $236,475 (3)

LaBelle, James W. Dartmouth College, Hanover, New Hampshire. Low-frequency/midfrequency/high-frequency radio observations from a Southern Hemisphere auroral zone site. OPP 93-17621. $45,013 (2)

LaBelle, James W. Dartmouth College, Hanover, New Hampshire. Low-frequency/midfrequency/high-frequency radio observations from a Southern Hemisphere auroral zone site. OPP 95-42727. $4,423 (3)

LaBelle, James W. Dartmouth College, Hanover, New Hampshire. Presidential Young Investigator Award. OPP 95-41114. $31,247 (3)

Lubin, Philip M. University of California, Santa Barbara, California. Studies of long-duration medium-scale cosmic background radiation anisotropy. OPP 95-42728. $11,816 ($13,500) (3)

Meyer, Stephan S. University of Chicago, Chicago, Illinois. Anisotropy of the cosmic microwave background radiation on large and medium angular scales. OPP 93-16535. $56,480 ($249,783) (3)

Morse, Robert M. University of Wisconsin, Madison, Wisconsin. The AMANDA project: The antarctic ice sheet as a high-energy particle detector. OPP 92-15531. $500,000 (1)

Morse, Robert M. University of Wisconsin, Madison, Wisconsin. The AMANDA project: The antarctic ice sheet as a high-energy particle detector. OPP 94-44205. $172,000 (1)

Morse, Robert M. University of Wisconsin, Madison, Wisconsin. Observation of very-high-energy gamma-ray sources from the South Pole (GASP). OPP 92-21768. $50,234 (3)

Morse, Robert M. University of Wisconsin, Madison, Wisconsin. The antarctic muon and neutrino detector array (AMANDA) project: The antarctic ice sheet as a high-energy particle detector. OPP 95-43219. $100,000 ($106,450) (4)

Murcray, Frank J. University of Denver, Denver, Colorado. Infrared measurements in the Antarctic. OPP 92-19209. $44,028 ($79,028) (2)

Papen, George C. University of Illinois–Urbana-Champaign, Urbana, Illinois. Rayleigh and sodium lidar studies of the troposphere, stratosphere, and mesosphere at the Amundsen–Scott South Pole Station. OPP 92-19898. $130,000 (2)

Petit, Noel J. Augsburg College, Minneapolis, Minnesota. Automatic geophysical observatories (AGO) data support and distribution. OPP 92-19799. $26,500 (2)

Rosenberg, Theodore J. University of Maryland, College Park, Maryland. Polar Experiment Network for Geophysical Upper-atmosphere Investigations (PENGUIN). OPP 89-18689. $459,700 (3)

Rosenberg, Theodore J. University of Maryland, College Park, Maryland. Riometry in Antarctica and conjugate regions. OPP 95-05823. $30,926 ($662,705) (4)

Rust, David M. Johns Hopkins University, Baltimore, Maryland. An optical investigation of the genesis of solar activity. OPP 91-19807. $100,000 ($237,900) (2)

Seward, Fred. American Physical Society, College Park, Maryland. Travel support for the 24th International Cosmic Ray Conference, Rome, Italy, 28 August to 8 September 1995. OPP 95-06430. $2,500 ($17,540) (4)

Sivjee, Gulamabas. Embry-Riddle Aeronautical University, Daytona Beach, Florida. Spectroscopic and interferometric studies of airglow and auroral processes in the antarctic upper atmosphere over Amundsen–Scott South Pole Station. OPP 92-18557. $104,003 (2)

Wilkes, R.J. University of Washington, Seattle, Washington. Antarctic long-duration balloon flight for the JACEE collaboration. OPP 92-20316. $151,900 (3)

Glaciology

Allen, Christopher T. University of Kansas, Lawrence, Kansas. Feasibility study for mapping the glacial ice bottom topography using interferometric synthetic aperture radar techniques. OPP 95-23454. $19,303 ($43,110) (4)

Alley, Richard B. Pennsylvania State University, University Park University Park, Pennsylvania. Continuation of antarctic ice-sheet stability on a deforming bed: Model studies. OPP 93-18677. $75,443 (2)

Alley, Richard B. Pennsylvania State University, University Park, Pennsylvania. Physical studies of west antarctic shallow ice cores. OPP 94-17848. $125,000 (3)

Alley, Richard B. Pennsylvania State University, University Park, Pennsylvania. Presidential

Young Investigator Award. OPP 90-58193. $15,000 ($37,500) (4)

Anandakrishnan, Sridhar. Pennsylvania State University, University Park, Pennsylvania. Microearthquake monitoring of ice stream C, West Antarctica: A sensor for sticky spots. OPP 93-18121. $102,716 (3)

Baker, Ian. Dartmouth College, Hanover, New Hampshire. *In situ* synchrotron x-ray topographic studies of polycrystalline ice. OPP 92-18336. $87,500 (3)

Bender, Michael L. University of Rhode Island, Kingston, Rhode Island. Studies of trapped gases in firn and ice from antarctic deep ice cores. OPP 91-17969. $147,368 (3)

Bentley, Charles R. University of Wisconsin, Madison, Wisconsin. Airborne radar sounding over ice stream D, West Antarctica. OPP 93-19043. $151,222 ($263,971) (4)

Bindschadler, Robert A. National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland. West antarctic glaciology—IV. OPP 95-41734. $197,000 (3)

Blankenship, Donald D. University of Texas, Austin, Texas. Lithospheric controls on the behavior of the west antarctic ice sheet: Corridor Aerogeophysics of the Eastern Ross Transect Zone (CASERTZ). OPP 93-19369. $150,000. ($151,402) (1)

Blankenship, Donald D. University of Texas, Austin, Texas. Lithospheric controls on the behavior of the west antarctic ice sheet: Corridor Aerogeophysics of the Eastern Ross Transect Zone (CASERTZ). OPP 93-19369. $155,000 ($336,782) (4)

Blankenship, Donald D. University of Texas, Austin, Texas. Support Office for Aerogeophysical Research (SOAR). OPP 95-43530. $15,000 ($915,000) (4)

Braaten, David A. University of Kansas, Lawrence, Kansas. Measurements and model development of antarctic snow accumulation and transport dynamics. OPP 94-17255. $99,017 (3)

Conway, Howard. University of Washington, Seattle, Washington. Origin and properties of subfreezing basal ice. OPP 94-18381. $177,681 (3)

Denton, George H. University of Maine, Orono, Maine. Landscape analysis applied to Pliocene ice-sheet sensitivity and Transantarctic Mountains evolution. OPP 93-18515. $146,970 (4)

Fahnestock, Mark. University of Maryland, College Park, Maryland. New applications of advanced very-high-resolution radiometer technology to the study of small-scale ice-sheet surface morphology: A window on regional ice dynamics. OPP 94-19223. $47,101 (3)

Faure, Gunter. Ohio State University, Columbus, Ohio. Age of the last transgression of the east antarctic ice sheet, Transantarctic Mountains, southern Victoria Land. OPP 93-16310. $19,350 ($38,690) (3)

Friedmann, E. Imre. Florida State University, Tallahassee, Florida. Living and fossil microorganisms, a sensitive paleoclimate indicator in the McMurdo Dry Valleys. Implications for Plio-Pleistocene climate and ice sheet. OPP 94-20227. $57,973 ($117,949) (4)

Hamilton, Gordon S. Ohio State University, Columbus, Ohio. Ice-sheet mass balance using global positioning system measurements. OPP 94-19396. $217,433 (4)

Harwood, David M. University of Nebraska, Lincoln, Nebraska. Presidential Young Investigator Award. OPP 91-58075. $62,500 (4)

Jacobel, Robert W. Saint Olaf College, Northfield, Minnesota. Siple Dome glaciology and ice stream history. OPP 93-16338. $34,998 (2)

Kamb, Barclay. California Institute of Technology, Pasadena, California. Fast flow of antarctic ice streams—Bed deformation or basal sliding? Borehole study of ice streams B and C. OPP 93-19018. $250,975 ($932,869) (4)

Kurz, Mark D. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. Chronology of antarctic glaciations. OPP 94-18333. $105,798 (3)

Kyle, Philip R. New Mexico Institute of Mining and Technology, Socorro, New Mexico. Volcanic record in antarctic ice. OPP 93-16505. $85,122 (4)

Lal, Devendra. University of California, San Diego, California. Nuclear studies of accumulating and ablation ice using cosmogenic carbon-14. OPP 92-19931. $67,977 (2)

Lea, David W. University of California, Santa Barbara, California. Antarctic ice-core records of oceanic emissions: Sulfur, selenium, bromine, and iodine. OPP 92-23951. $12,000 (3)

Mahaffy, Mary-Anne W. Pennsylvania State University, University Park, Pennsylvania. Sensitivity study of processes pertaining to the ice dynamics of the west antarctic ice sheet using a three-dimensional time-dependent whole-ice-sheet model. OPP 94-18622. $59,745 (3)

Mayewski, Paul A. University of New Hampshire, Durham, New Hampshire. Ross ice drainage system (RIDS) Late Holocene climate variability. OPP 93-16564. $158,231 (3)

Meier, Mark F. University of Colorado, Boulder, Colorado. National Ice Core Curatorial Facility. OPP 95-41701. $54,470 ($142,184) (3)

Mosley-Thompson, Ellen. Ohio State University, Columbus, Ohio. Holocene/Late Wisconsinan dust history from Taylor (McMurdo) Dome, Antarctica. OPP 93-16282. $49,594 (3)

Mosley-Thompson, Ellen. Ohio State University, Columbus, Ohio. Long-term trend in net mass accumulation at South Pole. OPP 91-17447. $29,484 (3)

Plasker, James R. U.S. Geological Survey, Reston, Virginia. Antarctic surveying and mapping program. OPP 95-42588. $6,000 ($225,000) (4)

Powell, Ross D. Northern Illinois University, De Kalb, Illinois. Evaluation of processes at polar glacier grounding-lines to constrain glaciological and oceanographic models. OPP 92-19048. $35,332 ($42,791) (3)

Powell, Ross D. Northern Illinois University, De Kalb, Illinois. Evaluation of processes at polar glacier grounding lines to constrain glaciological and oceanographic models. OPP 92-19048. $7,459 ($42,791) (3)

Raymond, Charles F. University of Washington, Seattle, Washington. Siple Dome glaciology and ice-stream history. OPP 93-16807. $88,182 (3)

Saltzman, Eric S. University of Miami, Rosentiel School of Marine and Atmospheric Sciences, Miami, Florida. Antarctic ice-core records of oceanic emissions: Sulfur, bromine, iodine, and selenium. OPP 92-22178. $127,636 (3)

Scambos, Theodore A. University of Colorado, Boulder, Colorado. Siple Dome glaciology and ice stream history. OPP 93-17007. $16,283 (2)

Scambos, Theodore A. University of Colorado, Boulder, Colorado. New applications of advanced very-high-resolution radiometer technology to the study of small-scale ice-sheet surface morphology: A window on regional ice dynamics. OPP 94-18723. $185,870 (3)

Sivjee, Gulamabas G. Embry-Riddle Aeronautical University, Daytona Beach, Florida. Spectroscopic and interferometric studies of airglow and auroral processes in the antarctic upper atmosphere over Amundsen–Scott South Pole Station. OPP 95-42892. $13,600 (4)

Stuiver, Minze. University of Washington, Seattle, Washington. Cosmogenic beryllium-10 and chlorine-36 in a new antarctic ice core. OPP 93-16162. $70,039 (2)

Stuiver, Minze. University of Washington, Seattle, Washington. Cosmogenic beryllium-10 and chlorine-36 in a new antarctic ice core. OPP 93-16162. $52,368 (2)

Taylor, Susan. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. Retrieval and analysis of extraterrestrial particles from the water well at Amundsen–Scott South Pole Station, Antarctica. OPP 95-41975. $70,706 (4)

Thonnard, Norbert. University of Tennessee, Knoxville, Tennessee. Development of laser-based resonance ionization spectroscopy techniques for krypton-81 and krypton-85 measurements in the geosciences. OPP 94-10695. $20,000 ($241,292) (4)

Waddington, Edwin D. University of Washington, Seattle, Washington. Analysis of existing geophysical data from Taylor (McMurdo) Dome for ice core interpretation and relation to the dry valleys geomorphological climate record. OPP 94-21644. $76,047 (3)

Waddington, Edwin D. University of Washington, Seattle, Washington. Reconstruction of paleotemperatures from precision borehole temperature logging: A Transantarctic Mountains transect from Taylor (McMurdo) Dome to the Ross Sea. OPP 92-21261. $97,069. (3)

Webb, Peter-Noel. Ohio State University, Columbus, Ohio. Sirius Group in the Shackleton Glacier region of the Queen Maud Mountains. OPP 94-19056. $86,360 (4)

Whillans, Ian M. Ohio State University, Columbus, Ohio. Mass balance and ice-stream mechanics in West Antarctica. OPP 93-16509. $137,724 (3)

White, James W. University of Colorado, Boulder, Colorado. Stable isotope measurements on shallow cores from West Antarctica. OPP 94-18642. $50,000 (3)

Wilson, Gary S. Ohio State University, Columbus, Ohio. The use of fossil microorganisms for the study of ancient climates in the McMurdo Dry Valleys. OPP 94-20260. $75,871 (4)

Support and services

Andrews, Martha. University of Colorado, Boulder, Colorado. A user-based polar information system: Coordinating responsibilities through the U.S. Polar Information Working Group. OPP 93-21320. $10,956 ($21,912) (2)

Blankenship, Donald D. University of Texas, Austin, Texas. Support Office for Aerogeophysical Research (SOAR). OPP 95-43530. $660,000 ($915,000) (4)

Brown, Otis B. University of Miami, Rosentiel School of Marine and Atmospheric Sciences, Miami, Florida. Satellite communications for scientific purposes: University National Oceanographic Laboratory System fleet management and polar program support. OPP 91-13074. $125,000 ($140,000) (4)

Comberiate, Michael A. National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland. Real-time ozone imaging at McMurdo Station. OPP 95-05762. $30,000 (3)

Crockett, Alan B. Idaho National Engineering Laboratory, Idaho Falls, Idaho. Environmental measurements support for the U.S. Antarctic Program. OPP 95-41507. $161,000 (3)

Ferrell, William M. Department of Defense, Washington, DC. Logistic support of the U.S. program in Antarctica. OPP 94-44341. $2,015,960 ($2,203,660) (1)

Fowler, Alfred N. American Geophysical Union, Washington, DC. Council of Managers of National Antarctic Programs Secretariat. OPP 93-21509. $63,854 (2)

Fraser, William R. Montana State University, Bozeman, Montana. Changes in Adélie penguin populations at Palmer Station: The effects of human disturbance and long-term environmental change. OPP 95-05596. $54,136 ($210,047) (4)

Gordon, R. Lee. RD Instruments, San Diego, California. Ocean ambient sound instrument system (OASIS). DMI 93-22786. $275,610 (1)

Hall, Michael J. National Oceanic and Atmospheric Admininstration, Washington, DC. Support for Argos data collection and location system. OPP 95-43519. $61,840 ($479,174) (4)

Hibben, Stuart G. Library of Congress, Washington, DC. Abstracting and indexing service for *Current Antarctic Literature*. OPP 94-43355. $194,958 (1)

Hibben, Stuart G. Library of Congress, Washington, DC. Abstracting and indexing service for *Current Antarctic Literature*. OPP 95-42448. $266,047 (4)

Humphrey, Kimberly M. U.S. Air Force Systems Command, Dayton, Ohio. Acquisition of government furnished equipment (GFE) for NSF's new LC-130H3. OPP 94-19764. $1,500,000 (1)

Kamb, Barclay. California Institute of Technology, Pasadena, California. Fast flow of antarctic ice streams—Bed deformation or basal sliding? Borehole study of ice streams B and C. OPP 93-19018. $205,091 ($932,869) (4)

Koger, Ronald G. Antarctic Support Associates, Englewood, Colorado. Logistics support of operations and research activities related to the U.S. program in Antarctica. OPP 94-44339. $13,956,371 ($13,997,335) (1)

Koger, Ronald G. Antarctic Support Associates, Englewood, Colorado. Logistics support of operations/research activities related to the United States Program in Antarctica. OPP 95-42227. $30,000,000 ($30,098,868) (4)

Kuivinen, Karl C. University of Nebraska, Lincoln, Nebraska. Logistic and engineering support for the Polar Ice Coring Office. OPP 95-41768. $1,375,000 ($2,244,236) (4)

Lubin, Dan. University of California at San Diego, Scripps Institution of Oceanography, La Jolla, California. The Arctic and Antarctic Research Center: A unique resource for polar science and operations. OPP 94-14276. $172,000 ($192,000) (3)

Mullen, Roy R. U.S. Geological Survey, Reston, Virginia. Antarctic surveying and mapping program. OPP 94-43652. $123,012 ($257,849) (1)

Naveen, Ron. Oceanites, Inc., Cooksville, Maryland. Antarctic site inventory and monitoring program. OPP 94-07212. $76,595 ($105,215) (1)

Naveen, Ron. Oceanites, Inc., Cooksville, Maryland. Antarctic site inventory and monitoring program. OPP 94-07212. $108,500 (4)

Nelson, Marilyn. Blue Pencil Group, Inc., Reston, Virginia. Editorial services for the *Antarctic Journal of the United States*. OPP 95-42549. $44,693 (4)

Oliver, John S. San Jose State University, San Jose, California. Hydrographic survey and geographic information system database development for anthropogenic debris and marine habitats at McMurdo Station, Antarctica. OPP 94-03833. $116,727 (1)

Oliver, John S. San Jose State University, San Jose, California. Hydrographic survey and global information system database development for anthropogenic debris and marine habitats at McMurdo Station, Antarctica. OPP 95-42825. $36,982 ($48,082) (4)

Onuma, Tsuyoshi. Navy Facilities and Engineering Command, Arlington, Virginia. Engineering support for antarctic program. OPP 94-43844. $55,000 (1)

Petty, Jimmie D. U.S. Department of the Interior, Columbia, Missouri. Application of semipermeable membrane devices (SPMDs) as passive monitors of the environment of Antarctica. OPP 94-43169. $87,200 (1)

Petty, Jimmie D. U.S. Department of the Interior, Columbia, Missouri. Application of semipermeable membrane devices (SPMDs) as passive monitors of the environment of Antarctica. OPP 95-41987. $80,900 (4)

Plasker, James R. U.S. Geological Survey, Reston, Virginia. Antarctic surveying and mapping program. OPP 95-42588. $100,000 ($225,000) (4)

Proenza, Luis M. University of Alaska, Fairbanks, Alaska. Preliminary fifth year program plan budget: Polar Ice Coring Office. OPP 94-42766. $886,512 ($2,723,422) (1)

Proteau, Paul R. Capital Systems Group, Inc., Rockville, Maryland. A proposal to provide services to store, publicize, and fulfill requests for NSF-owned visual materials regarding polar subjects. OPP 94-41350. $67 (1)

Reed, Robert M. Oak Ridge National Laboratory, Oak Ridge, Tennessee. Technical support for the U.S. Antarctic Program environmental review. OPP 94-43570. $40,000 (1)

Rounds, Fred. National Aeronautics and Space Administration, Washington, DC. Internet telecommunications support for the U.S. Antarctic Program. OPP 95-28497. $562,000 (4)

Rummel, John D. National Aeronautics and Space Administration. Washington, DC. National Science Foundation/National Aeronautics and Space Administration technology demonstration. OPP 94-43921. $1,053,750 (1)

Setlow, Loren W. National Academy of Sciences, Washington, DC. Support of the Polar Research Board. OPP 95-06731. $79,291 ($158,582) (3)

Shah, Raj N. Capital Systems Group, Inc., Rockville, Maryland. Proposal processing and travel support to Office of Polar Programs, National Science Foundation. OPP 92-00919. $221,439 (1)

Shah, Raj N. Capital Systems Group, Inc., Rockville, Maryland. Proposal processing and travel support to Office of Polar Programs, National Science Foundation. OPP 95-41194. $41,319 (3)

Shah, Raj N. Capital Systems Group, Inc., Rockville, Maryland. Proposal processing and travel support to the Office of Polar Programs, National Science Foundation. OPP 95-41040. $174,902 (4)

Smith, Charles H. Department of Defense, Washington, DC. Logistic support of the U.S. Program in Antarctica. OPP 95-43375. $12,600,000 ($12,626,262) (4)

Smith, Kenneth L. University of California at San Diego, Scripps Institution of Oceanography, La Jolla, California. Seasonal ice cover and its impact on the epipelagic community in the northwestern Weddell Sea: Long time-series monitoring. OPP 95-42643. $100,000 ($126,065) (4)

Smith, Raymond C. University of California, Santa Barbara, California. Ozone diminution, ultraviolet radiation, and phytoplankton biology in antarctic waters. OPP 94-44084. $6,187 (1)

Spilhaus, A.F. American Geophysical Union, Washington, DC. Publication of *Antarctic Research Series*. OPP 94-14962. $66,258 (1)

Spilhaus, A.F. American Geophysical Union, Washington, DC. Publication of *Antarctic Research Series*. OPP 94-14962. $66,258 ($132,516) (4)

Stearns, Charles R. University of Wisconsin, Madison, Wisconsin. Antarctic Meteorological Research Center. OPP 92-08864. $113,569 ($170,354) (4)

Stearns, Charles R. University of Wisconsin, Madison, Wisconsin. Continuation for the antarctic automatic weather station climate program 1995–1998. OPP 94-19128. $340,000 ($421,442) (4)

Sutherland, Woody C. University of California at San Diego, Scripps Institution of Oceanography, La Jolla, California. Shipboard technicians support. OCE 94-00707. $14,400 ($891,847) (2)

Terra, Joseph A. Department of Health and Human Services, Washington, DC. Industrial and environmental hygiene services. OPP 94-18764. $150,000 (1)

Tumeo, Mark A. University of Alaska, Fairbanks, Alaska. Examination of *in situ* oil spill remediation at McMurdo Station. OPP 94-03677. $131,720 (1)

Tumeo, Mark A. University of Alaska, Fairbanks, Alaska. Examination of *in situ* oil spill remediation at McMurdo Station. OPP 95-41974. $8,000 (3)

Walker, Alan. Department of Transportation, U.S. Coast Guard, Washington, DC. Icebreaker support in the U.S. Antarctic Program. OPP 94-44171. $2,287,460 (1)

Walker, Alan. Department of Transportation, U.S. Coast Guard, Washington, DC. Icebreaker support in the U.S. Antarctic Program. OPP 95-40197. $3,013,405 (1)

Errata

June 1994 issue

The photo article appearing on pages 14 and 15 of volume 29, number 2, inaccurately stated that the cross erected by the surviving members of Robert F. Scott's ill-fated expedition atop Observation Hill in memory of their fallen comrades had remained in place for 80 years. In fact, fierce winds during July and August 1974 had brought down the cross, which was reinstalled in its original foundation in September 1974 by Scott Base personnel. We thank *AJUS* reader and former member of the Naval Support Force Antarctica RMC Billy-Ace Baker, USN (Ret.) for pointing out this inaccuracy.

September 1994 issue

In the ***Marine and terrestrial geology and geophysics*** project summary section, Carol Finn of the U.S. Geological Survey should also have been listed as a co-principal investigator for **Lithospheric controls on the behavior of the west antarctic ice sheet: Corridor Aerogeophysics of the Eastern Ross Transect Zone (CASERTZ/WAIS)** project (S-098).

1994 annual review issue

- The following is a corrected caption and credit line for the main cover photograph on the 1994 review issue of the *Antarctic Journal* (volume 29, number 5). The caption and credit for the inset photograph remain the same.

  Cover photographs**:* In the Transantarctic Mountains, deep crevasses form circular patterns in a glacier. This image and the flat, barren vistas of the polar plateau are ones most commonly associated with Antarctica. In sharp contrast is the idea of Antarctica and high-tech scientific research, but as the ***Inset photo illustrates, advanced technology is improving and expanding the research possibilities even at the geographic South Pole… *(Main photo by Cornelius Sullivan, Director, Office of Polar Programs, NSF…)*

- Kenneth Mopper, Department of Chemistry, Washington State University, Pullman, Washington 99164, co-authored with David J. Kieber the article "Photochemistry of antarctic waters during the 1993 austral spring" (pp. 100–102). His name was inadvertently omitted in the printed version of volume 29, issue 5

Weather at U.S. stations, November 1994 through January 1995

Feature	November 1994			December 1994			January 1995		
	McMurdo	Palmer*	South Pole*	McMurdo*	Palmer	South Pole*	McMurdo	Palmer	South Pole
Average temperature (°C)	–8.8				1.8		–3.0	3.5	–32.0
Temperature maximum (°C)	–2.1				9.0		3.5	9.0	–24.3
(date)	(4)				(5)		(9)	(3)	(10)
Temperature minimum (°C)	–16.1				–4.3		–9.8	–1.0	–39.7
(date)	(26)				(16)		(26)	(13)	(24)
Average station pressure (mb)	986.49				986.3		982.5	988.8	683.0
Pressure maximum (mb)	1000.5				1000.2		993.9	1005.9	690.5
(date)	(18)				(1)		(31)	(9)	(31)
Pressure minimum (mb)	972.1				969.9		975.0	972.8	676.5
(date)	(2)				(29)		(11)	(13)	(12)
Snowfall (mm)	83.8				118.0		68.6	27.0	Trace
Prevailing wind direction	180°				W, NE		120°	N	90°
Average wind (m/sec)	5.2				4.5		3.6	5.4	3.2
Peak wind (m/sec)	28.3				30.9		17.4	26.8	93.0
(date, direction)	(3, 200°)				(17, 10°)		(26, 180°)	(24, 10°)	(18, N)
Average sky cover	6.3				9.8		8.1	9.4	5
Number of clear days	6				0		8	0	12
Number of partly cloudy days	11				0		7	1	9
Number of cloudy days	13				31		16	30	10
Number of days with visibility less than 0.4 km	1				—*		0	—*	0

*Data unavailable.

Prepared from information from the stations. Locations: McMurdo 77°51'S 166°40'E, Palmer 64°46'S 64°3'W, Amundsen–Scott South Pole 90°S. Elevations: McMurdo sea level, Palmer sea level, Amundsen–Scott South Pole 2,835 meters. For prior data and daily logs, contact the National Climate Center, Asheville, North Carolina 28801.

Weather at U.S. stations, February 1995 through April 1995

Feature	February 1995			March 1995			April 1995		
	McMurdo	Palmer	South Pole	McMurdo*	Palmer*	South Pole	McMurdo*	Palmer*	South Pole
Average temperature (°C)	–8.6	2.4	–40.8			–52.9			–58.0
Temperature maximum (°C)	3.7	6.5	–28.0			–40.3			–44.1
(date)	(2)	(11)	(8)			(24)			(28)
Temperature minimum (°C)	–18.3	–2.6	–54.3			–66.8			–74.8
(date)	(15)	(20)	(17)			(30)			(23)
Average station pressure (mb)	983.4	990.3	683.6			683.1			677.3
Pressure maximum (mb)	996.4	1018.8	693.1			691.2			692.1
(date)	(1)	(18)	(20)			(19)			(2)
Pressure minimum (mb)	967.7	960.4	674.4			671.1			656.7
(date)	(22)	(7)	(14)			(28)			(20)
Snowfall (mm)	147.3	25.0	Trace			Trace			Trace
Prevailing wind direction	120°	N, SW	20°			10°			10°
Average wind (m/sec)	5.1	5.1	5.4			6.2			6.5
Peak wind (m/sec)	23.7	30.9	13.4			14.4			15.4
(date, direction)	(22, 250°)	(28, 40°)	(23, NW)			(13, N)			(28, N)
Average sky cover	7.2	9.9	7			5			4
Number of clear days	3	0	6			12			14
Number of partly cloudy days	12	0	7			12			12
Number of cloudy days	13	28	15			7			4
Number of days with visibility less than 0.4 km	0.3	—*	6			15			16

*Data unavailable.

Prepared from information from the stations. Locations: McMurdo 77°51'S 166°40'E, Palmer 64°46'S 64°3'W, Amundsen–Scott South Pole 90°S. Elevations: McMurdo sea level, Palmer sea level, Amundsen–Scott South Pole 2,835 meters. For prior data and daily logs, contact the National Climate Center, Asheville, North Carolina 28801.

Weather at U.S. stations, May 1995 through July 1995

Feature	May 1995			June 1995			July 1995		
	McMurdo*	Palmer*	South Pole*	McMurdo*	Palmer*	South Pole	McMurdo*	Palmer	South Pole*
Average temperature (°C)						–58.5		–8.5	
Temperature maximum (°C) (date)						–39.4 (6)		–1.4 (30)	
Temperature minimum (°C) (date)						–72.4 (18)		–19.0 (17)	
Average station pressure (mb)						682.3		988.15	
Pressure maximum (mb) (date)						698.7 (29)		1010.1 (27)	
Pressure minimum (mb) (date)						667.2 (4)		962.1 (18)	
Snowfall (mm)						Trace		640	
Prevailing wind direction						90°		E	
Average wind (m/sec)						5.4		4.9	
Peak wind (m/sec) (date, direction)						13.4 (10, N)		28.3 (24, 80°)	
Average sky cover						3		8.9	
Number of clear days						20		—*	
Number of partly cloudy days						6		—*	
Number of cloudy days						4		—*	
Number of days with visibility less than 0.4 km						7		—*	

*Data unavailable.

Prepared from information from the stations. Locations: McMurdo 77°51'S 166°40'E, Palmer 64°46'S 64°3'W, Amundsen–Scott South Pole 90°S. Elevations: McMurdo sea level, Palmer sea level, Amundsen–Scott South Pole 2,835 meters. For prior data and daily logs, contact the National Climate Center, Asheville, North Carolina 28801.

Weather at U.S. stations, August 1995 through October 1995

Feature	August 1995			September 1995			October 1995		
	McMurdo*	Palmer	South Pole*	McMurdo*	Palmer	South Pole*	McMurdo*	Palmer	South Pole*
Average temperature (°C)		–12.4			–8.2			–2.7	
Temperature maximum (°C) (date)		0 (18)			2.0 (29)			5.0 (10)	
Temperature minimum (°C) (date)		–26.0 (24)			–22.0 (6)			–14.2 (27)	
Average station pressure (mb)		992.9			984.6			989.4	
Pressure maximum (mb) (date)		1018.5 (10)			1008.3 (21)			1010.1 (27)	
Pressure minimum (mb) (date)		962.9 (31)			947.1 (4)			963.0 (19)	
Snowfall (mm)		470			910			140	
Prevailing wind direction		N			N			N	
Average wind (m/sec)		5.0			6.8			5.7	
Peak wind (m/sec) (date, direction)		31.4 (16, N)			38.1 (1, N)			35.5 (2, N)	
Average sky cover		8.0			8.0			7.5	
Number of clear days		—*			—*			—*	
Number of partly cloudy days		—*			—*			—*	
Number of cloudy days		—*			—*			—*	
Number of days with visibility less than 0.4 km		—*			—*			—*	

*Data unavailable.

Prepared from information from the stations. Locations: McMurdo 77°51'S 166°40'E, Palmer 64°46'S 64°3'W, Amundsen–Scott South Pole 90°S. Elevations: McMurdo sea level, Palmer sea level, Amundsen–Scott South Pole 2,835 meters. For prior data and daily logs, contact the National Climate Center, Asheville, North Carolina 28801.

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