INTERNATIONAL TRANS-ANTARCTIC SCIENTIFIC EXPEDITION (ITASE)

An aerial view of the Nimrod Glacier as it flows the Transantarctic Mountains to the Ross Ice Shelf. *(NSF/USAP photo by Josh Landis)*

From its original formulation in 1990, the International Trans-Antarctic Scientific Expedition (ITASE) has coordinated the efforts of scientists from several nations to collect and interpret a continent-wide array of environmental parameters. This cooperative endeavor is geared to produce an improved description and understanding of environmental change in Antarctica over approximately the past 200 years. These original ITASE scientific objectives have been adopted as key science initiatives by both the International Geosphere Biosphere Program (IGBP) and the Scientific Committee on Antarctic Research (SCAR).

In 1996, the National Science Foundation (NSF) held a workshop to develop a science and implementation plan for the U.S. contribution to ITASE (called U.S. ITASE). Because of the long-standing U.S. research effort in West Antarctica, U.S. ITASE chose to focus its activities there. At the NSF workshop, participants developed a multidisciplinary research plan that integrates different approaches to environmental research. The primary scientific lenses through which West Antarctica is being examined are meteorology, remote sensing, ice coring, surface glaciology, and geophysics. The plan has four phases:

- In phase 1, meteorological modeling and remote sensing were used to plan sampling strategies in support of the major objectives of U.S. ITASE.
- Phase 2 initiates ground-based sampling over four study areas (corridors). Despite the broad spatial sampling of West Antarctica that was proposed, the logistic requirements for this sampling are modest and highly efficient.

- Phase 3 will continue ground-based sampling at a limited number of key sites where monitoring is required.

- Phase 4 follows through with data interpretation and modeling.

The U.S. component of ITASE (which has established a wide range of general scientific objectives) is trying to refine answers to the following questions:

- At what rate is the mass balance over West Antarctica changing?

- How do the major oceanic and atmospheric circulation systems (for example, the El Niño Southern Oscillation) influence the moisture flux over West Antarctica?

- How and why does climate (that is, temperature, accumulation rate, atmospheric circulation) vary over West Antarctica on seasonal, interannual, decadal, and centennial scales?

- What are the frequency, magnitude, and effect (local to global) of any extreme climate events recorded in West Antarctica?

- What is the impact of anthropogenic activity (for example, ozone depletion, science work, airborne pollutants) on the climate and atmospheric chemistry of West Antarctica?

- How much has biogeochemical cycling of sulfur, nitrogen, and carbon, as recorded in West Antarctica, varied over approximately the past 200 years

Radar studies of internal stratigraphy and bedrock topography along the U.S. ITASE traverse.
Robert W. Jacobel, Saint Olaf College.

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

This radar system works as a complement to the one operated by the Cold Regions Research and Engineering Laboratory. Theirs is a high-frequency radar, most suited to the shallower portion of the record down to approximately 60 meters (m); it can detect near-surface crevasses. Our radar system is most sensitive at depths below 60 m and is able to depict deep bedrock and internal geological layers deep in the ice. (IU-133-O; NSF/OPP 98-14574)

Science management for U.S. ITASE.
Paul A. Mayewski, University of Maine.

The Science Management Office (SMO) coordinates the effort developed for the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE), the broad aim of which is to develop an understanding of the past 200 years of west antarctic climate and environmental change. ITASE is a multidisciplinary program integrating remote sensing, meteorology, ice coring, surface glaciology, and geophysics. To marshal this effort, SMO runs a series of annual workshops to coordinate the science projects that will be involved in ITASE. It also establishes and operates the logistics base that supports ground-based sampling in West Antarctica. (IU-153-A; NSF/OPP 97-25057)

U.S. ITASE glaciochemistry.
Paul A. Mayewski, University of Maine, and Loren D. Meeker, University of New Hampshire.

Among the research targets for scientists in the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE) are the impact of anthropogenic activity on the climate and atmospheric chemistry of West Antarctica and the variations in biogeochemical cycling of sulfur and nitrogen compounds over the past 200 years.

Begun during the 1999-2000 austral summer, this 5-year project focuses on glaciochemical analyses of the major anions and cations to be found in shallow- and intermediate-depth ice cores collected on the U.S. ITASE traverses. The ionic composition of polar ice cores provides one of the basic stratigraphic tools for relative dating. These data can also be used to document changes in chemical-species source emissions, which in turn facilitate mapping and characterization of the major atmospheric circulation systems affecting the West Antarctic Ice Sheet. (IU-153-B; NSF/OPP 97-25057)

Snow and firn microstructure and transport properties: U.S. ITASE.
Mary R. Albert and Robert E. Davis, U.S. Army Cold Regions Research and Engineering Laboratory.

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

This project does the field and laboratory work to characterize snow and firn properties along the traverses of the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE) in West Antarctica. We provide field measurements of snow and firn properties near the surface [down to 2 meters (m)], including surface roughness, permeability, density, grain size, surface-to-volume ratio, and tortuosity. In the laboratory, firn cores from as deep as 20 m will be analyzed for these same properties and for their microstructure. Ultimately, we will develop a transport model to elucidate the nature of the air/snow/firn exchange and the firnification process at the various sites along the U.S. ITASE traverse. (IU-155-O; NSF/OPP 98-14676)

Hydrogen peroxide, formaldehyde, and subannual snow accumulation in West Antarctica: Participation in the west antarctic traverse.
Roger C. Bales, University of Arizona.

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

This project will collect samples and take atmospheric measurements along the traverses of the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE). The wide-ranging extent of these traverses will focus on a variety of locations, covering much of the west antarctic region and reflecting a range of different depositional environments. The study of atmospheric chemistry requires good estimates of the interannual patterns of snow accumulation at subannual resolution in the pits and cores.

We will measure the concentration of seasonally dependent species (including hydrogen peroxide, nitrate, and chloride) on all samples. When supplemented by stable isotope and ionic analyses done by others, these data will provide a highly resolved accumulation record. We will then use a recently developed, physically based atmosphere-to-snow transfer model to elucidate the photochemistry that led to the concentrations in the snow/firn.

These snow chemistry data will also shed light on the interannual variability of snow accumulation over a wide area of West Antarctica. In addition, the data we develop on current atmospheric levels of hydrogen peroxide, higher peroxides such as methylhydroperoxide, and formaldehyde will constrain model boundary conditions and the state of photochemistry in the austral summer. (IU-158-O; NSF/OPP 98-14810)

Mass balance and accumulation rate along U.S. ITASE routes.
Gordon S. Hamilton, University of Maine.

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

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

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

We will also investigate the iceflow effects on accumulation rates derived from U.S. ITASE ice-core records. At sites along flow lines, ice cores record the integrated accumulation rate history of the core site for a certain distance up-glacier. Changes in surface topography along this flow line will lead to apparent variations in accumulation rate in the ice-core record. By studying local ice dynamics (for example, horizontal velocities, surface slope) around each ice-core site, we will be better able to understand why the accumulation rate in the core records varies. (IU-178-O; NSF/OPP 98-15510)

The physical properties of the U.S. ITASE ice cores.
Debra Meese, U.S. Army Cold Regions Research and Engineering Laboratory.

As part of the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE), our objective is to examine, measure, and analyze the visual stratigraphy and physical and structural properties of ice cores spanning the past 200 years of snow accumulation in Antarctica.

- First, visual stratigraphy-this will delineate the annual layer structure for dating purposes and determine (to as great a depth as possible) the accumulation variability over the full length of a stratigraphically dated core.
- Second, depth-density profiles-the rate of snow and firn densification depends on both the in-situ snow temperature and the rate at which the snow is deposited. These data will be used to derive average snow accumulation rates for those sites where annual layer structure is difficult to decipher or where stratigraphic analysis fails altogether.
- Third, the mean crystal size over the full length of a core-crystal growth is a strongly temperature-dependent process, and measurements to be made on U.S. ITASE cores will help bridge a significant gap in the mean annual temperature data between -31º and -50ºC. Data on crystal size can also be used (in conjunction with ice loads based on density profile measurements) to extract mean accumulation rates for those sites where the stratigraphic dating of cores along the traverse routes proves difficult or impossible to accomplish; this is likely to occur at the sites where the temperature is the lowest and snow accumulates the least. (IU-185-O; NSF/OPP 99-80434)

Stable-isotope studies at West Antarctic U.S. ITASE sites.
Eric Steig, University of Washington; James White and Christopher Shuman, Goddard Space Flight Center, National Aeronautics and Space Administration.

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

Our objectives are to

- obtain detailed oxygen-18, deuterium, deuterium-excess, and stratigraphic histories in snowpits at most or all of the U.S. ITASE coring sites;
- provide direct calibration of the isotope/climate relationship at each site through a combination of direct (automatic weather stations) and indirect (passive microwave satellite) temperature measurements;
- obtain isotope profiles covering the past 200 years; and
- use the results to provide climate histories at high temporal and broad spatial resolution across West

Antarctica for the past two centuries.

These climate histories should provide the context to test the relationships that have been proposed among isotopes, moisture source conditions, synoptic scale climatology, and site-specific meteorological parameters. They will also enhance our ability to interpret isotope records from older and deeper antarctic ice cores. (IU-193-O; NSF/OPP 99-04947)

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

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

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

We are also using a wide range of frequencies (as high as 10 gigahertz and as low as 100 MHz) to distinguish between conductivity and density as a cause of the reflections. The horizon tracking develops spatially averaged, historical accumulation rates that can be correlated with global positioning system data to find the effects of topography on local accumulation rates. In addition, the radar is also being used for advanced crevasse detection. (IU-311-O; NSF/OPP 98-14589)

Deposition of the HFC degradation product trifluoroacetate in antarctic snow and ice.
Joseph McConnell, Desert Research Institute.

The threat to global ozone posed by the migration of chlorofluorocarbons into the atmosphere, a threat recognized by the 1987 Montreal Protocol and the passage of the 1995 Clean Air Act in the United States, has led to the release into the biosphere of some worrisome substitutes. One of these, trifluoroacetate (TFA), is a highly persistent atmospheric degradation product of the halogenated ethane derivatives.

Since this class of chemicals is now in widespread industrial use, there is growing concern that TFA will accumulate in aquatic ecosystems. Pilot data on TFA deposition at the South Pole indicate a significant increase in the 1990s. However, extant data on the preindustrial (background, or baseline) concentration of TFA in meteoric and surface waters, including antarctic ice, are ambiguous; thus, the impact of anthropogenic TFA on these background concentrations is hard to specify. Ice-core records can provide a useful proxy for background and enable models of anthropogenic TFA deposition to be developed.

Our primary objective is to use ice cores and snow pits at the South Pole to develop a record of TFA deposition for the past millennium, especially the past 20 years. This preindustrial to present record of TFA in near-surface snow and ice at the South Pole and in West Antarctica will be unique. It should elucidate the origin, transport, and fate of this contaminant over Antarctica and, possibly, the globe. More generally, it enhances the context for assessing potential impacts on antarctic ecosystems from natural and anthropogenic sources by providing vital data on the regional and long-range movement, and the eventual fate, of contaminants. (IU-323-O; NSF/OPP 00-87776)