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Historic flight triples transport capacity of opening flights to McMurdo Station

The effective use of airplanes to transport personnel, supplies, and equipment between Antarctica and the continental United States and in Antarctica has enabled the U.S. government to build a large, diverse science program in one of the world's most isolated regions. Since November 1966, wheeled C-141 Starlifter jets from the Military Airlift Command (MAC) have improved the delivery of supplies, cargo, and personnel to McMurdo Station from Christchurch, New Zealand, during the early austral summer. This austral summer, air operations in Antarctica took an historic step forward when the first MAC C-5B Galaxy airplane successfully landed on the sea-ice runway near McMurdo Station.

The C-5B airplane, assigned to Travis Air Force Base in California, arrived at McMurdo Station's sea-ice runway on 4 October 1989 after a 2,400-mile trip from Christchurch. Onboard the airplane were 72 U.S. Antarctic Program (USAP) personnel, two fully-assembled UH-1N helicopters, and additional cargo—a load of about 168,000 pounds. Earlier, in September, the airplane had made a single trip of more than 12,000 miles with passengers, cargo, and four helicopters from Point Mugu Naval Air Station in California to Christchurch. A second flight from Christchurch on 6 October carried a 157,000-pound load—bringing 73 people, the two remaining helicopters and additional cargo.

A wheeled airplane like the C-141 Starlifter, the C-5B Galaxy is the largest airplane operated by the United States. The airplane is 248 feet long (76 meters long) and 65 feet high (20 meters high) with a wingspan of 223 feet (68 meters). It can carry a maximum load of 261,000 pounds (118,000 kilograms).

In October the C-5B carried nearly triple the average amount that is carried by a C-141 (a load of approximately 55,000 pounds) from Christchurch. This combined with airplane's ability to carry fully-assembled helicopters helped the United States to begin the 1989–1990 austral summer research program earlier. To be transported to Antarctica by other air-

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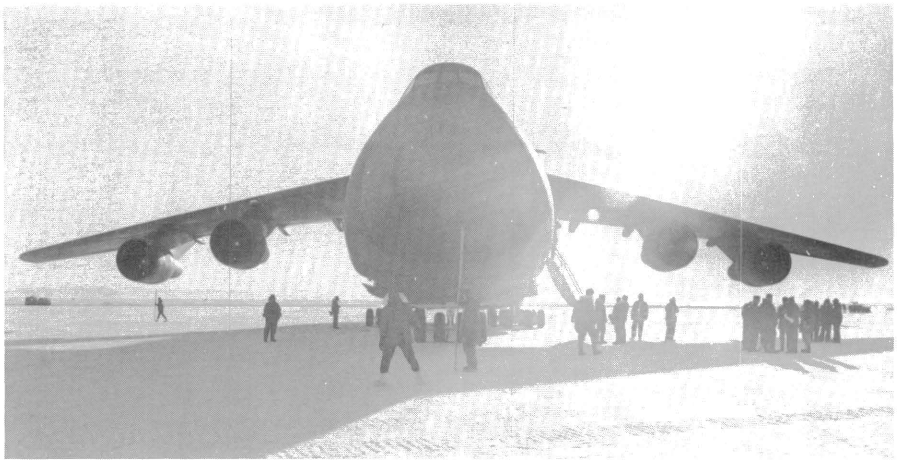
An historic touchdown—The first C-5B Galaxy to fly to Antarctica in support of the U.S. Antarctic Program landed on the sea-ice runway near McMurdo Station on 4 October 1989, after a 2,400-mile flight from New Zealand.

U.S. Navy photo by Dan Simon.

planes, the U.S. Navy UH-1N helicopters, which support researchers near McMurdo Station and at times at remote field camps, must be dissassembled. Once at McMurdo Station, the helicopters are reassembled and flight tested—a process that takes several weeks.

Because it has wheels, like the C-141 Starlifter airplanes, C-5B must land on the sea ice where a hard, smooth runway surface can be prepared. This runway is used between early October and mid-December. After mid-December, increasingly warmer weather weakens the sea ice, and the runway can no longer be used. Air operations then switch entirely to the six USAP ski-equipped transports (LC-130), flown by U.S. Navy crews of the Antarctic Development Squadron 6 (VXE-6). Because of their skis, these four-engine, turboprop airplanes can use Williams Field, a skiway prepared on the snow surface of the Ross Ice Shelf. The smaller LC-130s also are capable of landing anywhere in Antarc-



This C-5B Galaxy carried four fully assembled UH-1N helicopters to McMurdo Station from the United States. The helicopters were brought two at a time along with passengers and cargo. Because the helicopters did not have to be disassembled, U.S. Navy helicopter crews from the Antarctic Development Squadron Six were able to begin austral summer operations several weeks earlier than usual. The National Science Foundation, which funds and manages the U.S. Antarctic Program, hopes to continue to use these airplanes to improve operations in Antarctica.

U.S. Navy photos by Dan Simon.

The nose of the C-5B is raised (first photograph) so that personnel can begin to remove cargo from the airplane. A C-5B can carry up to 261,000 pounds and in October brought approximately 155,000 pounds of cargo to McMurdo Station from Christchurch, New Zealand. This payload is nearly triple what a C-141 airplane usually carry to Antarctica on each flight. The C-5B, which is the largest airplane operated by the United States, is 248 feet long and 65 feet high with a wingspan of 223 feet.

United States of America Antarctic Program

Editor: Winifred Reuning

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tica and are used by the program to supply inland stations and transport researchers to remote areas of Antarctica.

Previously, in February 1989, a MAC C-5 was used by the antarctic program to help U.S. personnel contain a fuel spill near Palmer Station, the U.S. research station on Anvers Island near the Antarctic Peninsula. The airplane brought 52 tons of equipment, supplies, and fuel-spill containment experts to Punta Arenas, Chile, where they met the USAP research ship *Polar Duke* for transport to Palmer Station. The rapid deployment of expert personnel and the necessary equipment was critical in reducing the detrimental effects of fuel on the local marine environment.

The October missions to McMurdo Station resulted from 2 years of planning between managers from the National Science Foundation (manager of USAP) and senior officers of the Military Airlift Command Headquarters. These flights, together with the 1988 introduction of MAC C-130 flights to a Chilean airstrip in Antarctic Peninsula region, illustrate the high level of cooperation between U.S. Federal agencies—both civilian and military—to further U.S. policy objective in Antarctica.

The National Science Foundation hopes to continue to use the C-5B airplanes to support U.S. research efforts in Antarctica. Among the potential uses are transporting medical emergency supplies and teams—such as field hospitals—to remote sites and supporting scientists in the field by delivering assembled helicopters or the program's hovercraft to remote sites. Presently, the Foundation is studying the feasiblity of building hard-surface or "blue-ice" runways at various interior sites in Antarctica. Because the C-5s could use such landing areas, they could speed up the transport of vital supplies and personnel to inland stations. In particular, they may be able to transport to the geographic South Pole large loads of the construction materials and personnel that will be necessary to rebuild Amundsen-Scott South Pole Station, the U.S. station there.

NSF photo by Russ Kinne.

One aspect of the existing safety program for U.S. personnel in Antarctica is "survival school." All science and support personnel who will be working at remote sites or inland stations are required to take the class each year.

Antarctic Services Associates named new support contractor

The National Science Foundation (NSF) announced on 3 October 1989 that the $250-million contract for operational support to the U.S. Antarctic Program was awarded to Antarctic Services Associates. The company, a joint venture composed of EG&G of Wellesley, Massachusetts, and Holmes and Narver Services of Orange, California, will take over support services on 1 April 1990.

Antarctic Services Associates (ASA) replaces ITT/Antarctic Services, Inc. (ITT/ANS), a subsidiary of ITT's Federal Electric Company. ITT/ANS, which is based in Paramus, New Jersey, has provided support services to the U.S. Antarctic Program since April 1980 and will continue to support the program through 1989–1990 austral summer field season.

Under the terms of this contract, ASA will directly support NSF-sponsored research projects in Antarctica and will operate and maintain facilities, vehicles, and other equipment at the three U.S. antarctic research stations (McMurdo, Amundsen-Scott South Pole, and Palmer) and at remote field camps. Among the activities for which the contractor is responsible are seasonal construction work at U.S. stations, operation and maintenance of the ice-strengthened research ship *Polar Duke*, and other specialized support to USAP research projects. They also will manage warehousing and staging facilities in California, New Zealand, and South America.

Both EG&G, Inc. and Holmes and Narver Services previously have worked in the Antarctic and have considerable experience in arctic operations. From early 1968 to the end of the 1979–1980 austral summer field season, Holmes and Narver provided support to the NSF-managed antarctic research program. EG&G operated the research ship *Hero*, the predecessor to *Polar Duke*, under contract to NSF during the early 1970s.

The support contract extends over a 6-year base period after which ASA will be eligible for two 2-year additional terms. Headquarters for the new company will be in Denver, Colorado.

Congress sends budget for USAP health, safety, and environment initiative to President

The 1990 National Science Foundation (NSF) budget initiative designed to support more comprehensive approach in the areas of health, safety, and environment in Antarctica moved one step closer to realization on 1 November when Congress sent the bill to the President. The budget initiative is aimed at improving health care and safety for U.S. scientists and support personnel in Antarctica as well as minimizing the environmental impact of U.S. operations there.

The $180-million, 5-year program was included in the NSF annual budget request and is part of the Veterans Administration, Housing and Urban Development, and Independent Agencies Appropriations Act that was cleared by Congress on 31 October. For the first year of the initiative, NSF has asked for $10 million for environmental activities.

Under the new initiative NSF will focus on waste disposal, environmental monitoring, communications, and emergency facilities. Over 5 years, NSF hopes to improve medical facilities and provide researchers working in remote areas with safety experts who have medical training, begin year-round operations with modern technology and minimum risk, clean up debris from past operations, and bring present operations into agreement with current environmental regulations, prevailing attitudes, new technology. Although $10 million has been set aside for environmental-related work during fiscal 1990, another $30 million for this effort has been included in the request. The actual work supported by the initiative will begin during the 1990–1991 austral summer, if President Bush approves the request.

Slides and photographs of Antarctica available

Over the last 10 years, the Division of Polar Programs has acquired more than 18,000 slides and black-and-white photographs of Antarctica and U.S. activities there. Until recently this material was maintained within the division; however, in 1987 DPP established a contract with the Capital Systems Group, Inc., of Rockville, Maryland, for curatorial and dissemination services for the collection. These services include organizing and cataloging the collection and providing photographic materials to requestors.

The slides and photographs were taken by U.S. Navy photomates, professional photographers hired by NSF, and scientists and other participants in the U.S. program. They describe research at U.S. and foreign stations and remote field camps, station life, support activities, vehicles, airplanes, and ships. There also are scenic photographs of the region, as well as many pictures of native antarctic flora and fauna.

Copies of the slides and photographs are available for loan to or purchase by book publishers, magazines, newspapers, scientists, professors, government officals, students, teachers, and other interested parties. User fees are listed in the chart that follows.

To obtain materials, contact Susan Shapiro between 9 a.m. and 3 p.m., Monday through Friday at the Capital Systems Group, Inc., 1401 Rockville Pike, Suite 200, Rockville, Maryland 20852 (telephone, 301/251-2730; fax, 301/251-2740). Requestors should identify their request by asking for the "Antarctic photo collection." It also is possible to view the collection at the Capital Systems office, but an appointment is required.

User fees

Color slides	*B&W photos*	*Color photos*
$15 up to three slides and $3 for each additional slide	8 × 10 $15 each	8 × 10 $20 each

Experts gather to discuss long-term environmental monitoring

Scientists studying Antarctica have learned that environmental factors—such as the extreme cold and dryness, large dynamic sea-ice ecosystems, and extended periods of light and dark—combine with the continent's physical isolation to create an unique natural laboratory. Here, they can study the processes and species that are special to Antarctica and probe the continent's relationship with global environmental processes.

To study these phenomena, scientists and support personnel have travelled to Antarctica for more than 30 years. The results of their research have extended scientific understanding of such phenomena as ozone depletion in the atmosphere above Antarctica, the types of marine ecosystems of the waters surrounding the continent, the geologic evolution of the Southern Hemisphere, and the role of this region in global processes. Now, however, scientists and managers of national antarctic programs are asking

- What effect has our presence had on this unique region?
- In environments that are relatively unperturbed by humans, what constitutes a significant impact?
- How do we choose the correct environmental parameters to study or determine what approaches and methods are best to minimize the environmental, health, and safety-related risks of living and working in Antarctica?

Despite the volume of data that is available, the information is not sufficient to accurately predict the effects of human activities on the terrestrial and marine ecosystems. Recognizing the need to improve environmental planning and management, the National Science Foundation (NSF), as manager of the U.S. national research program in Antarctica, brought together in September 1989 scientists knowledgeable about the antarctic environment and environmental experts to assist with environmental management plans. The table accompanying this article provides a list of participants and their affiliations.

NSF will use the advice provided by this group to develop a set of guidelines for antarctic environmental measurements and assessments. These guidelines are part of the proposed initiative that responds to recommendations resulting from two special NSF studies—*Safety in Antarctica: Report of the U.S. Antarctic Program Safety Review Panel* (July 1988) and *The Role of the National Science Foundation in the polar regions: A report to the National Science Board* (June 1987). When completed, the guidelines will be distributed to the other Antarctic Treaty Consultative Parties as part of the regular exchange of information. (The 1990 budget request for NSF's safety, health, and environment initiative is described in the June 1989 issue of the *Antarctic Journal of the United States*, Volume 23, number 2, on pages 1–2. An update on the status of this request appears on page 4 of this issue.)

Workshop objectives

To develop an effective environmental management plan, a clear definition of "environmental monitoring" is needed. The parameters of specific ecosystems must be identified and the current state of each ecosystem evaluated, before changes can be recognized and, if necessary, acted upon. At the opening of the meeting, workshop-organizer Sidney Draggan, Division of Polar Program's Environmental Officer, reminded the group of the precedent set by the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). This convention is based on the assumption that it is not possible to monitor everything. Consequently, the scientists and managers who developed the monitoring programs for CCAMLR focused on the "elements" of and species in antarctic marine ecosystems where change is most likely to be perceived.

Dr. Draggan proposed that workshop participants take a similar approach as they assessed existing methods of measuring environmental parameters and reviewed what is known environmentally about the Antarctic and its regions. With this information, they then could begin developing reliable means of identifying recognized and expected impacts of human activities and selecting geographic areas and environmental parameters most likely to be sensitive to changes, especially those affected in detectable ways by human activities. He noted that only after establishing such parameters would it be possible to design and conduct long-term measurement programs, to verify predicted impacts, and to detect unforeseen effects of human activity. In addition, reliable decisions aids for interpreting the results of these measurements and predictions must be developed, and the data must be accessible.

The specific goals of the workshop were to

- formulate hypotheses from experience or predictive models that can be used to determine how human activities may affect antarctic atmospheric, terrestrial, aquatic, or marine environmental components (biotic and abiotic);
- determine the best types of long-term, scientifically based studies needed to examine these hypotheses and to detect expected and unexpected impacts of human activity on Antarctica and the global environment;
- describe the approaches and mechanisms that most likely will provide a better understanding of antarctic environmental protection, conservation, and management;
- identify what financial and human resources and what types of special equipment, logistic support, planning and coordination, and data management are required to implement environmental monitoring program;
- prepare a concise set of monitoring guidelines that can be justified scientifically.

To assist participants in considering these problems, each participant was asked to prepare a brief discussion paper, which focused on his or her area of expertise. Opening remarks by Lee Kimball provide a national and international policy context for the broader discussion of environmental monitoring and protection in Antarctica, they are included in this issue of the *Antarctic Journal* on pages 7–11.

The discussion papers focused on topics ranging from the record of environmental change contained in ice and marine sediment cores to established methods of environmental monitoring used in the United States. Throughout these discussions, speakers emphasized that all of the elements of an ecosystem—the flora and fauna as well as the interactions among these components and between them and the environment—need to be studied and understood before an effective monitoring program can be designed. From the policy point of view, participants stressed that national and international policies need to be taken into account as plans evolve. Additionally, because of the scope of this project, they foresaw making use of the experience and resources of other Federal agencies.

Examples of long-term monitoring programs and data management systems used in the United States also were discussed. Of interest to the group was that the Foundation's Long-Term Ecological Research (LTER) program now uses the Geographic Information System (GIS). Such a combination of a long-term monitoring program (LTER) with an environmental management system

The changing face of "downtown" McMurdo—Although additional funds have been requested under a special safety, health, and environmental initiative, NSF has already begun refurbishing and cleaning up McMurdo Station. This 1988 photo shows in the center background the steel structure of the new science laboratory, which replaces two outdated buildings and will provide scientists with up-to-date technical facilities.

U.S. Navy photo by Dirk Meehan.

NSF photo.

How has the operation of remote camps, aircraft, and stations to support scientists affected the environment of Antarctica? What can national antarctic programs do to minimize the effects of working and living in Antarctica? These are among the questions now being considered by managers of the U.S. Antarctic Program, as well as by managers of other national antarctic programs. They also were the focus of a recent workshop on environmental monitoring hosted by the National Science Foundation's Division of Polar Programs.

that makes use of maps, remote sensing data, and aerial photography could help NSF better track its operations in Antarctica. The group agreed it would be wise to explore how useful this system would be for antarctic environmental assessment and management.

Early in the workshop discussions participants decided to focus on environmental problems and monitoring issues that directly affect the U.S. Antarctic Research Program, rather than consider how to develop a monitoring strategy for all of Antarctica or for specific geographic regions. Keeping in mind that these considerations are only one part of the antarctic environmental monitoring issue, the group looked at how operating and maintaining antarctic stations and conducting research already have affected the environment.

They felt an important issue to be the definition of "pollution." John Oliver, Moss Landing Marine Laboratories, emphasized that "pollution" should be described as a "loss of an amenity or a significant biological change." Agreeing with this statement, participants felt that before designing a monitoring system for U.S. stations managers needed to define more clearly what type of waste materials may be entering the environment from U.S. stations and how waste materials were handled in the early years of the research program.

The group outlined the following specific problems that USAP managers need to consider:

- monitoring and disposal of domestic waste water effluents from McMurdo and Palmer stations;
- surveillance of waste pits at Amundsen-Scott South Pole Station;
- monitoring of leachate and gaseous effluents from the McMurdo Station's burn area (to be used to determine the feasibility and workability of installing incinerators);
- monitoring of contaminants leached from McMurdo Station's old dump and old snow dump (overlooking Winter Quarters Bay);
- monitoring of the water column and sediments in Winter Quarters Bay during ship operations
- monitoring for the effects of ship and air operations;
- monitoring for the effects of field camp operations;
- using sediment and ice cores to establish historical records near stations;
- continued monitoring of the environment near Palmer Station for effects resulting from fuel spilled by *Bahia Paraiso* in early 1989.

Although participants agreed that scientists working in Antarctica could contribute information acquired as part of their own basic research projects, they felt that funding for environmental monitoring should be kept separate from funding for basic research. They also stressed that for any protocols developed or contractors hired to conduct monitoring programs should undergo peer review.

Conclusion

The 2-day meeting concluded with a special briefing to environmental groups. Erich Bloch, Director of the National Science Foundation, chaired the briefing and answered questions about the agency's plans for environmental management in Antarctica.

During the briefing, Mr. Bloch provided environmentalists and other attendees with an update on the special safety, health, and environment initiative, while NSF members described the ongoing review of the agency's compliance with U.S. environmental regulations, monitoring activities in Antarctica, and the results of the environmental workshop. In addition to NSF staff, three members of the workshop group also participated.

USAP workshop on antarctic environmental monitoring
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The policy framework for environmental monitoring in Antarctica

During this workshop, we will focus on identifying methods of detecting, verifying, and ultimately predicting the impacts—both expected and unforeseen—of human activities on antarctic terrestrial, atmospheric, aquatic, and marine environments. We will discuss not only how our activities affect the environment but also how they affect ongoing and future research in Antarctica.

Our objective is to begin preparing a concise set of guiding principles that are scientifically justifiable and that will guide efforts to monitor changes in the antarctic environment. The process of developing these guidelines requires that we investigate what will be needed in terms of financial and human resources, special equipment, logistic support, coordination, and data management. We also must endeavor to see this effort in terms of the national and international political arena.

We can approach the issue of environmental monitoring in Antarctica from two perspectives. First, the monitoring of environmental parameters can help to detect, verify, and eventually predict how activities such as field research and the logistics activities in support of those research projects directly affect the environment. This approach also can be extended to the effects of tourism, the harvesting of marine living resources and, over the long term, possibly mineral-resource and related activities. Second, by monitoring and learning about changes in the environment of Antarctica, scientists will be able to establish baseline data against which to measure environmental changes that may be occurring globally and to distinguish between those changes caused by natural processes and those brought about by human activities.

During this workshop, we will discuss environmental monitoring as it relates directly to the U.S. Antarctic Program (USAP); however, to ensure that any monitoring programs developed for USAP are structured to mesh with those conducted by other national programs in Antarctica, we must consider how to define environmental monitoring in broad terms. Because adequate and targeted scientific data, along with related information, is needed for all antarctic decision-making purposes, including those concerning conservation, the monitoring programs of those countries working in the Antarctic should be designed to be complementary and cost-effective. To facilitate this, the Antarctic Treaty Consultative Parties, as well as antarctic operators, should consider adopting shared methodologies when ever possible. This approach should apply to not only monitoring programs but also data management efforts.

Clearly, no matter what approach is taken, it encompasses the existing national and international regulations and policies. In 1964, the Antarctic Treaty Consultative Parties declared Antarctica a "Special Conservation Area" through the "Agreed Measures for the Conservation of Antarctic Fauna and Flora" (Recommendation III-8). Since that time a number of Antarctic Treaty System (ATS) decisions and recommendations have addressed the need for environmental protection in Antarctica. During the 1980s, heightened public attention, the expanding scale of national research programs, the increased number of participants in these programs, and the growing number of tourists, along with the potential for resource activities, have caused the treaty parties to upgrade and amplify existing conservation measures.

Although the specifics of the Antarctic Treaty System policy developments are summarized in the appendix to this paper, I will present here the general flavor of the increasing concern with environmental measures. This may be the best way to indicate where we are today and what is pending on the environmental agenda for the XV Antarctic Treaty Consultative Meeting (ATCM).* From there we can work backwards and attempt to fill in some of the detail.

The Antarctic Treaty System—Opportunities for a comprehensive approach to environmental monitoring

In a major departure from previous treaty meetings, representatives have included on the agenda for the fifteenth meeting two items that specifically address a comprehensive look at antarctic environmental issues. These items offer the treaty nations the opportunity to

- integrate environmental planning and management, as well as monitor the human impact to antarctic environment, with respect to all activities governed by the Treaty (science, logistics, tourism, etc.) and
- further the integration of antarctic research into broader international programs to understand and monitor global change.

A third agenda item will explore how to promote international scientific cooperation. Representatives will discuss whether and how to identify research and monitoring programs that will make a vital contribution to antarctic research and will consider the possibility of exchanging information on planned national programs earlier to facilitate better coordination. A fourth agenda item will concentrate on research stations. Through this topic, representatives will be able to focus their discussions on opportunities for contributing to scientific knowledge and observations that can only result from locating stations in the widest possible range of sites around the continent.

At the October treaty meeting, various treaty-related and international organizations will address the representatives of the Antarctic Treaty Consultative Parties. The Commission for the Convention for Conservation of Antarctic Marine Living Resources (CCAMLR) and representatives from the Scientific Committee on Antarctic Research are expected to present reports on their activities that are relevant to these agenda items. These presentations will, no doubt, highlight CCAMLR's ecosystem monitoring program and various SCAR initiatives relevant to conservation. The International Union for the Conservation of Nature (IUCN) will present a report and recommendations on an "Antarctic Conservation Strategy." Additional presentations are expected from international organizations involved in global research and monitoring programs. These groups include the International Oceanographic Commission (IOC), the World Meteorological Organization (WMO), and the Intergovernmental Panel on Climate Change (IPCC).

By inviting a wide range of organizations to attend the treaty meeting, the Antarctic Treaty Consultative Parties have significantly changed the treaty meeting. These invited observers can contribute by broadening the debate on how to provide for and implement antarctic conservation. They will have the opportunity to stress the need for baseline data and a coordinated, integrated monitoring program and to propose and discuss monitoring protocols. The input of these observers also may be useful to treaty nations as they decide whether work toward revising standards and requirements of to take immediate action to avoid significant adverse environmental impacts.

Some of the specific environmental monitoring issues that the treaty parties will consider are

- implentation of environmental impact assessment (EIA) and consideration of the concentration of stations to avoid adverse environmental impacts
- waste disposal systems and methods. (See box entitled "Scientific Committee on Antarctic Research Waste Disposal Report, 1989.")
- marine pollution.
- the system of protected areas. (This discussion will include the development of management plans to facilitate research and monitoring in designated areas, including control sites to be studied because they are unaffected by human impacts, the system to review data about protected areas, and the integration of areas protected under the treaty.)
- comparability and accessibility of antarctic scientific data.
- the effects of tourism.
- the development of environmental checklists to be used during treaty inspections.

Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). To implement CCAMLR's unique "ecosystem" conservation standard, treaty parties had to determine the most cost-effective way to amplify the limited scientific knowledge about southern ocean species and ecosystemic interactions among these species. The CCAMLR Ecosystem Monitoring Program (CEMP) is the first to comprehensively approach monitoring in Antarctica to distinguish neutral changes in marine ecosystems from those brought about by commercial fishing. CCAMLR also has instituted a program to monitor plastic debris and discarded fishing gear and to relate these to mortality of southern-ocean species. These efforts and related data management programs should be meshed with the design of any additional environmental monitoring programs.

Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA). Significant environmental monitoring programs will be required to provide the data and information necessary to judge whether a mineral resource activity is acceptable under this convention. Any efforts that we might make today would be particularly useful insofar as they would help to define the types and quality of information necessary to apply the standards set forth in Article IV of CRAMRA.** They also would help to distinguish particularly the types of *independent* information and analyses (as opposed to those supplied by applicants to conduct minerals activities) that could be used in assessing proposed activities and reviewing activities after they have been initiated.

The U.S. policy context

The U.S. laws and policy directives that are relevant to environmental monitoring in Antarctica are set forth in the appendix following this paper. These provide means to advance environmental monitoring programs, as witnessed by this workshop. Among these are the update of the 1980 programmatic environmental impact statement (EIS) for the U.S. Antarctic program and the recommendations, set out in the recent NSF General Counsel's report "A NSF Strategy for Compliance with Environmental Laws in Antarctica," to apply other U.S. laws to Antarctica. U.S participation in several other international bodies, including the World Meteorological Organization, the International Oceanographic Commission, and the Intergovernmental Panel on Climate Change, offers further opportunities to define and

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*A report of the XV Antarctic Treaty Consultative Meeting, which was held in Paris, France, during October 1989, will appear in the March 1990 issue (volume 25, number 1) of the *Antarctic Journal of the United States*. This report also will include all recommendations adopt during the meeting by the representatives of the Antarctic Treaty Consultative Parties.

**Article 4 of CRAMRA outlines the "Principles concerning judgments on antarctic mineral resource activities." Paragraph 1 of this article states "Decisions about antarctic mineral research shall be based upon information adequate to enable informed judgments to be made about their possible impacts and no such activities shall take place unless this information is available for decisions relevant to those activities." Following this, paragraphs 2 and 3 specify those areas and impacts that must be considered. These considerations are significant changes to air and water quality; to atmospheric, terrestrial, or marine environments; and to the distribution, abundance, or productivity of fauna and flora populations; further jeopardy to endangered or threatened species; "degradation of or substantial risk to areas of special biological, scientific, historic, aesthetic, or wilderness significance"; and "significant adverse effects on global or regional climate or weather patterns." Paragraph 4 emphasizes that technology and procedures used in antarctic resource activities must be safe; that key environmental parameters and ecosystem components must be monitored to identify potentially adverse effects; that if adverse effects occur, then operations must be modified; and that antarctic mineral resource operators are prepared to respond to accidents. Paragraph 5 closes this article by emphasizing that all judgments must consider the cumulative impact of mineral resource activities both by themselves and in relation to other antarctic activities.

coordinate antarctic research and monitoring programs.

In relation to CCAMLR and CRAMRA, U.S. implementing legislation provides a vehicle for developing directed research and monitoring programs. The United States can take the lead in recommending and funding appropriate programs in both cases. Implementing legislation for CRAMRA could specifically address some of the data and information requirements that I noted previously and also could specify programs and funding to meet them.

Constraints on the development and implementation of environmental monitoring in Antarctica

At the international level, it will be difficult enough to design and implement a multidisciplinary monitoring strategy, along with the related data management systems, that is integrated and coordinated among the different nations active in Antarctica. Building one that can integrate environmental monitoring requirements under the Antarctic Treaty itself, as well as CCAMLR and CRAMRA, further complicates the task, although the CCAMLR monitoring program may offer some guidance and may provide a solid building block with which the treaty nations may be begin constructing comprehensive system. Branching out to encompass broader global monitoring programs represents another order of magnitude challenge. On the other hand, the international treaty forums can be mobilized to help accomplish these tasks—that is as long as the scientific community can reach some relatively specific conclusions about what needs to be done.

At the national level, the development of recommendations for an integrated and coordinated multidisciplinary approach by the U.S. scientific community that actively works in Antarctica can provide substantial leadership for the international community, as has been evident in the CCAMLR experience. Even a narrower program design that focuses solely on the U.S. Antarctic Program can provide useful guidance for other nations.

To date, neither in the United States nor among foreign antarctic research programs has the development and support of long-term environmental monitoring programs been a priority among antarctic research programs. The objective of this workshop is focus on the development of such monitoring programs. Once the desired monitoring programs have been formulated, then antarctic program managers will have to make the decisions to fund monitoring activities and to ensure that data management requirements are met.

—Lee Kimball, Director, The Antarctic Program, World Resources Institute, Washington, D.C.

December 1989

Appendix

The Antarctic Treaty System policy context

Environmental impact assessment and monitoring: The 1975 Code of Conduct (Recommendation VIII-11) includes guidelines for antarctic operating organizations that call for an evaluation of the environmental impact of major planned operations. This issue is also addressed in Recommendations VIII-13 and IX-5, both of which for the first time refer to the need for monitoring. The 1983 Antarctic Treaty Consultative Meeting call for environmental impact assessment procedures was finally realized in 1987 with adoption of Antarctic Treaty Consultative Meeting Recommendation XIV-2, which recognizes that key indicators of environmental effects should be monitored and calls for consideration of cumulative impacts as well. The Convention on the Regulation of Antarctic Mineral Resource Activities provides for environmental impact assessment of all proposed minerals activities, bearing in mind cumulative impacts in accordance with standards set out in the treaty. *It also stipulates that the capacity to monitor key environmental parameters and ecosystem components to identify adverse changes must exist before any minerals activities may take place.*

The Scientific Committee for Antarctic Research (SCAR), at the request of the 1983 Antarctic Treaty Consultative Meeting, produced a report on *Man's Impact on the Antarctic Environment*. (W.S. Benninghoff and W.N. Bonner. 1985. Scientific Committee on Antarctic Research, Scott Polar Research Institute, Lensfield Road, Cambridge, United Kingdom.) This report was presented to the XIII Antarctic Treaty Consultative Meeting. In 1986, SCAR established BIOTAS, whose objectives include integration of environmental monitoring studies and establishment of research sites associated with scientific stations, where human-induced biological and environmental changes can be monitored by comparing impacted sites with unaffected control sites. In 1986, SCAR established a Group of Specialists on Southern Ocean Ecology, among other things specifically to respond to requests for scientific advice from the Antarctic Treaty System, including possible impacts on marine ecosystems of resources activities. In 1988, SCAR established a new Group of Specialists on Environmental Affairs and Conservation to advise on environmental criteria and other matters.

Concentration of stations: One aspect of this issue is to avoid adverse environmental effects arising from cumulative impacts (Recommendation XIII-6). Establishment of multiple-use protected areas and management plans is considered one means to avoid such impacts (see the *Antarctic protected areas system* below).

Waste disposal: The 1975 Code of Conduct for Antarctic Expeditions and Station Activities (Recommendation VIII-11) recommends procedures for disposal of solid and liquid wastes. Pursuant to 1983 and 1985 decisions (Recommendations XII-4 and XIII-4) and 1987 interim recommended practices for waste disposal, the XV Antarctic Treaty Consultative Meeting in October 1989 will consider a 1989 SCAR report *Waste Disposal in the Antarctic* that recommends a variety of improvements and changes in national practice. It explicitly calls for research and monitoring programs in four areas (see sidebar on page 10).

Under the Convention on the Conservation of Antarctic Marine Living Resources, a specific program has been established to monitor disposal of plastics and discarded or abandoned fishing gear in the area south of the antarctic convergence. In 1988, SCAR became involved in recommending improved study and monitoring of the ingestion of plastics by marine birds and incidental entanglement of marine mammals.

Oil contamination in the antarctic marine environment: In 1977 and 1979 (Recommendations IX-6 and X-7), it was recommended that the Antarctic Treaty Consultative Parties consider programs to determine baseline levels of contamination of the antarctic marine environment by oil and hydrocarbon and the effects of concentration in the marine ecosystem, including birds and mammals.

Antarctic conservation strategy: This was first proposed in 1981 by the International Union for the Conservation of Nature (IUCN). It received "official" endorsement in a joint paper by Martin Holdgate and John Heap of the United Kingdom during the 1985 workshop the "Antarctic Treaty System: An Assessment" that was held at the Beardmore South Field Camp, Antarctica. Later, the strategy was endorsed at the 1985 SCAR/IUCN symposium on "Scientific Requirements for Antarctic Conservation." In late 1985, these two organizations formed a working group that produced a report on *Long-Term Conservation in the Antarctic* (May 1986). The report was subsequently approved by IUCN and SCAR governing bodies. In October 1989, IUCN plans to present an updated Antarctic Conservation Strategy to the XV Antarctic Treaty Consultative Meeting.

The strategy idea was carried forward at the XIII Antarctic Treaty Consultative Meeting in 1985, from which emerged two requests to SCAR for advice: (1) on possible additions to the categories of antarctic protected areas and (2) on steps to improve the comparability and accessibility of scientific data on Antarctica.

Scientific Committee on Antarctic Research Waste disposal report 1989

Antarctic operators should arrange for research and monitoring programs in the following areas:

(a) baseline studies of the levels of contaminants in the environment. Comparable studies at occupied sites and at remote localities will allow measurement of the local contaminant concentrations over background levels;

(b) site-specific investigations aimed at identifying the type and severity of environmental impacts peculiar to individual disposal sites and operational areas;

(c) the feasibility of establishing routine monitoring of the levels of contaminants in the environment; and

(d) on the basis of the above research, consideration should be given to the establishment, where appropriate, of formal monitoring programs aimed at the continuing assessment of the environmental impacts of waste disposal.

Antarctic protected areas system: The 1964 Agreed Measures (Recommendation III-8) established a category of "Specially Protected Area" (SPAs) to protect sites of exceptional ecological importance. Subsequently additional protected areas concepts have been adopted to protect on-going scientific research tes of Special Scientific Interest (SSSIs), Recommendations VII-3 and VIII-3, 1972 and 1975); and historic sites and monuments (Recommendations V-4 and VI-4, 1968 and 1970). In 1987, the XIV Antarctic Treaty Consultative Meeting for the first time provided for designation of marine SSSIs (Recommendation XIV-6) and accepted three. Also in 1987, the XIV Antarctic Treaty Consultative Meeting requested that states' parties undertake a review of protected areas designations and noted that mechanisms to incorporate the results into a data bank should be considered in 1989.

In 1985, as noted above, the XIII Antarctic Treaty Consultative Meeting requested SCAR's advice on possible additions to the categories of antarctic protected areas. Their proposals to the XIV Antarctic Treaty Consultative Meeting in 1987 received due consideration and examples of several additional protective arrangements will be considered at the October 1989 the XV Antarctic Treaty Consultative Meeting. These will include multiple-use Antarctic Protected Areas (APAs), the idea of a Special Reserve category to protect values, and amendments to the SPA concept that will provide for management plans. Both of the latter would require that management plans describe the means for monitoring the designated status.

Protected area designations also exist under the 1972 Convention for Conservation of Antarctic Seals, which closed areas to sealing, and CCAMLR, which closed areas to fishing. Similar designations are provided for in the 1988 CRAMRA. In all of these areas, scientific research may take place. Additionally, the CCAMLR Ecosystem Monitoring Program has identified certain study sites to be afforded appropriate protection.

SCAR plays a particular role in reviewing and recommending for Antarctic Treaty Consultative Meeting approval, proposed SPAs and SSSIs. It has produced a publication on *Conservation Areas in the Antarctic* (SCAR, March 1985), which among other things sets forth a matrix of ecosystem classifications and recommends that additional designations be completed to flush out the matrix of representative sites.

Coordination of data and research: As a result of Recommendation XIII-5 in 1985, a SCAR ad hoc committee on the Coordination of Antarctic Data has been working on recommendations in relation to improved data management, to be presented to the XV Antarctic Treaty Consultative Meeting.

Data reporting: Under the different antarctic treaties certain kinds of data reporting requirements have been established. Those relevant to environmental monitoring include:

- Antarctic Treaty: Although scientific observations and results are required to be made freely available, there are no widely agreed-upon formats for doing so. The annual exchange of information covers notice of research and tourist activities from each state and reporting, as provided under the Agreed Recommendation XIV-2, environmental impact assessments are to circulated as part of the annual exchange of information, which is publicly available. The XV Antarctic Treaty Consultative Meeting will consider how to deal with information produced from reviews of the protected areas, conducted as a result of a 1987 Antarctic Treaty Consultative Meeting decision and will address whether waste management plans should be included in the annual exchange.

SCAR annual reports of activities, in the revised 1988 format, will include a list of permits issued and brief rational for entry into SPAs and SSSIs, as well as a list of long-term monitoring programs and sites.

- CCAMLR: This convention has established detailed data reporting forms and standard method sheets for monitoring selected parameters.

Under the BIOMASS program, a data-management center has been established in Cambridge, England.

- CRAMRA: In addition to preparation of environmental impact assessments and monitoring requirements noted previously, prospectors must report annually on their activities and the data and information collection and reporting requirements for those conducting exploration and development will be elaborated once the treaty has entered into force and as interest in conducting these activities is expressed.

Confidentiality of data: In addressing the types of information required to evaluate human impacts and changing environments, it is important to bear in mind that under CRAMRA, operators of minerals activities will have certain rights to retain data and information as proprietary. CRAMRA has been constructed to provide disincentives for applicants to retain as proprietary information required for the environmental judgments called for, but as noted previously, it will be important to develop environmental monitoring programs that define monitoring needs and independently supplement data provided by prospective or existing operators.

Coordinated research:

- Antarctic Treaty: To date little has been done at the policy level, although this issue is on the agenda for the XV Antarctic Treaty Consultative Meeting.
- CCAMLR: In an effort to better coordinate scientific research and monitoring programs, each state party in its annual report describes existing *and planned* activities. In 1987, it was decided that the Scientific Committee of CCAMLR should develop and evaluate on an annual basis a 5-year projection of its work, to further coordinated research efforts.
- SCAR: The role of this international organization is to contribute to collaborative research under the Antarctic Treaty. One of the major programs that it coordinated in the last decade was BIOMASS—Biological Investigations of Marine Antarctic Systems and Stocks. In 1988, the committee produced a report on "The Role of Antarctica in Global Change," in order to coordinate and integrate antarctic research into the International Geosphere-Biosphere Program.

Inspection: As a result of U.S. initiatives, the inspection system in Antarctica has been applied in recent years to review national practice in relation to Antarctic Treaty Consultative Meeting recommendations bearing on environmental protection. The most recent 1989 U.S. inspection used a detailed checklist relating to compliance with the Code of Conduct on Waste Disposal and other waste disposal recommendations, the Agreed Measures, protected-area designations, disturbance of habitats, and practices with respect to storage of fuels and hazardous materials, construction, scientific drilling, and environmental impact assessment.

The U.S. law and policy context

Antarctic Treaty Consultative Meeting recommendations and decisions: The United States considers Antarctic Treaty Consultative Meeting recommendations binding in principle and has approved all those adopted to date. It also take the view that these apply to U.S. activities in the interim before they enter into force. Only the Agreed Measures (Recommendation III-8) were determined to require enactment into U.S. law—the 1978 Antarctic Conservation Act. The Secretary of State approves the Antarctic Treaty Consultative Meeting Recommendations, following review by the interagency Antarctic Policy Group. The Antarctic Conservation Act implements the Agreed Measures and provides in addition for regulations with respect to management plans for SSSIs and to designate pollutants and action to prevent or control their discharge or disposal. It applies to U.S. citizens, U.S.-issued permits pursuant to the Antarctic Conservation Act, and foreign persons organizing expeditions in the United States that proceed to Antarctica from the United States. Some regulations were promulgated by the National Science Foundation (NSF) in 1979. With respect to pollutants, regulations have not yet been promulgated. U.S. Antarctic Program (USAP) Program Directive No. 84-1, effective 1 October 1983, addresses USAP-recommended procedures for waste disposal. These are not fully consistent with the Antarctic Treaty Consultative Meeting Code of Conduct on Waste Disposal. On 16 February 1989, regulations were promulgated to provide for formal enforcement and hearing procedures regarding administrative handling of alleged violations of the Antarctic Conservation Act, including provision for penalties or other sanctions.

Executive Order 12114, January 1979, addressing extraterritorial application of the National Environmental Policy Act (NEPA), specifically applies it to activities in Antarctica. In 1980, the NSF prepared a programmatic environmental impact statement, which it has recently indicated will be updated. It has not yet issued the mandatory guidelines required to implement compliance with NEPA, although these are reported to be under preparation. Among the research projects contemplated in the 1980 environmental impact statement to assess selected impacts on antarctic ecosystem were study of:

(1) impacts of sewage disposal on marine ecosystems at McMurdo and Palmer stations,

(2) potential accumulation of chemical contaminants in lakes of the dry valleys, and

(3) duration and fate of petroleum products in marine environments and soils and air-quality impacts from combustion of petroleum products on lichens.

Executive Order 12088 requires NSF to apply in Antarctica environmental pollution-control standards applied in the United States. The design of any monitoring studies must bear in mind national standards for control of waste-

Annex to Antarctic Treaty Recommendation VIII-11
Code of conduct for antarctic expeditions and station activities*

1. *Waste disposal*

The following are recommended procedures:

(a) *Solid waste*

(i) *Noncombustible, including chemicals (except batteries).* These materials may be disposed of at sea either in deep water or, if this is not possible, at specified sites in shallow water.

(ii) *Batteries* should be removed from the Antarctic Treaty area.

(iii) *Combustibles.* Wood, wood products, and paper should be incinerated, the ash being disposed of at sea. Lubricating oils may be burned except those containing harmful additives which should be removed from the Antarctic Treaty area. Carcasses and materials associated with imported experimental animals should be incinerated. All plastics and rubber products should be removed from the Antarctic Treaty area.

(b) *Liquid waste.*

(i) Human waste, garbage, and laundry effluents should, where possible, be macerated and be flushed into the sea.

(ii) Large quantities of photographic liquids should be treated for the recovery of silver, and the residue should be flushed into the sea.

(c) The above procedures are recommended for coastal stations. Field sites supported from coastal stations should where feasible, use the facilities of their supporting station. Inland stations should concentrate all waste in deep pits. Except as stated for inland stations, waste should not be buried.

(d) Waste containing radioisotopes should be removed from the Antarctic Treaty area.

(e) Every effort should be made to reduce the plastic packaging of products imported into the Antarctic Treaty area.

(f) If possible the use of leaded fuels or fuels containing ethylene bromide and ethylene chloride should be avoided.

(g) When incinerators are used it is desirable to monitor the effluents.

2. *Introduction of alien species*

Procedures to safeguard against the introduction of alien species are covered by Article IX of the Agreed Measures for the Conservation of Antarctic Fauna and Flora.

3. *Disturbance of breeding colonies and concentration of birds and mammals*

Procedures to minimize such disturbances are covered by Article VII of the Agreed Measures for the Conservation of Antarctic Fauna and Flora.

4. *Guidelines for antarctic operating organizations planning major antarctic projects*

(a) In the planning of major operations in the Antarctic Treaty area, an evaluation of the environmental impact of the proposed activity should be carried out by the antarctic operating organizations concerned. Such an evaluation should include:

(i) A description of the proposed action and an assessment of its potential benefits and its possible impact on the relevant ecosystems.

(ii) A consideration of alternative actions which might alter the pattern of benefits versus adverse environmental effects expected to result from the action.

(b) These evaluations may be circulated for information through SCAR channels to all the states engaged in antarctic activities.

*The above text is the recommendation approved by representatives of the Antarctic Treaty Consultative Parties at the VIII Antarctic Treaty Consultative meeting in 1975. As noted in the appendix to Ms. Kimball's remarks, the Treaty Parties modified these guidelines in 1983, 1985, and 1987.

water discharges, solid and hazardous wastes, and atmospheric emissions, pursuant to the Clean Water Act and the Clean Air Act.

Among other U.S. laws that apply in Antarctica are the 1972 Marine Protection, Research, and Sanctuaries Act (Ocean Dumping Act); the 1972 Marine Mammal Protection Act; the 1973 Endangered Species Act; the Migratory Birds Treaty Act.

CCAMLR: Implementing legislation for CCAMLR was enacted in 1984: the Antarctic Marine Living Resources Convention Act. This was followed by implementing regulation to give effect to the act and conservation and management measures adopted by the CCAMLR Commission. It respectively directs NSF and the National Oceanic and Atmospheric Administration (NOAA) to support basic research into antarctic marine ecosystems and directed research to be coordinated with USAP. The directed research program is developed through an interagency process and appropriate consultations with interested private-sector constituencies. It is reviewed annually.

USAP: In 1987, a report on *The Role of the National Science Foundation in Polar Regions* was prepared for the National Science Board, which recommended, among other things, that environmental protection practices for USAP be studied and upgraded where necessary. It cites recommendations that NSF's Division of Polar Programs fund long-term data collection and monitoring programs and basic research needed for ecosystem management and conservation, as well as the importance of polar research in understanding and predicting climate change.

The 15 July 1987 Division of Polar Programs "Dear Colleague" letter No. 9 requested that anyone observing adverse impact of human activity in their work in polar areas inform an NSF representative of the specifics and suggest corrective measures. The same note also asked that they keep an eye open for indications of environmental change, no matter what the possible cause.

In June 1988, the USAP Safety Review Panel prepared a report on *Safety in Antarctica*, at the direction of NSF Director Erich Bloch. Its chapter on "Environment and Energy" addresses wastes management at antarctic stations, responsibility for environmental management, wastes disposal and water quality, and energy production and conservation. It recommends that the Division of Polar Programs establish a full-time Safety, Environment, and Health Officer, to establish a comprehensive set of safety, environment, and health standards for use by USAP, *which "should mimic and adopt by reference, to the extent feasible in the USAP environment, existing national standards and practices."* It also recommends monitoring of the input and output of station water supply systems, and of surface water runoff around the McMurdo landfill. (In response, the Division of Polar Programs hired a full-time Safety, Environment, and Health Officer in May 1989.)

On 31 August 1988, NSF produced an Environmental Protection Agenda for USAP, which notes among other things that monitoring data are needed on biological and environmental change, station effluents, the results of waste management strategies, and on baseline physical and chemical parameters characteristic of antarctic ecosystems.

Other reports

Abbott, S.B., and W.S. Benninghoff. Orientation of environmental change studies to the conservation of antarctic ecosystems. In G. Hempel and K.R. Kerry (Eds.), *Antarctic ecosystems: Change and conservation.* (Proceedings of the Fifth Symposium on Antarctic Biology, 29 August to 3 September, Hobart, Tasmania, Australia.) Heidelberg: Springer-Verlag.

Information management for antarctic conservation. (Report to the Polar Research Board from the Workshop on Indicators of Environmental Change in the Antarctic, Washington, D.C., 24–25 February 1986.

Rutford, Robert H. (Ed.). 1986. *Reports of the SCAR group of specialists on antarctic environmental implications of possible mineral exploration and exploitation (AEIMEE).* Washington, D.C.: Scientific Committee on Antarctic Research.

U.S. Research in Antarctica in 2000 A.D. and beyond: A preliminary assessment. 1986. Washington, D.C.: National Academy of Sciences Press.

An evaluation of antarctic marine ecosystem research. 1981. Washington, D.C.: National Academy of Sciences Press.

Final EIS on the negotiation of an international regime for antarctic mineral resources. 1982. Washington, D.C.: U.S. Department of State.

Science and the environment

Editor's note: This statement by Dr. J.A. Heap, Head of the United Kingdom's delegation, was delivered on 12 May 1989 at the preparatory meeting for the Fifteenth Antarctic Treaty Consultative Meeting.

Mr. Chairman,

I wonder if I might say a few words reflecting on the outcome of our meeting.

I have been casting my mind back over a lengthy series of preparatory meetings I have attended and the Consultative Meetings which followed them. I detect a change in this meeting, which if it becomes habit, will in my view, not be helpful to the future of the Antarctic Treaty System. I hope, Mr. Chairman, that this is not just a question of an old hand looking back and saying, in the words of the old London music hall song, "Things ain't what they used to be"!

I dare to hope that this is not the case because what I see as being the change is that we are in danger of upsetting the balance of our work. I fear that we may not be facing up to the real challenges and opportunities. Let me not imply that this is a question of black and white. It is not. It is, as I have said, a matter of balance.

We have, at this meeting, been deeply concerned with questions of the environment. I do not argue that it is wrong to have been so concerned. But, Mr. Chairman, we are dealing with one tenth of the world's land surface in which only a handful of people have temporary residence. In no other area of the world of comparable size has there been such a concern for the environment, expressed at an international level, as there has been in the Antarctic. Do not think from this that the United Kingdom is going to drag its feet with respect to the environmental items on our agenda for October. We shall be pulling our weight as we always have done. There are real problems of adequacy and ensuring compliance on the ground. There are real opportunities for concrete progress on environmentally significant issues such as marine pollution and hydrographic charting. But we shall be looking, too, for realism and an understanding of the balance that needs to be struck between looking after the environment and getting things done.

I spoke a moment ago about challenges and opportunities. Some time ago I said in the First Committee of the United Nations that competition between parties to the Antarctic Treaty—be it for land or influence or resources—was inevitable. But, I added, Mr. Chairman, that the genius of the Antarctic Treaty is, in very large part, to have channeled such competitive drives into the pursuit of knowledge. It is for that reason that Article II of the Treaty proclaims the principle of the "freedom of scientific investigation."

Now, Mr. Chairman, it is commonplace amongst those who have to deal with environmental-impact assessment procedures that the question on the bottom line is whether the ends justify the means. It follows from this that if no "good" were coming out of the Antarctic, then our impact on the antarctic environment would not be justifiable. But, Mr. Chairman, there is a "good" coming out of the Antarctic. It is the result of our separate and joint endeavors in the pursuit of knowledge.

We are, I believe, faced with a choice. On the one hand, we can accept the present rate of scientific endeavor and seek by all possible means to reduce the environmental impact of that rate. On the other hand, we can accept the present scale of impact and seek to increase the rate of scientific endeavour. Friends will immediately say that there is a third choice—to both reduce the impact and increase the rate. I would agree with them. To make that latter choice would be to opt for the best. But, Mr. Chairman, on the evidence of this meeting that is not the choice for which we seem to be heading. The choice towards which we seem to be moving is the first—to maintain the rate and reduce the impact. I do not believe that that is the choice we should make.

Mr. Chairman, it was the discovery of the ozone hole which, more than any other single event, changed the world's attitude towards its environment. It would be a tragic irony if that discovery—which was made in Antarctica—were to lead to a situation in which the very basis of our common pursuit of knowledge, the Antarctic Treaty itself, was to be undermined by a blinkered concern for the minor effects that that pursuit of knowledge is having on the antarctic environment—or, indeed, if it were to be undermined by a distant future threat which we have collectively foreseen and collectively guarded against.

In my third of a century of working in antarctic affairs I find it both remarkable and, if I may say so, immensely satisfying, that scientific research is at last, a sufficiently understood political argument to justify presence in Antarctica. The reason why it is sufficient is that it is now politically accepted the world over that we are desperately in need of science as an aid to predicting what our common future may hold in store for us; that policy decisions of enormous significance will need to be based, not on scientifically proved certainties but on scientifically predicted probabilities; and that therefore we cannot afford to leave any scientific stone unturned. One such stone, of critical importance to the major proportion of humanity which lives close to the sea, is the Antarctic. The world as a whole need to know what the Antarctic holds in store. Is it, or is it not, a sword of Damocles, and how strong is the thread holding it up?

The international community—and indeed our own environmental communities—should be urging us on to increase our scientific output. While such communities should not allow us to get away with environmental irresponsibility—and rightly so—they should be saying to us that we should justify the environmental impact of our stations and logistics by increasing our scientific output.

Mr. Chairman, there are many of us who, when asked to identify the premier forward-looking item on our agenda for October, would point to the item on "Comprehensive measures for the protection of the antarctic environment. . . ." It is not my purpose in any way to deny the importance of that item. My purpose is to point to the need for that item to be balanced by equally serious consideration to be given to the item on the "Promotion of international scientific cooperation."

If we can achieve substantial progress on both the scientific and the environmental fronts there is a chance, just a chance, that we could achieve our best choice—that of increasing the rate of scientific endeavor and reducing its impact. But if we let the environmental considerations dominate at the cost of scientific output, we could find ourselves heading down a road to a point where the collective impact of our presence in Antarctica might not be justified by the return, in science, we were making on it.

To find ourselves at such a destination would be tragic indeed—not only for us, but for the wider community of which we are part. Failure to get our priorities right would be a failure to keep the trust with the rest of the world that we have claimed for ourselves.

Thank you, Mr. Chairman.

Three young Americans selected to participate in U.S. Antarctic Program

As the 1989–1990 austral summer begins, three young people are eagerly awaiting their first view of Antarctica. Two of these young people, Kevin C. Engel and Catherine Anne Blish, are participants in the National Science Foundation's Young Scholars program and are first Young Scholars to join U.S. researchers in Antarctica. The third participant is 19-year-old Eagle Scout Robert Scot Duncan, the sixth scout selected by the Boy Scouts of America to join U.S. investigators in Antarctica since 1928.

Young Scholars program

The NSF Science and Engineering Education Directorate began the Young Scholars program in 1988. Through this program, NSF tries to encourage students in grades 8 through 12 to pursue science careers by offering them the opportunity to work with scientists. During 1989, the program supported 136 Young Scholar projects at more than 4,500 junior- and senior-high schools around the United States.

Mr. Engel and Ms. Blish, participants in the 1988 Young Scholars program, were selected by NSF from 2,500 students because of their scholastic achievements, interest in science, and leadership abilities. Each has been paired with a scientist conducting research in Antarctica. During the 1989 northern summer, they visited with these two scientists for about 3 weeks to learn about the field projects with which they will be working. In December, they will travel to Antarctica to work with the two research teams for about a month.

Mr. Engel, an 18-year-old from West Salem, Wisconsin, will work with Robert Morse, a University of Wisconsin physicist. Kevin, who will enter the University of Wisconsin this fall, will assist Dr. Morse's field team at Amundsen-Scott South Pole Station where they are using a special telescope to investigate gamma-ray sources.

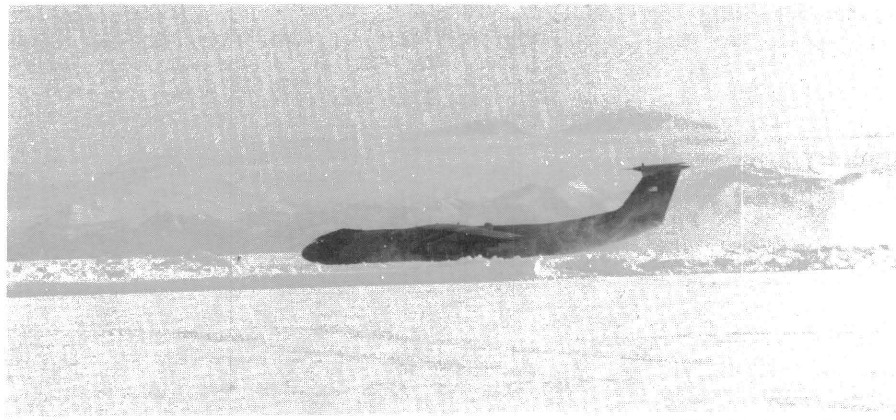
Eighteen-year-old Catherine Blish will assist a research team under the direction of Cornelius Sullivan from the University of Southern California. Dr. Sullivan's group is studying the relationship between changing light conditions and the ecology of sea-ice algae. Ms. Blish, who is from Saratoga, California, will begin studying at the University of California at Davis this year.

Boy Scout participant

The first Boy Scout to go Antarctica was Paul Siple, who was selected to accompany Richard E. Byrd's 1928–1930 antarctic expedition. Robert Duncan of

Gulf Breeze, Florida, continues this tradition. A sophomore at Eckerd College, Robert competed with Eagle Scouts from around the United States and was selected from a group of 77 young men by a review panel that included three scouts who have gone previously to Antarctica with the U.S. program. He is working on his bachelor's degree in biology and hopes to become an environmental journalist.

Mr. Duncan traveled to Antarctica in October where he began a 3-month visit that includes working with various research parties in the field and traveling to the U.S. station at the geographic South Pole. In addition to the other Boy Scouts, three Girl Scouts also have participated in the U.S. Antarctic Program.



NASA photo by Lary Sammons.

An Air Force C-141 Starlifter airplane lands on the sea ice near McMurdo Station. For more than 20 years these airplanes have enabled the U.S. Antarctic Program to rapidly transport cargo, supplies, and personnel to McMurdo Station during the early part of the austral summer.

Presidential message and airdrop highlight Midwinter's celebration

Midwinter's Day, 21 June, is the midpoint of the austral winter and, since the beginning of the twentieth century, has been a day of celebration for all who have remained in Antarctica during the long polar night. Each year since 1959, the President of the United States has commemorated this day by sending greetings to all personnel wintering in Antarctica.

Following in this tradition, President George Bush sent a message on 21 June 1989, commending antarctic personnel for the sacrifices that they have chosen to make to pursue their work. The message was sent to the three U.S. stations (McMurdo, Amundsen-Scott South Pole, and Palmer) where 157 U.S. personnel are wintering, as well as to 37 other stations around the continent where scientists and support staff of 15 countries are working. For a list of U.S. wintering personnel, please see the June 1989 issue of the *Antarctic Journal*, pages 13 and 14. The text of President Bush's message follows this article.

Airdrop at McMurdo and South Pole

For Americans at McMurdo and Amundsen-Scott South Pole stations and New Zealanders at Scott Base, Midwinter's Day 1989 had a special significance. Immediately before the midwinter's holiday, a C-141B Starlifter airplane from the Military Airlift Command (MAC), accompanied by a Strategic Air Command KC-10A tanker, airdropped 114 containers, holding more than 68,000 pounds of supplies, food, and mail for the three isolated stations.

Under a rainy, early morning sky on 18 June, the C-141B Starlifter, commanded by Major Bill Burt (USAF) of the 62nd Military Air Wing, left Christchurch, New Zealand, for Ross Island, Antarctica. This 16-hour mission to McMurdo and Amundsen-Scott South Pole stations was possible because the KC-10 tanker carried 115,000 pounds of jet fuel with which to refuel the Starlifter in flight.

Six hours later, the cargo handlers aboard the Starlifter dropped 44 parachute-equipped containers holding more than 24,344 pounds of fresh produce, frozen food, cargo, and mail to personnel at McMurdo Station and Scott Base. Before flying on to Amundsen-Scott South Pole Station, the KC-10 tanker refueled the jet in mid-air one more time. During the mission the Starlifter had to refuel three times to make the nearly 6,000-mile round trip from New Zealand to the geographic South Pole, where they delivered a record-breaking 14,343 pounds of supplies and mail. On 20 June, the C-141B flew to Antarctica a second time to drop an additional 29,368 pounds of supplies and mail to Ross Island residents, bringing the total amount of material delivered to McMurdo and Scott Base to more than 53,712 pounds.

This was the tenth midwinter airdrop performed by U.S. military units in support of the U.S. Antarctic Program. This year, aircrews from McChord Air Force Base in Washington and March Air Force Base in California worked with cargo handlers from New Zealand's Royal Army and U.S. army personnel from MAC headquarters at Travis Air Force Base, California. The operation was coordinated by the Christchurch detachment of the Naval Support Force Antarctica and other U.S. military personnel station at Christchurch.

For winterers on Ross Island and at the South Pole, these airdrops provide an important connection with the outside world. At the South Pole, personnel are isolated between February and late October and at McMurdo Station between March and late August.

Midwinter's Day greetings from President Bush

I am delighted to send greetings to the members of the international community in Antarctica as you celebrate Midwinter's Day 1989.

Enduring the isolation and rigors of these cold, dark months, you are contributing enormously to some of the world's most important scientific research. Antarctica plays an essential role in maintaining the Earth's delicate environmental balance. Your studies of this vast region will help us to understand more fully the processes that sustain life around the globe.

The United States is committed to preserving this unique natural laboratory and invites all nations to join us in this effort. I have asked the United States Congress to support a special antarctic initiative that will effectively address global environmental concerns. I'm confident that nations can work together on environmental matters.

I commend you for the sacrifices you have made to pursue your work. All of you carry on a tradition of peaceful, cooperative inquiry that the Antarctic Treaty launched more than three decades ago. I wish you every success and a safe return following the long polar night. May God bless you always.

Signed George Bush.

Staff changes in the Division of Polar Programs

During 1989 several new staff members have joined the Division of Polar Programs, while some existing staff members have changed positions. These changes, organized by DPP section, are briefly outlined below.

Office of the Division Director. Charles Paul, formerly of the U.S. Agency for International Development, joined DPP in July 1989 as NSF Representative, New Zealand. This position, previously held by various members of the DPP staff, is now a full-time, year-round position.

Polar sciences section. Jane Dionne, previously program manager for coordinated research programs, returned to DPP from a special year-long assignment to NSF's Division of Engineering. Dr. Dionne now is serving as the staff associate to Ted DeLaca, head of the division's science section. Also joining DPP's science managers is Roger B. Hanson, a rotator from Skidaway Institute of Oceanography. As Assistant Manager for Polar Biology and Medicine, Dr. Hanson is assisting Polly Penhale, program manager for DPP's arctic and antarctic biology and medicine research programs.

Polar operations section. Special Projects Manager Erick Chiang has been appointed Deputy Manager for Operations, and Ocean Projects Manager Thomas F. Forhan was selected to lead the new Safety, Environment, and Health Implementation Team that will carry out plans developed by the USAP Safety, Environment, and Health Officer Gary Staffo. Two other members of the implementation team have also been hired. They are Deh-I Hsiung as operations research analyst and Sam Higuchi as environmental engineer. Ms. Hsiung was previously a member of the staff of NSF's budget and control office; Mr. Higuchi was with the Department of Commerce. Replacing Mr. Forhan as Ocean Projects Manager is Alexander L. Sutherland. Mr. Sutherland previously worked for the Oceanographic Centers and Facilities Section of NSF's Ocean Sciences Division.

Two Navy officers also have joined the operations staff. They are Captain Dwight Fisher, who is serving as Associate Manager for DOD Operations, and LCDR Robert T. Bohner, who is Associate Manager for Polar Plans and Coordination. Captain Fisher's last assignment was as Commander of the Naval Support Force Antarctica. Between 1983 and 1985 he also served as Commander of the Antarctic Development Squadron 6 (VXE-6). LCDR Bohner previously served in VXE-6 where he was helicopter pilot.

Safety, Environment, and Health Office. Sidney Draggan left the Polar Coordination and Information Section to become the Environmental Officer for the new safety, environment, and health initiative. He joins Safety, Environment, and Health Officer Gary Staffo and Safety Specialist Gwen Adams.

Polar Coordination and Information Section. Nadene G. Kennedy, formerly the section's senior program assistant, has been named Polar Activities Coordinator.

Availability of Landsat, Soyuzkarta, and SPOT data of Antarctica for ice and climate research

In the last 2 decades, three satellite systems—the U.S. system Landsat, the Soviet Soyuzkarta, and the French SPOT—have acquired more than 25,000 high-resolution (between 6- and 80-meter) images of Antarctica. Since 1972, the Landsat system alone has acquired more than 17,000 images. Landsats 1, 2, and 3 acquired more than 11,400 images of Antarctica between 1972 and 1983, 1,800 of which are in digital form. The images with 10 percent or less cloud cover provide coverage of about 70 percent of the continent. Only parts of the Antarctic Peninsula, Marie Byrd Land, and the Ross Ice Shelf and all of the area south of 81°S are not covered. From 1982 through the 1988–1989 austral summer season, Landsats 4 and 5, which are still operational, acquired more than 5,600 images of Antarctica. This imagery, covering about 40 percent of the coastal and ice-shelf areas, documents current conditions, and provides the opportunity to map changes.

Since 1976, the Soyuzkarta system has acquired more than 7,000 photographs of Antarctica. The U.S. Geological Survey (USGS) has plotted the location of these Soyuzkarta data on 30 index sheets by year and type of sensor. The index maps will be released through the U.S. Geological Survey Open-File Report Series. The French SPOT satellite has collected more than 1,500 scenes of the antarctic continent, extending to 85°S. When the coverage of all three satellite systems is combined, more that 75 percent of the Antarctic is covered by cloud-free, remotely sensed data.

Satellite data from these three systems have proven to be useful and cost effective for ice and climate research in Antarctica. They are being used in a variety of research efforts:

- monitoring coastal change (Ferrigno and Gould 1987; Williams and Ferrigno 1988a);
- determining velocities of outlet glaciers (Kent et al. 1981; Lucchitta and Ferguson 1986);
- defining blue-ice areas (Williams, Meunier, and Ferrigno 1983);
- tracking the movement of icebergs (Swithinbank 1977); and
- comparing with and as a base for overlaying radar, radar altimetry, geological, geophysical, and other data.

This paper reviews the image data acquired since 1972 by the Landsat, Soyuzkarta, and SPOT space systems and illustrates where good-quality (10 percent or less cloud cover) data are known to exist.

Landsat

Landsats 1,2, and 3: Between 1972 and 1983, the Landsat 1, 2, and 3 spacecraft acquired approximately 11,400 images of Antarctica in photographic and digital form. These images consisted of about 6,400 multispectral scanner (MSS) images and a few Landsat 1 and 2 return-beam vidicon (RBV) images that have 80-meter pixel resolution and 5,000 Landsat 3 RBV images that have 30-meter pixel resolution. The images, which cover an area about 180 kilometers on a side (32,400 square kilometers), were archived primarily in photographic form although about 1,800 computer-compatible tapes (CCTs) were archived as part of a basic data set. Archival rolls of film containing most of the 11,400 images acquired over 2,514 nominal scene centers (intersections of the orbital paths and rows) of the antarctic continent and adjacent island groups were visually inspected by USGS (Williams, Ferrigno, and Kent 1984; Williams and Ferrigno 1988b) to determine the feasibility of using them for glaciological, climatological, geological, and cartographic applications. They were evaluated on the basis of percentage of cloud cover. Images were rated excellent (0 to 5 percent or less cloud cover), good (more than 5 to 10 percent or less cloud cover), fair to poor (more than 10 percent to 100 percent cloud cover), and unusable (100 percent cloud cover). Nominal scene centers coverage broke down this way:

- 37 percent were rated excellent,
- 7 percent good,
- 37 percent fair to poor,
- 6 percent unusable, and
- 12 percent did not have any images acquired of the area.

The first two image categories, excellent and good, constituting 44 percent of the nominal scene centers, have less than 10 percent cloud cover and are considered very usuable for most applications. The coverage of these images is plotted on figure 1 and covers an area constituting about 70 percent of the antarctic continent.

Landsats 4 and 5: Landsat 4 data acquisition began in 1982, and Landsat 5 data acquisition began in 1984. Together, the two satellites have acquired more than 3,500 thematic mapper (TM) (30-meter pixel resolution) and 2,100 MSS images of Antarctica through the 1988–1989 austral summer season. Landsats 4 and 5 have orbital parameters that differ from those of Landsats 1, 2, and 3; consequently, different sequential and areal coverage results.

The data have also been archived differently. Whereas the Landsat 1, 2, and 3 data exist in film format, which makes examination and evaluation possible, the majority of Landsat 4 and 5 scenes exist only as high-density digital tapes that cannot be inspected before purchase. Another difference is the cost of the data. Landsats 1, 2, and 3 were completely subsidized by the Federal government, and the charge for data was based primarily on reproduction costs. In 1985, the Landsat system was semicommercialized, so development and management of the spacecraft are now shared by the Federal government and private industry. The data archive is now marketed by a commercial corporation. While still heavily supported by the government, the data cost has increased markedly to retrieve more of the expense of system operation. In 1989, prices range from \$90 to \$700 for the film products and \$660 to \$3,600 for digital data, depending on product. At this price, it costs \$0.0028 to \$0.0216 per square kilometer for film data and \$0.0204 to \$0.1111 per square kilometer for digital data (see the table).

Automatic computer evaluation of the Landsat 4 and 5 images by the vendor indicates that about 1,480 images, or 26 percent, have 10 percent or less cloud cover. A visual inspection of purchased data assessing actual cloud cover indicates that probably much less than half, perhaps fewer than 500 to 700 scenes, actually are in this category, because there are inaccuracies in the cloud-cover assessment system over ice- and snow-covered regions.

The transfer of the Landsat system to the commercial sector also caused a change in data-acquisition policy. Currently, acquisition is generally activated by an order of film or digital product and limited by the operating-power restrictions on the aging spacecraft, which have already exceeded their designed life time. Most of the Landsat 4 and 5 data of Antarctica have been acquired as a result of two main projects:

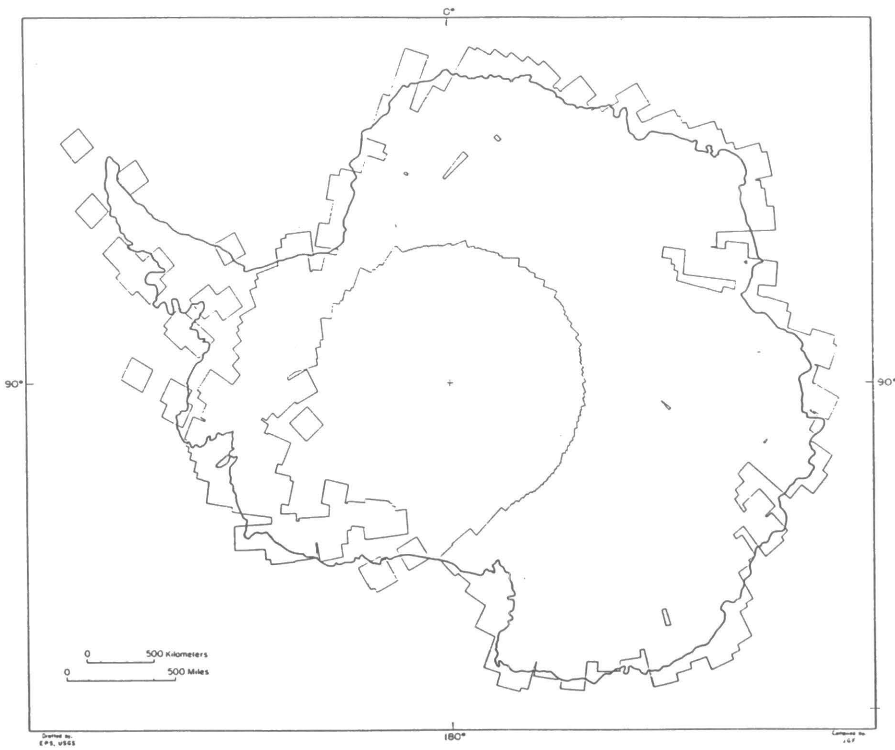


Figure 1. Coverage of Landsat 1, 2, and 3 images with cloud cover of 10 percent or less.

- the USGS/Scientific Committee on Antarctic Research (SCAR) project to acquire data of coastal Antarctica and its ice shelves for use by the antarctic research community and
- the West German project to acquire data for research, fieldwork, and mapping of a geographic area extending from the Ronne Ice Shelf east ward to the Greenwich Meridan.

The West German project has produced several maps, including a study by Swithinbank, Brunk and Sievers (1987) on glacier-flow lines. The USGS/SCAR project, which is funded by the USGS the National Aeronautics and Space Administration, and cooperating SCAR nations, has acquired data that are currently being used to measure surface glacier velocities, monitor coastal changes, correlate with radar and radar altimetry data, provide regional perspectives for glaciological field work and research, and generate map products.

It is physically impossible to evaluate all the Landsat 4 and 5 data because, as described earlier, many of the scenes are not archived in a visual form. Many good scenes (10 percent or less cloud cover), however, have been acquired to date and are in the EOSAT archive. Those that have been purchased by the USGS/SCAR project are plotted on figure 2. Because data from the 1988–1989 austral summer are still being processed, the coverage on figure 2 is regularly updated. The USGS/SCAR project to acquire Landsat data of Antarctica plans to continue data acquisition until new coverage of all coastal areas and the ice shelves is completed. This data set will allow documentation of ice and climate conditions in the late 1980s and permit studies to be undertaken for comparison with historic and future data sets. Of particular interest are comparisons of early- and mid-1970s with late-1980s Landsat image data.

Soyuzkarta

Since 1976, sophisticated photographic systems on the USSR's Soyuz satellites have acquired data of Antarctica. The most useful of these data are more than 7,000 photographs from the KATE-200 system and the KFA-1000 system evaluated to have 30 percent or less cloud cover. About half of these are reported to have 10 percent or less cloud cover. The KATE-200 photography has 20-meter spatial resolution, is multispectral, and covers an area about 180 kilometers on a side (32,400 square kilometers). The KFA-1000 data are panchromatic, have 6-meter spatial resolution, and cover an area 60 kilometers on a side (3,600 square kilometers). In 1988, film costs for KATE-200 data were approximately \$610 for a standard scene or \$0.0188 per square kilometer, and for KFA-1000 data were about \$777 for a standard scene or \$0.2158 per square kilometer.

Data coverage, plotted by the USGS on 30 separate sheets by year of acquisition and sensor, will be released through the USGS Open-File Report Series. The coverage of Antarctica shown by the plots is excellent and except for the Antarctic Peninsula and parts of the Ross Ice Shelf, covers most of the area within the orbital limits from the coastline to almost 84°S.

A printout evaluating the quality and cloud cover of the scenes accompanies the map plots. The evaluations were

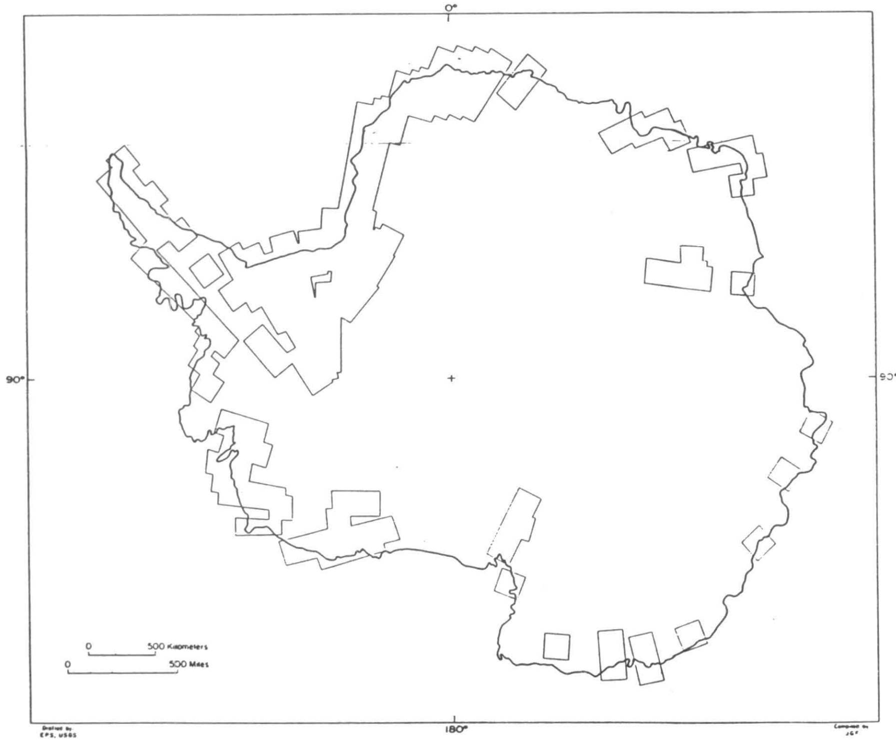


Figure 2. Coverage of Landsat 4 and 5 images with cloud cover of 10 persent or less.

supplied by the USSR. Scene in the Amery Ice Shelf area that we have examined visually are excellent, but we have inspected too few scenes to evaluate the accuracy of the USSR's cloud-cover estimations.

SPOT

The Systeme Probatoire d'Observation de la Terre (SPOT) was launched in 1986 and has acquired more than 1,500 scenes of Antarctica. The scenes are scattered around the continent and extend to 85°S. SPOT data consist of multispectral (20-meter pixel resolution) and panchromatic (10-meter pixel resolution) images in photographic or digital form. SPOT also possesses a mechanical plane mirror that permits oblique, or off-nadir, imaging and the collection of stereoscopic images.

SPOT scenes cover an area 60 kilometers on a side (3,600 square kilometers). The 1989 prices are: $1,300 for multispectral and $1,500 for panchromatic film products and $1,700 for multispectral or $2,200 for panchromatic digital tapes. The cost of using these data is $0.3611 to $0.4167 per square kilometer for photgraphic and $0.4722 to $0.6111 per square kilometer for digital products.

We attempted to evaluate SPOT data on the basis of the systematic cloud-cover evaluation furnished by SPOT; however, we found the SPOT systematic evaluation to be highly inaccurate because of the difficulty in discriminating between clouds and snow. Although one can purchase data by relying on SPOT's systematic cloud-cover rating or on "quick-look" film products generated in Toulouse, the quick-look film also is not optimum for cloud and snow discrimination. Refunds are given when the cloud-cover rating is proved inaccurate. Good-quality, cloud-free SPOT data have been reported by international researchers to exist in the Siple Coast area, the northwestern part of the Antarctic Peninsula, around the Rutford Ice Stream, and in scattered areas of East Antarctica.

Conclusion

There is excellent satellite-image coverage of Antarctica from remotely sensed data collected by the Landsat, Soyuzkarta, and SPOT systems (figures 1 and 2). Landsats 1, 2, and 3 have acquired, primarily in the early 1970s, good-quality photographic and digital data of almost 90 percent of Antarctica within the orbital limitations of the spacecraft (from the coastline to 81°S) with the exception of the Antarctic Peninsula and parts of Marie Byrd Land and the Ross Ice Shelf.

Good-quality Landsat 4 and 5 data collected during the middle to late 1980s are available for about 40 percent of the coastal and ice-shelf regions of the continent. The new data allow documentation of current conditions and can be compared with the older data to determine change in coastal areas. Data will continue to be acquired until complete coverage of the entire coastal area is achieved.

There are more than 7,000 Soyuzkarta scenes that cover most of the area within the orbital limitations of the spacecraft (from the coastline to 84°S) and 1,500 SPOT scenes that are scattered in the area from 72°S to 85°S. Several excellent scenes are known to exist from these two systems, but the scarcity of data that can be examined makes it impossible for us to assess the cloud cover accurately at this time.

Each system offers excellent data for research applications. Landsat data are superb for regional and global studies. The Soyuzkarta system provides primarily high-resolution photographic

Comparison of sensor resolution, area of coverage, and cost of Landsat, Soyuzkarta, and SPOT data.

Spacecraft	*Sensor*	*Resolution (in meters)*	*Approximate area of scene (in square kilometers)*	*Least expensive photo product*	*Cost per square kilometer*	*CCTs*	*Cost per square kilometer*
Landsat	TM	30	32,400	$ 700 (new)	$0.0216	$3,600	$0.111
	TM	30	32,400	$ 300 (archival)	$0.0093		
	MSS	80	32,400	$ 300 (new)	$0.0093	$ 660	$0.0204
				$ 90 (archival)	$0.0028		
Soyuzkarta	KFA-10000 Panchromatic	6	3,600	$ 777 (1988)	$0.2158		
	KATE-200 Multispectral	20	32,400	$ 610 (1988)	$0.0188		
SPOT						$2,200	
	Panchromatic	10	3,600	$1,500	$0.4167	$0.611	
	Multispectral	20	3,600	$1,300	$0.3611	$1,700	$0.4722

data. The SPOT photographic and digital data are excellent high-resolution remote-sensing products from small study areas, but the high cost becomes a consideration if one envisions large regional studies. The table presents a relative idea of cost per square kilometer for data from the different systems.

Remotely sensed data of Antarctica such as Landsat, Soyuzkarta, and SPOT imagery offer a valuable, economic tool for ice and climate research and determination of global change. On a global basis, determination of change requires the ability to define the extent and measure the change in an environmental component such as ice cover over the entire planet at different points in time. Remotely sensed data discussed here offer the most efficient method of accomplishing this task; however, the potential that these data have for research applications has scarely been realized.

—Jane G. Ferrigno and Bruce F. Molnia, U.S. Geological Survey, Reston, Virginia.

References

Ferrigno, J.G., and W.G. Gould. 1987. Substantial changes in the coatline of Antarctica revealed by satellite imagery. *Polar Record*, 23(146), 577–583.

Kent, T.M., J.G. Ferrigno, R.S. Williams, Jr., and J.W. Schoolmaker, Jr. 1981. Evaluation of Landsat images suitable for 1:250,000-scale image maps of Antarctica. *Proceedings of the American Congress on Surveying and Mapping Spring Meeting*, Washington, D.C.

Lucchitta, B.K., and H.M. Ferguson. 1986. Antarctica: Measuring glacier velocity from satellite images. *Science*, 234, 1,105–1,108.

Swithinbank, C. 1977. Drift tracks of Antarctic icebergs. *Polar Record*, 18(116), 495–501.

Swithinbank, C., K. Brunk, and J. Sievers. 1987. *A glaciological map of Filchner-Ronne Ice Shelf*. 1:2,000,000. Frankfurt: Institut für Angewandt Geodäsie.

Williams, R.S., Jr., and J.G. Ferrigno. 1988a. Documentation on satellite imagery of large cyclical or secular changes in Antarctic ice sheet margin. *EOS Transactions*, 69(16), 365.

Williams, R.S., Jr., and J.G. Ferrigno. 1988b. Landsat images of Antarctica. In C. Swithinbank (Ed.), *Antarctica*. (U.S. Geological Survey Professional Paper 1386-B, B139–B145.)

Williams, R.S., Jr., J.G. Ferrigno, and T.M. Kent. 1984. Index map and table to optimum Landsat images of Antarctica. *U.S. Geological Survey Open-File Report 84-573*, 1:5,000,000.

Williams, R.S., Jr., T.K. Meunier, and J.G. Ferrigno. 1983. Blue ice, meteorite, and satellite imagery in Antarctica. *Polar Record*, 21(134), 493–496.

Two volumes of Soviet polar science papers translated

Since 1965 the National Science Foundation's Division of Polar Programs has arranged for the translation of foreign books and periodicals into English. These publications, many of which were originally published in Russian, are translated by overseas contractors, using excess foreign currencies held by the United States. Most recently, this work has been accomplished by an Indian contractor Amerind and a Pakistani contractor Saad. Descriptions of two Soviet publications that have just been translated and are available for purchase follow below.

Problems of the Arctic and the Antarctic, Volume 60 (TT 82-00-108), edited by B.A. Krutskikh, focuses on topics in polar ocean sciences with particular attention to sea ice and its interactions with the ocean and with the atmosphere. The 152-page volume includes 15 scientific papers, one review, and two obituaries. Of the scientific papers, all of which were published in the Soviet Union in 1985, four are devoted specifically to antarctic topics. These are "Volumetric T-S analysis of water masses of antarctic origin in the Indian Sector of the southern ocean" (A.T. Boxhkov, A.A. Dimitrieva, and A.V. Men'shenin), "Heat and moisture exchange of antarctic fast ice with the atmosphere in Alasheev Bight" (Yu.L. Nazintsev), "Results and prospects of studies on the boundary layer of the antarctic atmosphere" (A.I. Voskresenskii and I.I. Tsigel'nitskii), and "Manifestation of forms of atmospheric circulation in the antarctic free atmosphere" (E.P. Lysakov and A.M. Seveshnikov). However, those papers dealing with arctic topics or general polar studies also may be useful to antarctic researchers. Among the topics discussed by authors of these papers are the use of a mathematical model to calculate temperature changes and snow and ice melting in areas polluted by petroleum products, use of a current eddy-resolving model to study ocean circulation, and special features of methods used to analyze hydrochemical elements and pollutants in arctic and antarctic waters.

Problems of the Arctic and Antarctic, Volume 61 (TT 82-00-109), also was edited by B.A. Krutskikh. As with Volume 60, the 12 scientific papers in this 103-page book were published originally in 1985. These papers focus entirely on oceanographic and meteorologic research in the Arctic.

The Division of Polar Programs encourages scientists to suggest titles of significant works for translations. Recommendations should be submitted in letter form and should contain full bibliographic information on each recommended title, evaluation of the work's scientific importance, and a description of tthe anticipated audience in and benefit to the United States. A copy of each recommended publication also should be included if possible. The letter should be sent to the Polar Information Program, Division of Polar Programs, National Science Foundation, Washington, D.C. 20550 (telephone, 202/357-7817). Usually more than a year is required for the translation to be completed and the book to be published.

To order already published translations, contact the National Technical Information Service (NTIS), 5822 Port Royal Road, Springfield, Virginia 22151 (telephone, 703/487-4835). Please also cite the TT number that is listed in parenteses after each title above. Because prices change periodically, interested readers should first contact NTIS for current information before ordering. A list of other books translated and published in this program is available from the Polar Information Program at the address above.

A long journey ends—"Juliet Delta 321" reaches the United States

After an 18-year absence, the ski-equipped Hercules (LC-130) known as "Juliet Delta 321" landed in the United States on 2 July 1989. The Hercules airplane, which was buried for 16 years in the ice of East Antarctica, began the last leg of its homeward journey on 29 June when it and a second, "pathfinder" LC-130 left Christchurch, New Zealand, for the U.S. Naval Air Station at Point Mugu, California.

Owned by the National Science Foundation (NSF), the airplane was flown to the United States by a U.S. Navy aircrew from the Antarctic Development Squadron Six (VXE-6). VXE-6 operates aircraft in Antarctica for the NSF-managed U.S. Antarctic Program (USAP). The commander of "321" for its homeward trip was LCDR Ed Dutra and the commander of its "pathfinder," Lt. Sharon Nutter.

Navy and Lockheed Corporation crews completed preliminary repairs in Antarctica during January 1988, but additional repairs were needed before the airplane could make the long trans-Pacific flight. This was done over the last 18 months in Christchurch by Air New Zealand, under contract to the National Science Foundation.

Built by Lockheed Aeronautical Systems Company's Georgia branch, "321" was one of the first four LC-130 airplanes to be used by the U.S. Navy to support antarctic research. The four airplanes arrived in Antarctica during the 1960–1961 austral summer. Shortly after the airplanes reached Antarctica, they demonstrated how effectively the ski-equipped transport airplane could expand the scope of the U.S. program. On 10 December 1960 two LC-103s transported a geology field team from McMurdo Station to Eights Coast, more than 1,300 miles.

Five months later, in April 1961, "321" made one of the U.S. program's most historic flights. After the long polar night had begun, personnel at Byrd Station in Marie Byrd Land, West Antarctica, sent word that one of the scientists, a Soviet exchange scientist Leonid Kuperov, was seriously ill and could not be treated at the station. A medical evacuation was needed. Two LC-130s were dispatched from the United States to Christchurch, and on 9 April 1961, Juliet Delta "321" left Christchurch alone for Byrd Station. The airplane returned safely with the scientist who was treated in Christchurch. This was the first mid-winter flight of an LC-130.

The airplane is scheduled to be flown to a U.S. Navy aircraft repair facility at Cherry Point, North Carolina, for final repairs and improvements to its navigation and communications equipment. The National Science Foundation anticipates returning the recovered airplane to Antarctica to support science when these repairs and improvements are completed.

Juliet Delta "321" prepares take off with its escort airplane on a skiway not far where it was buried in more than 30 feet ice for 16 years. In July 1989 the airplane finally returned to the United States for repairs that will enable it to return to operation in Antarctica.

U.S. Navy photo by Pat Gilliand.

Polar archivist dies

Herman R. Friis, former Director of the Center for Polar Archives of the National Archives, died on 23 September 1989 at the age of 83.

Although Mr. Friis assumed the position of Director of the Center for Polar Archives in 1967, his interest in the polar regions began much earlier and was outgrowth of his studies at the University of California where he received his bachelors and masters degrees in geography. His first position at the National Archives was as the Assistant Chief of the Division of Maps. He held this position from 1938 to 1942 when he left to serve in the U.S. Army Air Corps. He returned to the Archives' mapping division in 1946. In 1962, he became the Chief of Technical Records at Archives, and in 1967 he began his work with the country's polar archives. He was in charge of the Center for Polar Archives until his retirement in 1975.

In addition to his work at the Archives, Mr. Friis taught at the University of Wisconsin, the University of Southern Illinois, and Catholic University and was a guest lecturer at American University. During his career and after he retired, he also authored numerous papers on historical geography and exploration, mapping, and surveying.

His work with the U.S. Antarctic Program extended beyond his work at the Archives. He made two trips to Antarctica—in 1960 as a guest of the U.S. Naval Support Force Antarctica and during the 1969–1970 austral summer as an exchange scientist with the Japanese Antarctic Research Expedition II (JARE II). From 1957 to 1973, he was member of the U.S. Advisory Committee on Antarctic Names, the national committee that researches and recommends for approval names of antarctic features to the U.S. Board on Geographic Names and Secretary of the Interior.

In recognition of his dedication to antarctic research and his work with JARE II, Friis Hills (77°45'S 161°25'E) near the Taylor Glacier in southern Victoria Land were named for him.

Foundation awards of funds for antarctic projects, 1 July to 30 September 1989

Following is a list of National Science Foundation antarctic awards made from 1 July to 30 September 1989. Each item contains the name of the principal investigator or project manager, his or her institution, a shortened title of the project, the award number, and the amount awarded. If an investigator received a joint award from more than one Foundation program, the antarctic program funds are listed first, and the total amount of the award is list in parentheses. Award numbers for awards initiated by the Division of Polar Programs contain the prefix DPP, those by the Division of Earth Science the prefix EAR, those by the Division of Ocean Sciences the prefix OCE, and those by the Division of Industrial Science and Technological Innovation contain the prefix ISI.

Biology and medicine

Abbott, Sherburne B. National Academy of Sciences, Washington, D.C. An assessment of opportunities for human factor and biomedical research using the Antarctic as a laboratory and analogue for space. DPP 89-00258. $15,000.

Ainley, David G. Point Reyes Bird Observatory, Stinson Beach, California. Antarctic Marine Ecosystem Research at the Ice-Edge Zone (AMERIEZ): The distribution of sea birds. DPP 84-19894. $15,049.

Bengtson, John L. Point Reyes Bird Observatory, Stinson Beach, California. Antarctic Marine Ecosystem Research at the Ice-Edge Zone (AMERIEZ): Feeding ecology of pinnipeds. DPP 84-20851. $39,000.

Bennett, Albert F. University of California, Irvine, California. Physiological adaptation and phylogenetic constraints on reproduction in antarctic birds. DPP 87-16005. $11,400.

Frederick, John E. University of Chicago, Chicago, Illinois. The ultraviolet radiation environment of Antarctica. DPP 88-09294. $61,450.

Gowing, Marcia M. University of California, Santa Cruz, California. The role of phaeodarian radiolarians in antarctic biological oceanic processes. DPP 87-15974. $3,266.

Green, William J. Miami University, Oxford, Ohio. Trace-metal transport processes in Lake Vanda and the Onyx River, Antarctica. DPP 85-16465. $5,574.

Holm-Hansen, Osmund. Scripps Institution of Oceanography, La Jolla, California. Ultraviolet radiation in antarctic waters: Dynamic response of phytoplankton and attenuation by pigments. DPP 88-10462. $80,449.

Kooyman, Gerald L. Scripps Institution of Oceanography, La Jolla, California. Biology of king and emperor penguins while at sea. DPP 87-15864. $60,447.

Mitchell, Charles T. American Academy of Underwater Sciences, Costa Mesa, California. Polar diving workshop. DPP 88-16498. $23,426.

Priscu, John C. Montana State University, Bozeman, Montana. Photoadaptation by phytoplankton in permanently ice-covered antarctic lakes: Response to a nonturbulent environment. DPP 88-20591. $100,971.

Radtke, Richard L. University of Hawaii, Honolulu, Hawaii. Early life history of antarctic fishes. DPP 88-16521. $91,064.

Ross, Robin M. University of California, Santa Barbara, California. Energetics of the adults and larvae of antarctic krill. DPP 85-18872. $59,880.

Sullivan, Cornelius W. University of Southern California, Los Angeles, California. Photobiology of sea-ice microalgal species. DPP 87-17692. $80,375.

Sullivan, Cornelius W. University of Southern California, Los Angeles, California. Antarctic Marine Ecosystem Research at the Ice-Edge Zone (AMERIEZ): Synthesis. DPP 89-12529. $25,000.

Targett, Timothy E. University of Delaware, College of Marine Studies, Lewes, Delaware. Effects of acute petroleum exposure on the feeding, growth, and reproductive biology of antarctic fishes. DPP 89-12651. $19,601.

Virginia, Ross A. San Diego State University, San DIego, California. Nematode distribution and function in antarctic dry valley ecosystems. DPP 89-14655. $34,279.

Walker, Donald A. University of Colorado, Boulder, Colorado. Soil development and plant succession on pingos of the arctic coastal plain. DPP 85-20754. $13,868 ($18,000).

Wartzok, Douglas. Purdue University, West Lafayette, Indiana. Sensory components of under-ice movement and hole-finding behavior of ringed seals and Weddell seals. DPP 86-19272. $44,950.

Yen, Jeanette. State University of New York, Stony Brook, New York. Reproductive ecology of *Euchaeta Antarctica*, a carnivorous marine copepod. DPP 89-96224. $3,313.

Earth sciences

Boyce, Joseph. National Aeronautics and Space Administration, Washington, D.C. Antarctic meteorite working group. DPP 84-12353. $40,000.

Dalziel, Ian W. University of Texas, Austin, Texas. Workshop to prepare a detailed plan for U.S. participation in Antarctic Geoscience Transects. DPP 89-07205. $20,000.

Goodge, John W. Southern Methodist University, Dallas, Texas. Petrogenesis and crustal structure of metamorphic rocks in the central Transantarctic Mountains: An integrated petrologic, structural, and geochronologic study. DPP 88-16807. $6,648.

Hammer, William R. Augustana College, Rock Island, Illinois. Vertebrate paleontology and sedimentology of the Cynognathus Zone (late Early Triassic), Beardmore Glacier region. DPP 88-17023. $79,766 ($124,283).

Harrison, William D. University of Alaska, Institute of Geophysics, Fairbanks, Alaska. The West Fork Glacier surge. DPP 88-22624. $60,000 ($70,709).

Kennett, James P. University of California, Santa Barbara, California. Paleoceanographic and climatic evolution of southern high-latitude oceans based on deep-sea sedimentary sequences. DPP 89-11554. $5,000 ($80,000).

Mukasa, Samuel B. University of Florida, Gainesville, Florida. Tectonic evolution of the antarctic sector of the Pacific Margin: Mesozoic and Paleozoic development of Marie Byrd Land. DPP 87-16020. $0.

Nelson, Eric P. Colorado School of Mines, Golden, Colorado. A field-based study of some magmatic-tectonic effects of ridge collision on the continental margin of southern Chile: The taitao ophiolite and near-trench intrusions. EAR 86-18725. $10,000 ($48,168).

Starr, Lowell E. U.S. Geological Survey, Reston, Virginia. Antarctic surveying and mapping. DPP 85-12516. $349,400.

Weather at U.S. stations

Feature	August 1989			September 1989			October 1989		
	McMurdo	Palmer	South Pole	McMurdo	Palmer	South Pole	McMurdo	Palmer	South Pole
Average temperature (°C)	-26.4	-2.4	-55.9	-22.8	-2.4	-57.9	-16.4	1.2	-53.5
Temperature maximum (°C) (date)	-9.0 (29)	3.3 (23)	-37.1 (26)	-6.2 (20)	3.9 (17)	-41.3 (16)	-6.4 (13)	6.7 (10)	-34.7 (29)
Temperature minimum (°C) (date)	-40.0 (5)	-11.1 (18)	-72.8 (6)	-39.4 (10)	-10.0 (8, 25)	-72.8 (6)	-31.3 (2)	-3.7 (3, 1)	-66.8 (9)
Average station pressure (mb)	986.4	998.3	681.4	986.3	989.6	678.3	977.8	984.1	675.6
Pressure maximum (mb) (date)	1014.4 (31)	1015.5 (11)	707.8 (28)	1009.0 (13)	1020.9 (26)	694.9 (18)	991.1 (11)	1007.2 (9)	690.5 (15)
Pressure minimum (mb) (date)	967.7 (18)	980.7 (5)	660.1 (3)	956.32 (30)	955.1 (12)	654.8 (27)	954.4 (30)	950.1 (2)	657.9 (29)
Snowfall (mm)	134.6	395.0	TRACE	25.4	335.0	TRACE	104.1	171.0	TRACE
Prevailing wind direction	060°	182°	010°	080°	195°	040°	110°	045°	100°
Average wind (m/sec)	5.15	5.61	7.40	5.15	7.57	7.72	5.30	4.68	5.71
Fastest wind (m/sec) (date)	32.2 (30) 160°	39.6 (1) 020°	24.7 (24) 330°	32.2 (4) 150°	32.9 (16) 030°	20.6 (21) 040°	27.8 (11) 210°	24.2 (1) 040°	13.90 (13) 050°
Average sky cover	5.5	9/10	5.6	5.0	9/10	5.3	6.2	7.6	5.0
Number clear days	12.0	0.0	11.75	11.0	1.0	11.5	0.0	4.0	15.4
Number partly cloudy days	8.0	6.0	7.50	11.0	5.0	7.8	29.0	8.0	3.1
Number cloudy days	11.0	25.0	11.75	8.0	24.0	10.8	2.0	18.0	12.5
Number days with visibility less than 0.4 km.	1.3	---	3.25	0.3	---	3.5	0.08	---	0.25

Prepared from information received by teletype from the stations. Locations: McMurdo 77°51′S 166°40′3E, Palmer 64°46′S 64°3′W, Amundsen-Scott South Pole 90°S. Elevations: McMurdo sea level, Palmer sea level, Amundsen-Scott South Pole 2835 meters. For prior data and daily logs, contact National Climate Center, Asheville, North Carolina 28801.

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