



U.S. Antarctic Program, 2004 – 2005

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OCEAN AND CLIMATE SYSTEMS



The U.S. icebreaking research ship Laurence M. Gould is used by U.S. Antarctic Program scientists to support research including oceanography and marine biology. It is also used to transport personnel from Punta Arenas, Chile, to Palmer Station. (*NSF/USAP photo by Jeffrey Kietzmann, Raytheon Polar Service Corp.*)

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Overview

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

Antarctica should be viewed as its circulatory cooling component.

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



A researcher attaches an instrument to a tethered balloon to measure the characteristics of water vapor in the lower two kilometers of the atmosphere at Amundsen-Scott South Pole Station, Antarctica. (NSF/USAP photo by Jeff Ingles, Raytheon Polar Services Corp.)

The Ocean and Climate System Program sponsors research that will improve understanding of the high-latitude ocean environment, including the global exchange of heat, salt, water, and trace elements; there is also an emphasis on sea-ice dynamics, as well as the dynamic behavior and atmospheric chemistry of the troposphere. Major program elements include the following:

- **Physical oceanography:** The dynamics and kinematics of the polar oceans; the interaction of such forces as wind, solar radiation, and heat exchange; water-mass production and modification processes; ocean dynamics at the pack-ice edge; and the effect of polynyas on ventilation.
- **Chemical oceanography:** The chemical composition of sea water and its global differentiation; reactions among chemical elements and compounds in the ocean; fluxes of material, within ocean basins and at their boundaries; and the use of chemical tracers to map oceanic processes across a range of temporal and spatial scales.
- **Sea-ice dynamics:** The material characteristics of sea ice, from the level of the individual crystal to the large-scale patterns of freezing, deformation, and melting.
- **Meteorology:** Atmospheric circulation systems and dynamics, including the energy budget; atmospheric chemistry; transport of atmospheric contaminants to the antarctic; and the role of large and mesoscale systems in the global exchange of heat, momentum, and trace constituents.

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Antarctic Troposphere Chemistry Investigation (ANTCI).

Fred Eisele, Douglas Davis, Yuhang Wang, David Tan, and L. Greg Huey, Georgia Institute of Technology; Richard Arimoto, New Mexico State University; Detlev Helmig, University of Colorado-Boulder; Manuel Hutterli and Roger Bales, University of Arizona; Jack Dibb, University of New Hampshire; Donald Blake, University of California-Irvine; and Richard Shetter and Roy Mauldin, National Center for Atmospheric Research.

We will study sulfur chemistry in the antarctic atmosphere to enhance our understanding of the processes that control tropospheric levels of reactive hydrogen radicals, reactive nitrogen, sulfur, and other trace species for the further purpose of improving the climatic interpretation of sulfur-based signals in antarctic ice-core records. Specifically, we will be making observations of reactive hydrogen radicals, sulfuric acid and its sulfur precursors, and the flux of ultraviolet radiation. The results we derive will lead to a far more comprehensive understanding of antarctic atmospheric chemistry, as well as the factors that influence the levels and distributions of climate proxy species in antarctic ice cores.

Our major science objectives include:

- evaluating the processes that control spring and summer levels of reactive radicals in the atmospheric surface layer at the South Pole,
- assessing how representative previously obtained South Pole and coastal

measurements are in the larger context of polar plateau processes, and

- investigating the relative importance of the oxidative processes involved in the coast-to-plateau transport of reduced sulfur and determining the principal chemical transition regions.

Secondary objectives include investigating snow/firn chemical species that undergo extensive exchange with the atmosphere and assessing the different chemical forms of the trace elements and their relationships to levels of ozone and other oxidants.

Atmospheric sulfur chemistry is important in climate change because both naturally and anthropogenically emitted sulfur compounds form minute particles in the atmosphere (so-called aerosols) that reflect solar radiation, produce atmospheric haze and acid rain, and affect ozone depletion. These sulfate particles may also act as condensation nuclei for water vapor and enhance global cloudiness. The primary natural sources of sulfur are volcanic emissions and dimethylsulfide production by oceanic phytoplankton.

On the millennial time scale, the variability and background level of atmospheric aerosols can be reconstructed from ice cores. It is, however, necessary to understand how the physical and chemical environment of the process affects the relative concentrations of the oxidation products that become buried in the ice. (O-176-M/S; NSF/OPP 02-30246, NSF/OPP 02-29633, NSF/OPP 02-29605, NSF/OPP 02-30046, NSF/OPP 02-30051, NSF/OPP 02-30117, and NSF/OPP 02-30178)

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Solar radiation processes on the east antarctic plateau.

Stephen G. Warren and Thomas C. Grenfell, University of Washington.

This project is an experimental study of solar radiation processes near the surface at Concordia Base at Dome C, the French-Italian station in East Antarctica. It will be carried out in cooperation with the Laboratoire de Glaciologie et Geophysique de l'Environnement in Grenoble, France. The emphasis is on the reflection of sunlight by snow and the transmission of sunlight through clouds. The observations we gather will be relevant to climate, remote sensing, and the physics of ice and snow.

Observations of the angular pattern of solar radiation reflected from the snow surface will allow us to validate information from satellite-derived radiances. Using radiative transfer modeling through the atmosphere, we will reconcile measured surface-reflection functions with the empirical functions obtained from the Advanced Very-High-Resolution Radiometer on the polar orbiting satellites of the National Oceanic and Atmospheric Administration. (O-201-M; NSF/OPP 00-03826)

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Antarctic Meteorological Research Center (2002-2005).

Charles R. Stearns, University of Wisconsin-Madison.

The Antarctic Meteorological Research Center (AMRC) was created in 1992 to improve access to meteorological data from the Antarctic. The AMRC's mission is to conduct research in observational meteorology and the stewardship of meteorological data, along with providing data and expert assistance to the antarctic community to support research and operations. The AMRC fulfills its mission by

- continuing to maintain and expand, as appropriate, the long-term record of all meteorological data on Antarctica and the adjacent Southern Ocean and make these data available to the scientific community for multidisciplinary use (special attention will be given to obtaining data not normally or readily available by other means);
- continuing to generate satellite products, specifically, but not limited to, antarctic composite imagery, and expand and improve on them as much as possible;
- conducting research in observational meteorology, especially with regard to

climatological analyses and case studies; and

- continuing to conduct and expand, as appropriate, educational and public outreach activities associated with antarctic meteorology and related fields.

Using available meteorological interactive processing software and other standard computing tools, we will collect data from all available sources for processing, archiving, and distribution. The mission of the AMRC not only includes the opportunity to advance the knowledge of antarctic meteorology, but with the free availability of its data holdings, the AMRC gives others the opportunity to advance the frontiers of all antarctic science.

Continuing educational outreach activities on meteorology and the Antarctic, an important component of this work, have the potential to raise the science literacy of the general public, as well as the level of K-12 science education. (O-202-M/P/S; NSF/OPP 01-26262)

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Measurements of variations in atmospheric oxygen/nitrogen and argon/nitrogen ratios in carbon dioxide concentration in relation to the carbon cycle and climate.

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

Oxygen, the most abundant element on Earth, comprises about a fifth of the atmosphere. But much of the Earth's oxygen resides in other chemical species (in water, rocks, and minerals) and, of course, in the flora and fauna that recycle it (both directly and as carbon dioxide) through photosynthesis and respiration. Thus, scientists are interested in measuring the concentration of molecular oxygen and carbon dioxide in air samples; our project includes a subset of sample collections being made at a series of baseline sites around the world.

These data should help improve estimates of the processes whereby oxygen is cycled throughout the global ecosystem, specifically through photosynthesis and atmospheric mixing rates, and also improve predictions of the net exchange rates of carbon dioxide with biota, on land and in the oceans. An important part of the measurement program entails developing absolute standards for oxygen-in-air to ensure stable long-term calibration. In addition, we are conducting surveys of the oxidative oxygen/carbon ratios of both terrestrial- and marine-based organic carbon, hoping to improve the quantitative basis for linking the geochemical cycles of oxygen and carbon dioxide.

These results should help enhance our understanding of the processes that regulate the buildup of carbon dioxide in the atmosphere and of the change processes, especially climate change, that regulate ecological functions on land and sea. (O-204-P; NSF/ATM 00-00923)

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Processes driving spatial and temporal variability of surface pCO₂ in the Drake Passage.

Taro Takahashi, Columbia University, and Jorge L Sarmiento, Princeton University.

The Southern Ocean is an important component of the global carbon budget. Low surface temperatures with consequently low vertical stability, ice formation, and high winds produce a very active environment for the exchange of gaseous carbon dioxide between the atmospheric and oceanic reservoirs. The Drake Passage is the narrowest point through which the Antarctic Circumpolar Current and its associated fronts must pass and is the most efficient location for the measurement of latitudinal gradients of gas exchange.

We will expand the measurement suite and lengthen the time series of dissolved carbon dioxide gas (pCO₂) along with occasional total carbon dioxide (TCO₂) in surface waters on transects of Drake Passage. This expanded suite will include the addition of an oxygen

probe to the $p\text{CO}_2$ system, as well as the addition of nutrient and carbon-13 measurements to the discrete TCO_2 samples now collected on regularly scheduled transects on the U.S. Antarctic Program research ship *Laurence M. Gould*.

Two short cruises (4 to 5 days) will also be dedicated to providing a baseline for surface measurements with water column profiles of TCO_2 , $p\text{CO}_2$, nutrients, oxygen, and carbon-13. The continuation and expansion of the Drake Passage time series will contribute to achieving two main goals:

- quantifying the spatial and temporal variability and trends of surface $p\text{CO}_2$, TCO_2 , oxygen, nutrients, and carbon-13 in four major regimes in the Drake Passage between March 2002 and June 2007 and
- understanding the dominant processes that contribute to variability in surface $p\text{CO}_2$ and the resulting air-sea flux of CO_2 in the Drake Passage.

We will test the hypothesis that the mean annual surface water $p\text{CO}_2$ in the Drake Passage is determined by the degree of winter mixing. This has special significance in light of two scenarios that may affect the ventilation of deep water in the Southern Ocean:

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

If winter mixing determines the mean annual $p\text{CO}_2$ in the Drake Passage, the increase in atmospheric $p\text{CO}_2$ will have little effect on sea surface $p\text{CO}_2$. Because the Southern Ocean is a sink for anthropogenic carbon, further studies to understand the processes that determine this uptake and its response to climate change are needed. Our time series studies represent the highest concentration of $p\text{CO}_2$ measurements ever made both temporally and spatially in the Southern Ocean and so are an essential first step. Moreover, our study will make high-quality surface $p\text{CO}_2$ and discrete measurements of nutrients and carbon-13 available to help validate biogeochemical modeling efforts, as well as provide baseline data for studies throughout the Southern Ocean. (O-214-L/N; NSF/OPP 03-38248 and NSF/OPP 03-38155)

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AnSlope—Cross-slope exchanges at the Antarctic Slope Front.

Arnold L. Gordon, Stanley S. Jacobs, Martin Visbeck, William M. Smethie, and Peter Schlosser, Lamont-Doherty Earth Observatory, Columbia University; Alejandro H. Orsi and Thomas Whitworth, Texas A&M University; R. Dale Pillsbury, Oregon State University; and Laurence Padman, Earth and Space Research.

The importance of cold water masses originating in the Antarctic to the global ocean circulation and climate is now understood, but the processes by which these water masses enter the deep ocean circulation are not. Our program will address this issue.

Our primary goal is to identify the principal physical processes that govern the transfer of shelf-modified dense water into intermediate and deep layers of the adjacent deep ocean. At the same time, we seek to understand the compensatory poleward flow of waters from the oceanic regime. The upper continental slope is the critical gateway for the exchange of shelf and deep ocean waters. Here the topography, velocity, and density fields associated with the nearly ubiquitous Antarctic Slope Front (ASF) must strongly influence the advective and turbulent transfer of water properties between the shelf and oceanic regimes.

We will join the research icebreaker *Nathaniel B. Palmer* for three transects over a 12- to 14-month period beginning in austral summer 2003 and use an integrated observational and modeling program to achieve four objectives:

- determine the mean structure and principal scales of variability of the ASF and estimate its role on cross-slope exchanges and mixing of adjacent water masses;
- determine the influence of slope topography on frontal location and outflow of dense shelf water;

- establish the role of frontal instabilities, benthic boundary layer transports, tides, and other oscillatory processes on cross-slope advection and fluxes; and
- assess the effect of diapycnal (shear-driven and double-diffusive) mixing, lateral mixing, and nonlinearities on the rate of descent and fate of outflowing, near-freezing shelf water.

Our measurements will focus on the outer continental shelf and upper slope of the northwestern Ross Sea. We will also take benthic float measurements and develop the techniques for parameterizing cross-front exchanges in regional and global models. Ongoing studies by Italian and German researchers will complement our work and provide a test-bed for our parameterizations of cross-front exchange. Synergistic projects will sample for geochemical tracers, nutrients, and oxygen isotopes; make casts to measure ocean microstructure; investigate surface-water properties during transects to and from New Zealand; and survey the near-surface environment, including elements of its ecosystem and sea ice field.

AnSlope cruise III (NBPO4-08), the final cruise of this project, is the "late winter" component. We plan to occupy as many CTD/LADCP (Conductivity Temperature Depth/Lowered Acoustic Doppler Current Profiler) stations as possible across and along the ASF in the Ross Sea. These include a transect near previously deployed bottom-moored arrays of current, temperature, conductivity, and pressure sensors. Synergistic projects will sample for geochemical tracers, nutrients, and oxygen isotopes; make casts to measure ocean microstructure; investigate surface water properties during transects to and from New Zealand; and survey the near-surface environment, including elements of its ecosystem and sea ice field. (O-215-N; NSF/OPP 01-25172, NSF/OPP 01-25521, NSF/OPP 01-25523, NSF/OPP 01-25084, NSF/OPP 01-25431, and NSF/OPP 01-25602)

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***In situ* measurements of halogen oxides in the troposphere.**

Linnea M. Avallone, University of Colorado–Boulder.

The phenomenon of sudden and complete boundary-layer ozone loss has been observed at many northern high-latitude sites and more recently in Antarctica. Simultaneous observations of other species indicated that ozone loss was often tied to increases in pollutants, suggesting a relationship to the transport of polluted air from the northern continents into the more pristine arctic environment. However, subsequent studies showed that the ozone loss phenomena in the Arctic are tightly linked to catalytic gas-phase halogen chemistry similar to that responsible for Antarctica's ozone hole. Although the exact mechanism for the sudden boundary-layer ozone losses remains uncertain, it is clearly linked to active bromine. Modeling studies suggest that the ultimate source of bromine is sea salt, which undergoes transformation when it is airborne in particulate form or dissolved in surface snow.

Snow is both an important source and sink for reactive bromine. Widespread bromine activation in coastal regions seems to coincide with the average edge of the annual sea ice. Previous measurements of halogen oxides, ozone, and nitrogen oxides have revealed that McMurdo Station does indeed see some significant ozone loss events, many directly related to local pollution (perhaps power plant emissions). There were also a number of low ozone periods during and immediately after large southern storms. These bear further study.

We will attempt to answer three questions:

- How often is surface ozone at McMurdo Station affected by local pollution?
- What reactive bromine compounds are present and can we identify their source(s)?
- How much is the snow surface directly affecting ozone?

The relatively clean antarctic environment, far from most sources of anthropogenic sources of nitrogen oxides and hydrocarbons, will allow us to better constrain the natural role of snow- and ice-covered surfaces on the boundary-layer ozone budget. As sea-ice coverage changes in response to a changing climate, the frequency and duration of boundary-layer ozone loss related to the availability of bromine gases derived from sea

salt may change as well. A more thorough understanding of the nature and mechanism (s) for boundary-layer ozone losses will lead to better ways to predict the impact of future climate change on the chemical composition of the high-latitude troposphere. (O-251-M; NSF/OPP 04-11437)

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South Pole monitoring for climatic change—U.S. Department of Commerce NOAA Climate Monitoring and Diagnostic Laboratory.

David Hofmann, Climate Monitoring and Diagnostics Laboratory, National Oceanic and Atmospheric Administration.

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

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

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

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

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The Drake Passage High-Density XBT/XCTD Program.

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

We will study the seasonal to interannual variability and long-term change in upper-ocean temperature and geostrophic transport in the Drake Passage by means of high-density sections obtained on each crossing of the research ship *Laurence M. Gould*. Closely spaced temperature and salinity measurements are currently collected on six to eight crossings a year during which scientific shipboard personnel launch expendable bathythermographs (XBTs), supplemented by expendable conductivity-temperature-depth (XCTD) probes.

The information we gather from these studies will lead to the establishment of a high-quality database with which to study the magnitude and depth of penetration of seasonal signals, the connections to atmospheric forcing, and the effects of interannual variations such as those associated with the Antarctic Circumpolar Wave. These sections will supplement the approximately 20 sections obtained since September 1996. Continuing data analysis is carried out in cooperation with the Argentine Antarctic Institute in Buenos Aires. (O-260-L; NSF/OPP 00-03618)

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Collection of atmospheric air for the NOAA/CMDL worldwide flask-sampling network.

David Hofmann, Climate Monitoring and Diagnostics Laboratory, National Oceanic and Atmospheric Administration.

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

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

Personnel at Palmer Station collect air samples to be analyzed for carbon dioxide, methane, carbon monoxide, and stable isotopic ratios of carbon dioxide and methane. Flasks are also collected for analysis of halocarbons, nitrous oxide, and other trace constituents.

These measurements allow us to determine the rates at which concentrations of these atmospheric constituents change; they also point to likely sources, sinks, and budgets. We collaborate with climate modelers and diagnosticians to explore how the rates of change for these parameters affect climate. (O-264-P; NSF/NOAA agreement)

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Tracers of biological productivity and gas exchange.

Steven Emerson, University of Washington.

The export of carbon from the surface of the ocean is one of the processes controlling the atmospheric partial pressure of carbon dioxide ($p\text{CO}_2$), which greatly influences the Earth's climate. Changes in atmospheric $p\text{CO}_2$ over glacial time scales are often interpreted as a response to changes in the ocean's biological carbon pump. Models of the pump are limited by our understanding of the mechanisms that control it in different areas of the ocean. Satellite color images hold great promise for determining the biological pump globally, but only if the images can be validated by field measurements. To date, this calibration has been achieved in only four places in the ocean: the long-term time series locations and parts of the Equator.

Our goal, therefore, is to develop experimental methods of improving our knowledge of the ocean's biological carbon pump. We will use an upper-ocean oxygen mass balance method to determine the biologically produced flux of organic carbon from the euphotic zone of the ocean. In previous research, we approached the problem by measuring a suite of gases at a Hawaii site and by *in situ* measurements on a mooring.

We will build on these studies to improve methods for determining net biological oxygen production so that they can be used in different areas of the ocean. We will also build on our analytic ability to determine nitrogen, argon, and neon in sea water to characterize physical mechanisms like bubble processes that influence the flux and saturation state of oxygen in the upper ocean. Accurate measurements and a simple model can be used to determine the fraction of gas supersaturation caused by bubble processes in surface waters. We will measure this value as a function of wind speed on several short cruises in the Drake Passage.

By developing a correlation between bubble flux and wind speed, we will be able characterize the bubble process in locations where it is not possible to measure gases

and to improve estimates of the biologically produced oxygen flux from the ocean by using climatological surface ocean oxygen concentrations. Understanding the marine biological pump well enough to incorporate it into ocean-atmosphere models will greatly enhance the ability to predict climate. (O-271-L; OCE 02-42139)

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Operation of an aerosol sampling system at Palmer Station.

Colin G. Sanderson, U.S. Department of Energy, Environmental Measurements Laboratory.

Radionuclides, some of which occur naturally in the surface air, are atoms emitting radioactive energy. It is these, as well as nuclear fallout and any accidental releases of radioactivity, that the Environmental Measurements Laboratory's (EML's) Remote Atmospheric Measurements Program (RAMP) is designed to detect and monitor.

Since 1963, EML, which is part of the U.S. Department of Energy, has run the Global Sampling Network to monitor surface air. The RAMP system provides on-site analysis in 13 different locations around the world, including Palmer Station. Using a high-volume aerosol sampler installed in 1990, a gamma ray spectrometer, and a link to the National Oceanic and Atmospheric Administration's ARGOS satellite system, we will continue to sample the air at Palmer Station for anthropogenic radionuclides. Our data are analyzed and archived at EML and contribute significantly to its database on radionuclides. (O-275-P; NSF/DOE agreement)

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Antarctic automatic weather station program: 2004-2007.

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

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

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

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Solar/wind-powered instrumentation module development for polar environmental research.

Anthony D. Hansen, Magee Scientific Company.

We will develop and test a self-contained, transportable module that will provide a sheltered, temperature-controlled interior environment for standard, rack-mounted equipment. Electric power will be provided by solar panels and a wind generator, backed up by batteries with several days' capacity. The module will offer both alternating and direct current for internal and external use and will include data logging and communications capability for practical application in a polar environment.

At South Pole Station, McMurdo Station, and almost all other inhabited camps in Antarctica, aircraft, helicopters, ground vehicles, diesel generators, and other sources release exhaust, which can affect the environment. The collection of real-time pollution data at downwind locations can be used to assess the amount of pollution and the

effectiveness of efforts to improve air quality. At this time, optimal placement of measuring instruments is severely limited by the availability of power and shelter, a limitation that this module is intended to overcome.

Although designed to facilitate measurements at the South Pole, the module will be helpful in a variety of other situations where remotely located equipment is to be used for long-term monitoring of environmental phenomena. The module will have no emissions at all and therefore will not affect the environment that it is designed to study. Also, it can be placed anywhere it is needed. (O-314-M; NSF/DBI 01-19793)

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Southern Ocean current observations and acoustic Doppler current profiling from U.S. antarctic research vessels.

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

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

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

Our long-term objectives are to:

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

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

Finally, after the ship leaves dry dock, we will replace the current logging computer with a newer one and upgrade the acquisition and processing software to accommodate the new system. (O-315-N and O-317-L; NSF/OPP 03-37375 and NSF/OPP 03-38103)

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Physics and mechanics of the breakup of warm Antarctic Sea ice: *In situ* experiments and modeling.

John Dempsey, Clarkson University, and David Cole, U.S. Army Cold Regions Research and Engineering Laboratory.

We will investigate the breakup of antarctic sea ice in McMurdo Sound in light of recent findings indicating that the fracture strength of first-year ice is strongly dependent on size, that the deformation and fracture on the scale of tens of meters is influenced by microstructural variation (or anisotropy), and that the characteristic flaws of sea ice (such as brine drainage features) give rise to length scales relevant to transitions in fracture behavior.

We will investigate the following topics:

- coupled deformation-diffusion influences on the fracture of sea ice (due to fluid transport within the ice matrix),
- the influence of loading rate versus specimen size on fracture behavior,
- fractal descriptions of the failure surfaces, and
- a new cyclic loading geometry that should benefit the constitutive measurements.

The direct tensile cyclic loading geometry we will use will allow constitutive testing to be conducted independent of fracture testing and at significantly higher stress levels than were previously attained. We will make combined acoustic emission (AE), pore fluid pressure, crack-opening-displacement, and fracture surface roughness measurements for each test, thereby enabling quantitative comparison between deformation and AE-deduced fracture energy and the fractal dimension. The ability of sea water and brine to be transported within the ice matrix will be examined both theoretically and experimentally to formulate a suitable poroelastic fracture mechanics model.

Our findings will give important insight into the underlying mechanisms of ice breakup and will significantly improve the reliability of models of this process. In addition, our work will improve the understanding of and ability to model the deformation and fracture of antarctic sea ice at scales applicable to the breakup of ice sheets.

We will involve two graduate students, and every effort will be made to recruit them from underrepresented groups. These students will participate in Clarkson University's K-12 Project-Based Learning Partnership Program. CDs will be produced, and a Web page will be maintained to broaden the dissemination of research and educational material. Moreover, a different K-12 teacher will be invited for each of the three trips planned. (O-316-M; NSF/OPP 03-38226)

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