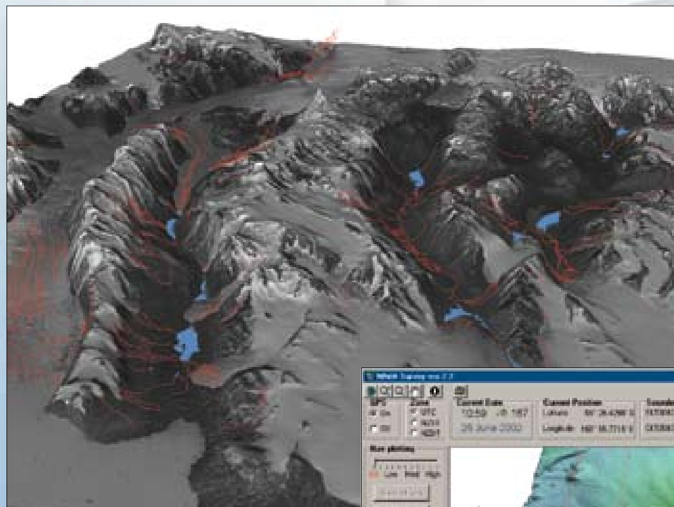
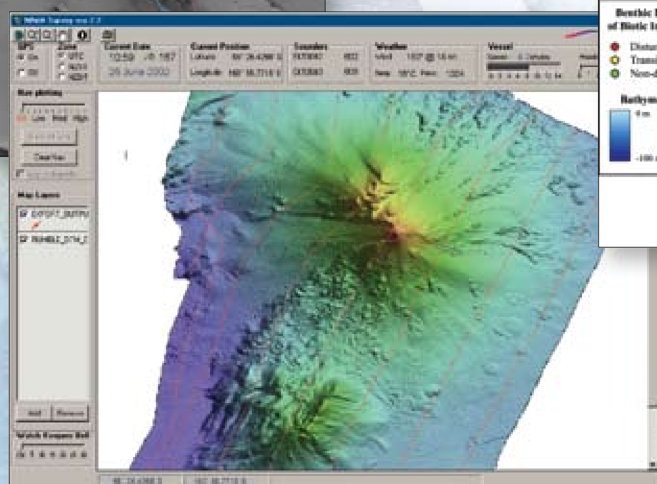
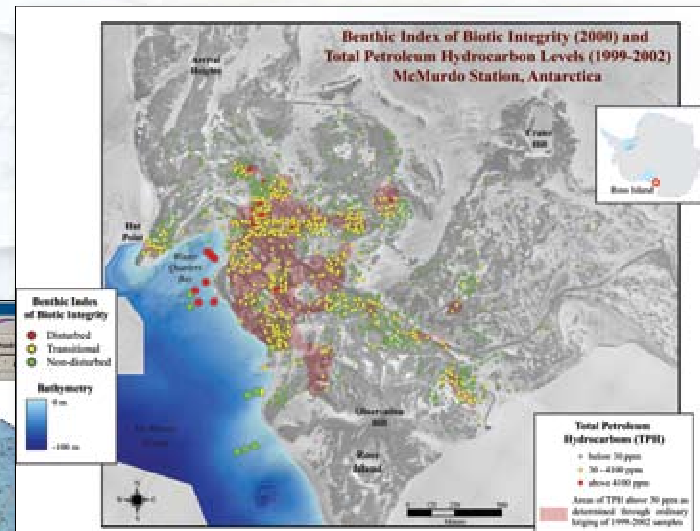
GIS Best Practices

GIS in Polar Regions







August 2009

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What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

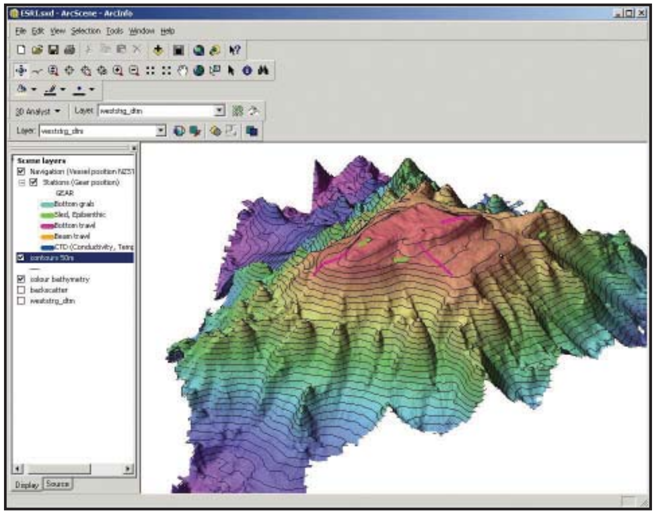
From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

Amongst the Icebergs, GIS Innovation Aids Antarctic Research

By Kevin Mackay, National Institute of Water and Atmospheric Research, New Zealand

In 1904, Captain Robert Falcon Scott and the crew of *Discovery* left the Ross Sea at the end of Scott's first expedition to Antarctica. Despite the onset of scurvy and malnutrition, as well as the loss of all their dogs, Scott and his team had reached 82°17'S—the furthest south any expedition had yet gone.

A hundred years later, the hurricane force winds and high seas that confronted a New Zealand-led international research team in the Ross Sea seemed little hardship in comparison. The Ross Sea 2004 voyage of discovery was undertaken by New Zealand's National Institute of Water & Atmospheric Research (NIWA) from January to March 2004. It was jointly funded by the New Zealand Ministry of Fisheries and Land Information New Zealand (a department responsible for official land and seabed information).

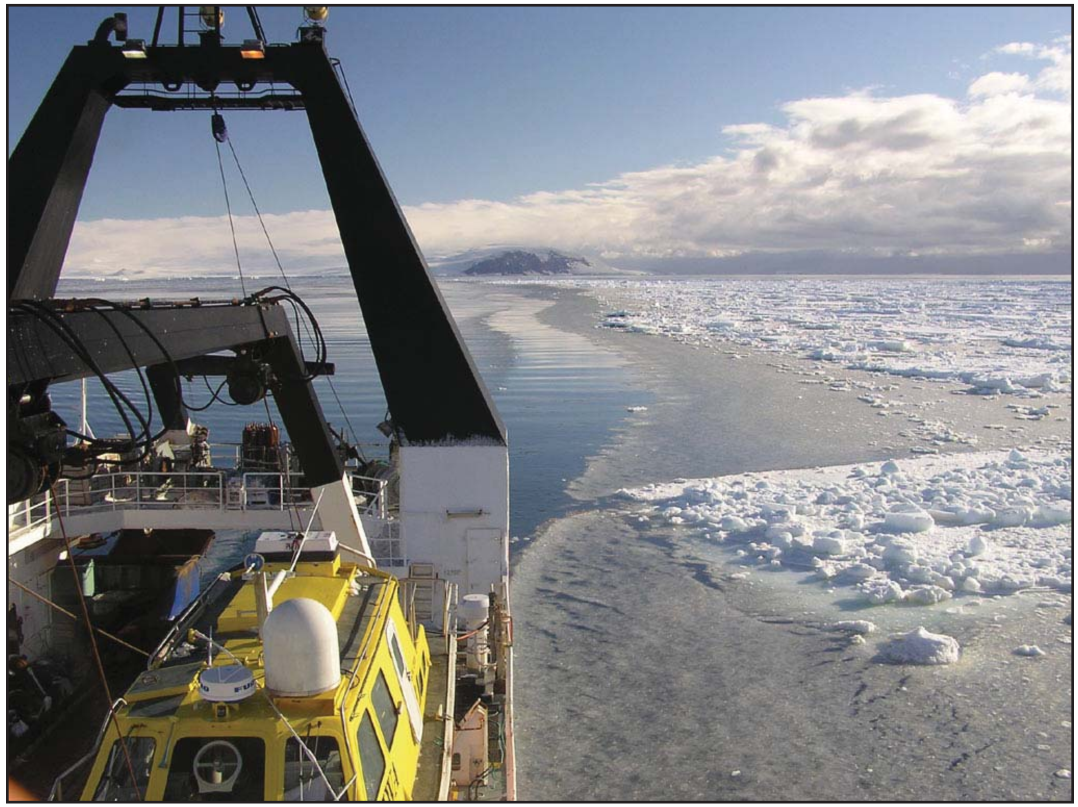


ArcGIS 3D Analyst allows 3D visualizaion of the seabed. The red and green lines show selected areas for sampling on a seamount off Sturge Island in the Balleny Island group, Ross Sea, Antarctica.

The voyage undertook a biodiversity study, in cooperation with the Italian Antarctic Research Programme, and continued hydrographic survey work in the northwestern Ross Sea.

It was the fifth Antarctic expedition for NIWA's 70-meter deepwater research vessel *Tangaroa.*

The biodiversity researchers wanted to describe and quantify the diversity of bottom-dwelling invertebrates and fish. They wanted to understand how different environmental factors affect the structure of these marine communities. Ultimately, this information will help scientists predict the likely impact of changes in ice conditions resulting from climate change or human activities.

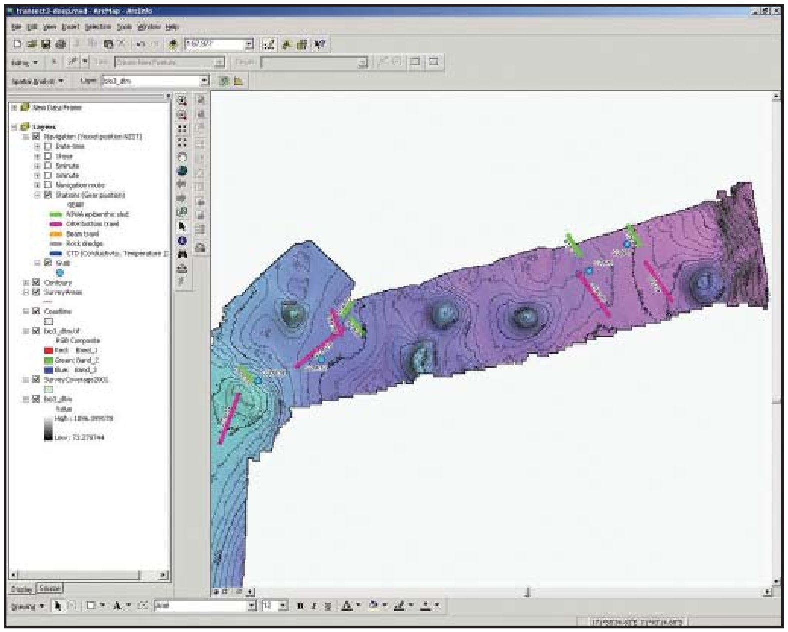


NIWA's ice-strengthened deep-sea research vessel, Tangaroa*, working in the Ross Sea.*

Much of the study area had not been surveyed in detail before. The scientists needed to

- Identify where to take samples representing a wide range of habitats and sea depths from nearshore (about 50 meters deep) to the edge of the continental shelf (about 750 meters).
- Determine which sort of sampling gear to use in a particular location to reduce the risk of expensive equipment being damaged or lost and to minimize damage to fragile ecosystems on the Antarctic seafloor.
- Act quickly in case changing ice conditions closed off areas that were open and workable a few hours earlier.

NIWA used ArcGIS Desktop (ArcInfo) with the ArcGIS Spatial Analyst and ArcGIS 3D Analyst with ArcScene extensions to enable people with no specialist GIS training or experience to produce extremely high-resolution images of the seafloor within minutes of surveying.



ArcGIS screen, showing biodiversity sampling sites on a newly surveyed section of seafloor, Ross Sea, Antarctica.

Tangaroa uses a Simrad EM 300 multibeam echo sounder to produce the equivalent of an aerial photograph of the seafloor. The EM 300 is mounted on the ship's hull and works by transmitting (pinging) "beams" of sound to the seafloor and measuring the time it takes for the signals to return. This time is directly related to water depth. With 135 beams fanning out across the seabed for each ping, up to 4.5 km of seabed can be mapped in a single pass.

Once the multibeam data has been "cleaned" to remove marks made by shoals of fish and the like, the multibeam operator onboard *Tangaroa* uses a special menu designed by NIWA using ARC Macro Language (AML), which means that no experience in ArcInfo Workstation is needed to produce the GIS images. The operator simply starts ArcInfo and types a command to launch the menu. The operator can browse directories, choose a file to process, adjust the settings, and then click "run" to produce whatever view is required.

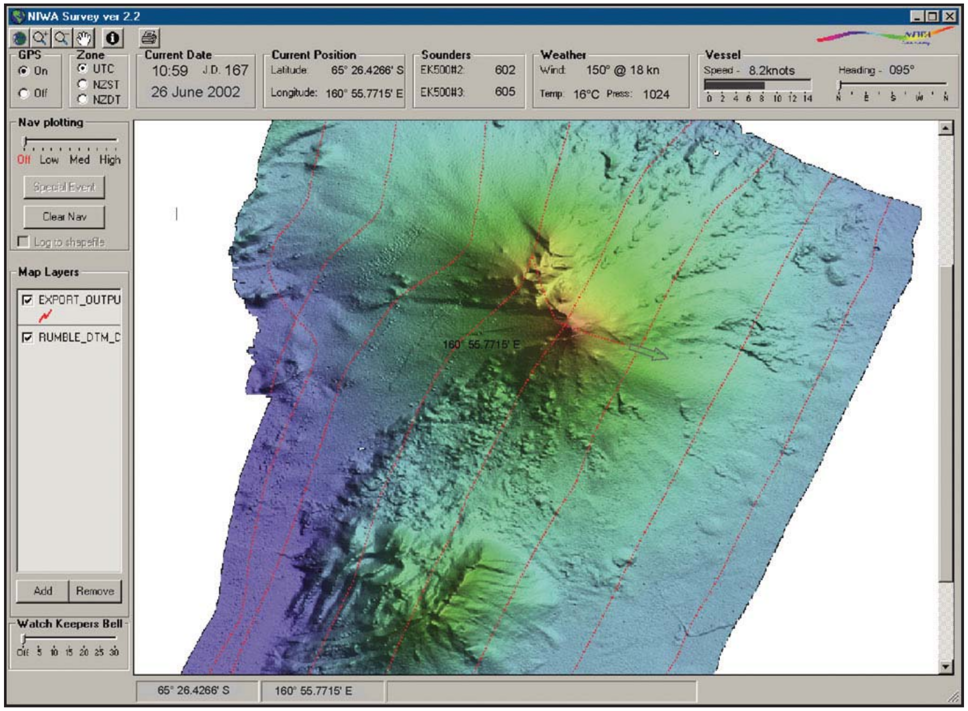
The team had planned to map all depth ranges over an entire survey area before collecting samples, but the voyage encountered two storms. The team spent seven and one-half days attempting to take shelter from winds gusting up to 95 knots and swells approaching 12 meters. With time, money, and safety at stake, the scientists opted to map a single depth range, take samples immediately, and then do more mapping.

As soon as each survey line was completed, the multibeam data was processed and maps of the survey area were produced within minutes, thereby minimizing vessel downtime before sampling operations could begin.

When mapping the seafloor with a multibeam echo sounder, the strength (or amplitude) of the returned signal depends on the nature of the seabed. Thus it is possible to assess what the substrate is made of (mud, sand, gravel, bedrock, or a mixture of these) and how rough or lumpy the seafloor is.

A standard template was created in ArcGIS to produce charts of any area of interest so the scientists could accurately plan the deployment of sampling gear in the right depth and in a suitable seabed type. The ArcGIS Spatial Analyst extension allows scientists to analyze the slope and aspect of the seabed to aid their decision making.

ArcGIS 3D Analyst with ArcScene was used to help scientists visualize the topography and inspect the study area at any angle, from any direction, and with varying vertical exaggerations.



NIWA Survey, built using MapObjects, is used to display the position of the vessel (gray arrow and trailing red dots) relative to processed multibeam data (georeferenced TIFF images) as well as other GIS map layers (shapefiles). (All images are reproduced courtesy of MFish & LINZ.)

NIWA software developers also wrote an application called NIWA Survey that provides a real-time view of the vessel's position. This application incorporates georeferenced TIFF images and shapefiles generated from the multibeam processing and overlays the position of the vessel as a tracking layer. The scientists were able to monitor Tangaroa's position from any of the laboratories onboard, giving the sampling equipment the best chance of reaching its desired target.

The benefits of using ArcGIS Desktop in planning biodiversity sampling in the Antarctic were many. It reduces the number of misdrops and aborted gear deployments and hence increased the amount of sampling that can be done within the survey period, as well as limits environmental damage. Despite the storms, the survey achieved its main objectives. NIWA and its international collaborators now face several years of work to fully define the diversity of fish and invertebrates found on the survey.

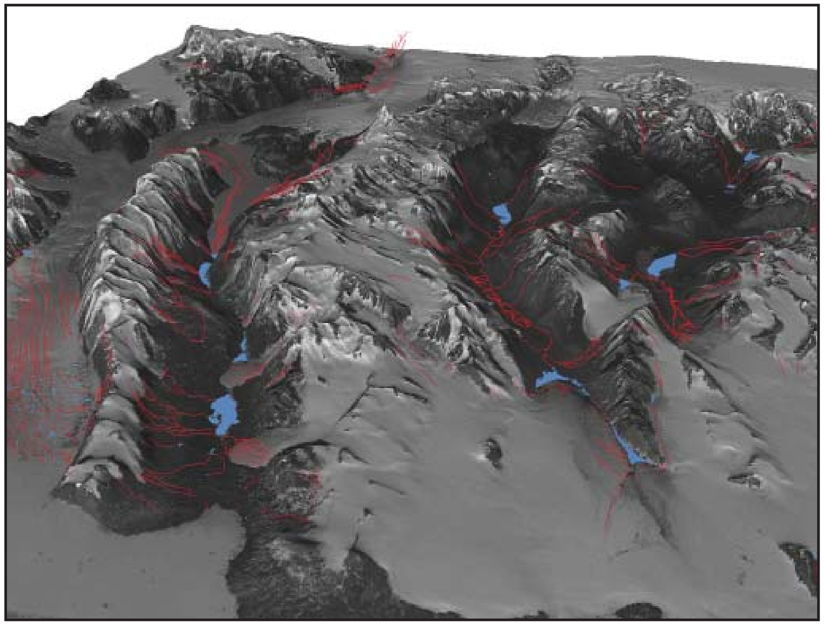
For More Information

Visit www.rosssea2004.govt.nz and www.niwa.co.nz.

(Reprinted from the Fall 2004 issue of *ArcNews* magazine)

Scientific Research Uses GIS in the McMurdo Dry Valleys, Antarctica

By Michael Prentice, University of New Hampshire



Looking west over the McMurdo Dry Valleys. From left to right (south to north), the valleys are named Taylor, Wright, and Victoria. The permanently ice-covered lakes are shown in blue. Red lines represent intermittent streams.

Many scientists, primarily from the United States and New Zealand, work on a wide variety of research projects in the McMurdo Dry Valleys (MDV), South Victoria Land, Antarctica. Covering 8,000 square kilometers, MDV is the largest ice-free area on Antarctica. How Antarctica formed, the role of Antarctica in global climate change, and the biologic processes necessary to sustain life in a polar desert are a few of the scientific questions being addressed. The scientists, as well as science program administrators and science support personnel, all need the capability to search for and use digital, highly resolved geospatial information describing the physical features of MDV. Additionally, because the location of sampling points is vital to sharing scientific data, the MDV science community needs a geospatial technology to manage and facilitate access to the data. A few specific examples follow.

- Geologists need digital rectified imagery and topography, as well as sediment and soils data, to identify and map rock formations and sediment deposits. Accurate maps permit improved reconstruction of processes by which these features formed.

- Biologists studying the diverse microscopic biota and microenvironments of the MDV polar desert, a site in the National Science Foundation (NSF) Long-Term Ecologic Research Program, need digital geospatial information on rock, sediment, ice, and water features to set the context for their work.
- Planetary geologists studying Mars using MDV features as a terrestrial analog need digital geospatial access to geological, biological, and meteorological data.
- McMurdo Dry Valleys are a Specially Protected Area under the Antarctic Treaty; thus, the NSF's programs need accurate geospatial information to manage research and tourism activities so as to minimize impact.

To address this need, a University of New Hampshire (UNH) team led by this author produced the first GIS of the major physical features of MDV. This effort was made possible by funding from NSF and collaboration with the U.S. Geological Survey (USGS) and the New Zealand Institute of Geological and Nuclear Sciences (NZ IGNS). The GIS has two major components. The first is landscape framework data. This includes a network of geographic control points, a satellite image basemap for use in mapping at a scale of 1:50,000 and aerial photographic basemaps for mapping restricted areas at a scale of 1:10,000. The second component is information describing the major physical features of MDV, principally bedrock geology, surficial geology and geomorphology, soils, glaciers, lakes, and streams. Both geospatial and tabular information for these features have been captured. A time dimension was added because MDV hydrologic features changed in size over the last few decades because of climate change.

The GIS project, referred to as VALMAP (for Valleys in Antarctica: Layered Mapping, Analysis, and Planning), involved numerous scientists from the United States and New Zealand. They chose ArcGIS Desktop (ArcInfo) as the GIS software because of its many features and wide usage both in the United States and New Zealand. They also used ESRI Business Partner Leica Geosystems GIS & Mapping's ERDAS IMAGINE software for imagery processing. The work was accomplished on both UNIX and PC machines.

Framework Data

VALMAP digitally captured the metadata for geographic control points (GCPs) collected previously in MDV by USGS and Land Information New Zealand. A USGS/VALMAP team also went into the field to collect new GCPs, as well as photographs of existing GCPs. A GCP point theme was produced as was extensive metadata, including imagery of the GCPs. Three SPOT images were rectified in ERDAS IMAGINE using these GCPs and served as the satellite image basemap for VALMAP.

Aerial photographic coverage of MDV is extensive (more than 20,000 frames) and dates to the late 1940s. VALMAP produced an arc theme that inventories all 250 flight lines and provides metadata. ArcInfo software's ARC Macro Language (AML) was used to produce point coverages of the center points of the individual frames. Michael Routhier, GIS scientist at UNH's Institute for the Study of Earth, Oceans, and Space, notes, "The power of GIS gives researchers easy access to invaluable resources that were previously difficult to access with conventional mapping methods."

Because detailed mapping was an important goal of VALMAP and aerial photography provided the only high-resolution imagery available at low cost, VALMAP personnel determined that some photographs should be rectified. "ERDAS IMAGINE provided us with a low-cost solution for producing quality high-resolution images for mapping," explains GIS scientist Stanley Glidden, also at UNH's Institute for the Study of Earth, Oceans, and Space.

Additional framework elements added to the VALMAP GIS by using ArcInfo geoprocessing tools were separate surface topographies for glaciers, unconsolidated sediment, and bedrock. The 50 m surface contours that were provided to VALMAP from the USGS 1977 topographic maps of MDV, as well as contours from miscellaneous topographic maps digitized by VALMAP, were the starting point. VALMAP added contours from point estimates of depth to glacier base, depth to lake bottom, and depth to bedrock from a variety of scientific studies. Prentice explains, "The dimensions for ice, lake, and sediment bodies today are fundamental to validating geophysical models that simulate past fluctuations in these systems. Despite meager data density, getting these data sets into the GIS is important for raising community awareness."

Thematic Data

Thematic layers on major physical features were provided by experts in their respective fields. Bedrock geologic information over much of MDV was provided by Mike Isaac, Ian Turnbull, and Dave Herron, of NZ IGNS, from the quadrangle maps published by that agency. The locations of more than 500 soil pits in MDV were reconstructed by the original investigators, Jim Bockheim, professor at the University of Wisconsin; Iain Campbell of Land and Soil Consulting NZ; and Graham Claridge, NZ IGNS, using points marked on aerial photographs that were also identifiable on VALMAP image basemaps. The value of the extensive morphological, physical, chemical, and climatic data from these pits was increased dramatically once the pits were geolocated. The distribution, character, and laboratory data describing unconsolidated MDV sediments, both at and below surface, was provided by a UNH team using the literature and original data. ArcInfo permitted VALMAP to improve consistency and agreement between the different data sets that share boundaries. Additionally, explains James Gaynor, UNH graduate student in the Department of Earth Sciences, "GIS, especially ArcGIS Desktop and its ArcMap application, strongly facilitated on-screen mapping of glacial deposits given the ability to interpret and edit multiple layers and tabular data simultaneously using various color, shading, and transparency options. This saved time because it cut out the step of producing hand drawn map sheets."

Thematic layers were also produced for the dynamic elements of the MDV landscape, including glaciers, semipermanent snowbanks, lakes, and streams. Some themes were produced for different years using the aerial photographs for change detection. Trevor Chinn, New Zealand National Institute of Water and Atmospheric Research, provided point data detailing the seasonal budget of snow accumulation and ice ablation on selected MDV alpine glaciers between 1972 and 1984. The sum of these terms gives the mass balance of the glaciers, which indicates whether they are growing or shrinking. Anna Krusic, UNH Earth Sciences graduate student, used ArcInfo to integrate point mass balance data with the surface topography to determine mass balance over glacier surface elevation zones and total glacier mass balance.

The VALMAP GIS has been used and significantly extended by MDV Long-Term Ecological Research project members. VALMAP GIS components are being made available using ArcIMS 9 at the USGS Atlas for Antarctic Research Web site (usarc.usgs.gov/antarctic_atlas) and at www.valmap.unh.edu.

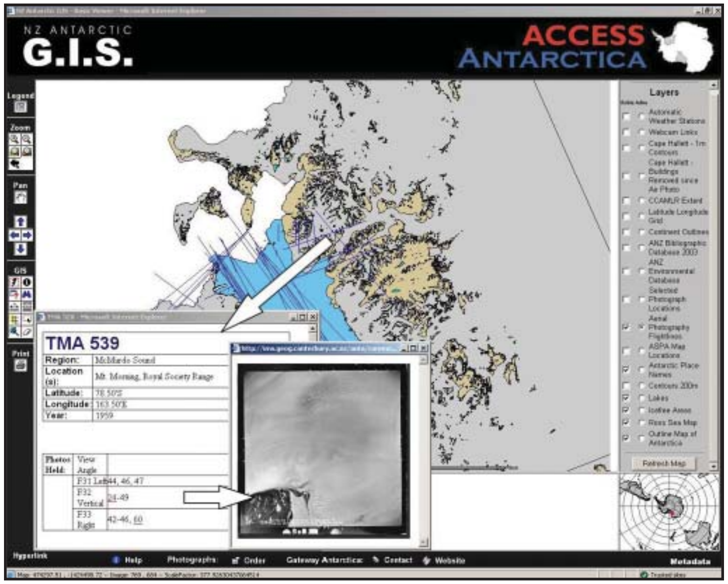
(Reprinted from the Fall 2004 issue of *ArcNews* magazine)

Access Antarctica: The New Zealand Antarctic GIS

By Paul Barr, GIS Technician, Gateway Antarctica, University of Canterbury, Christchurch, New Zealand

The Internet now extends its reach over the entire planet, and that includes Antarctica. Antarctica may be a vast expanse of snow, ice, rock, and yet more ice, but it is also a hotbed of international science, with many nations having research programs and bases on the Antarctic continent.

Where the Internet and Antarctica come together is in the need for data display management, and Internet mapping tools allow this to take place in a user-friendly and effective manner, accessible to anyone, anywhere.



Looking through dusty filing cabinets for Antarctic aerial photographs will become a thing of the past, thanks to the New Zealand Antarctic GIS. Users can simply zoom to their area of interest and click on the nearest flight line with the hyperlink tool to see flight line information and preview images.

Access Antarctica is the Web site (www.anta.canterbury.ac.nz/gis) through which Gateway Antarctica, the Centre for Antarctic Studies and Research at the University of Canterbury in Christchurch, New Zealand, is making Antarctic data and information resources available online via Internet mapping tools.

The New Zealand (NZ) Antarctic GIS provides a basemap using data from the Scientific Committee on Antarctic Research's Antarctic Digital Database. This allows a myriad of other Antarctic-related, digitally stored information to be presented in its geographic context, opening up a powerful, interactive geographic search using a point and click interface. Users can search for publications by drawing a box around their area of interest and at the same time find related aerial photographs, automatic weather station locations, protected area maps, documents, and much more.

The ArcIMS platform was chosen to implement the online GIS system because it integrates well with existing ESRI GIS resources and ensures compatibility with other emerging Antarctic Internet map server-based systems.

Thanks to ArcIMS, this pipe dream of data management can now be a reality and is quickly spreading around the world. The NZ Antarctic GIS is just one example of this. In the Antarctic realm, there are many GIS systems already established. New Zealand has two more, Landcare Research's Ross Sea Region Soils GIS and the Ministry of Fisheries GIS, which covers New Zealand and the Southern Ocean. Further afield there is the United States Geological Survey's *Atlas of Antarctic Research, the Australian Antarctica Division Atlas,* and the online Chinese Antarctic geodatabase, run from the Chinese Antarctic Center of Surveying and Mapping. The long-term goal, and subject of much discussion, is the integration of these different systems using a distributed model to provide a complete Antarctic data system to the end user, meaning that Antarctica will no longer be out of reach, despite its location at the end of the world.

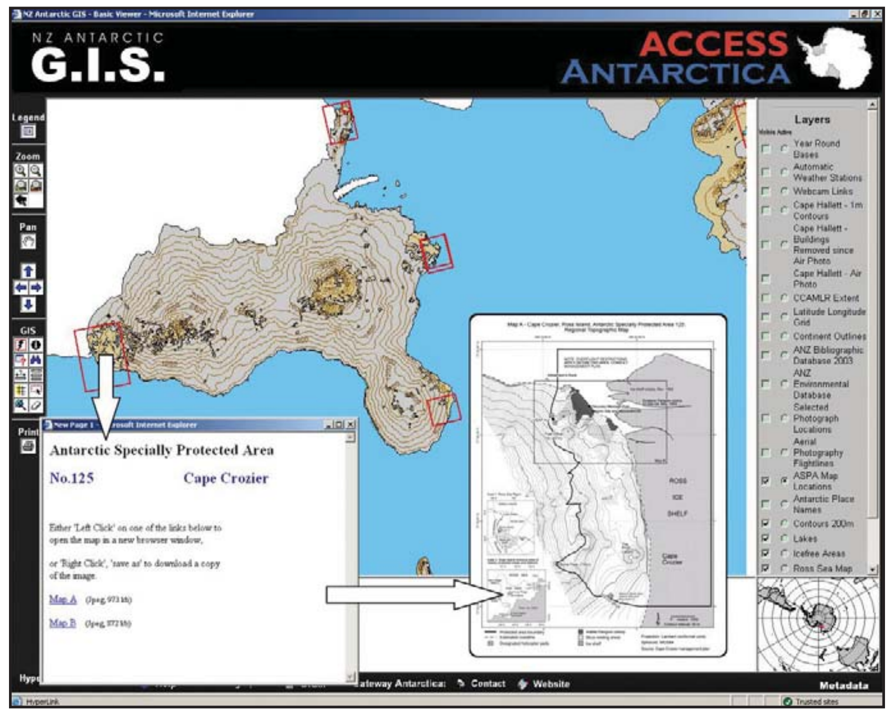
Although the NZ Antarctic GIS holds some layers for the entire continent, the focus remains on the Ross Sea region in keeping with New Zealand's Antarctic policy. This also means there is more Ross detail in the NZ Antarctic GIS, including digitized aerial photography flight lines and the location of New Zealand science events on the ice.

Maximizing Aerial Photos and Flight Lines With GIS

Aerial photography in a region so remote and inaccessible as Antarctica does not come cheap, and since the major United States Navy photographic missions of the 60s and 70s, there has been little increase in aerial photography of Antarctica.

Because most of these photos were acquired 30 to 40 years ago, there is no easy-to-use method for searching the imagery. The best is a series of flight lines drawn on multiple maps and transparencies for each area. Researchers may try to find the original photograph among thousands, only to find the study site had been missed.

New aerial photographs are seldom taken in Antarctica because of the high cost. Therefore, satellite imagery is by far the most convenient way to gather new topographic and visual information across terrain of such vast expanse. The resolution of these satellite images is fast approaching that of the original aerial photos.



The New Zealand Antarctic GIS provides a portal for environmental managers in Antarctica. Here hyperlinks from the ArcIMS viewer provide ready access to protected area maps.

So why bother organizing old aerial photographs at all? The answer lies in the extremely topical issue of climate change. The photos provide an invaluable historical record of the environment 30 to 40 years ago. Comparing the record provided by these old aerial photographs with satellite imagery of the present-day environment is a boon to investigation into changes in the distribution and extent of ice and the associated climate change.

Therefore, we are back to the original issue of finding a way to access these images quickly, easily, and efficiently. This is where the NZ Antarctic GIS using ArcIMS comes in. The flight lines and photo centers are digitized into ArcGIS Desktop (ArcInfo) using shapefiles, and this information is then transferred to ArcIMS. From here, using the hyperlink functionality of ArcIMS, users can zoom into their region of interest; select the relevant area using the select tool; and then, with one more mouse click (using the hyperlink tool), users can view photo information, availability, acquisition date, etc., and even preview the image itself. All this can be done from their own computer anywhere in the world with Internet access.

Environmental Management at the Bottom of the World

Environmental management is difficult under the best of conditions. Imagine protecting an area that is thousands of kilometers away, dark for half the year, and nearly completely frozen and covers millions of square kilometers.

Coping with vast and disparate information sources, which are all required to inform the management process, is not an easy task.

As Antarctica is designated a "natural reserve," environmental protection of the vast area is vital. Accurately identifying unique items, such as Antarctic species and sensitive ecosystems, is vital for environmental managers.

With ice covering 98 percent of the Antarctic continent, keeping track of the 2 percent fragment of ice-free land is difficult. On Ross Island alone, there are more than one-half dozen Antarctic Specially Protected Areas (ASPAs), and GIS has proven itself to be a great tool for enabling management of these ASPAs.

Existing vector and new GPS data points were transformed, using ArcGIS Desktop (ArcInfo) and its ArcMap application, into a series of maps of different scales that illustrates important sites for management across Ross Island from the emperor penguin colony at Cape Crozier to the historic huts at Cape Evans and Cape Royds.

Indeed, the NZ Antarctic GIS is able to serve information about this protected area at the click of a button across the Internet. This includes downloadable copies of the protected area maps and text of the management plans. It is also a user-friendly forum that allows policy makers to easily obtain important geographic information.

In addition, the NZ Antarctic GIS is also capable of performing a bibliographic search using a quick query or buffer feature: for example, find all the records for papers published about sites within 50 km of Ross Island. This is possible because of the inclusion of the Geo-Referenced Layer of the Antarctic Papers Bibliography, which is maintained by Antarctica New Zealand.

Begin a Personalized Journey

GIS has layers for all kinds of users from scientists to primary school students and everyone in between. The Webcam layer is an example of this diverse content range, providing a layer of links to cameras at different sites around the frozen continent allowing users to begin their own virtual tour. To begin your own journey, visit Access Antarctica at www.anta.canterbury.ac.nz/gis.

(Reprinted from the Fall 2004 issue of *ArcNews* magazine)

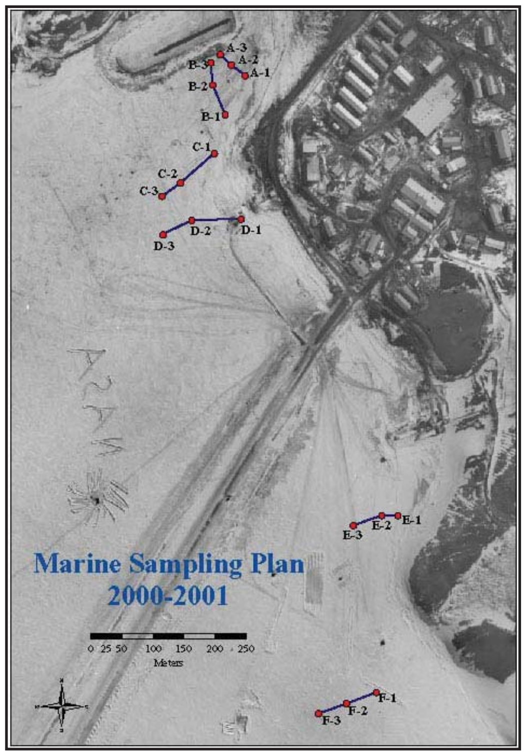
Long-Term Environmental Monitoring at McMurdo Station, Antarctica, Supported With GIS

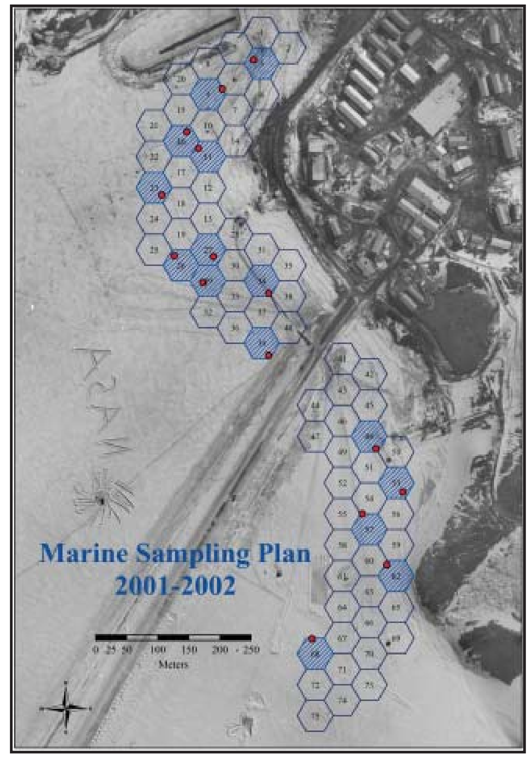
By Andrew Klein, Mahlon C. Kennicutt II, and Steve Sweet, Texas A&M University; and Paul Montagna and Sally Applebaum, University of Texas

In 1996, Texas A&M University and University of Texas researchers began developing a long-term environmental monitoring program for McMurdo Station, Antarctica. McMurdo Station is the largest U.S. Antarctic base and the logistical hub of the U.S. Antarctic Program (USAP) run by the National Science Foundation (NSF). It is located on the southernmost ice-free tip of Ross Island (77° 51´ S, 166° 40´ E). The station has been in continuous operation since 1955. The site was first visited by Sir Robert F. Scott's *Discovery* Expedition of 1901-1904, which overwintered there. Later British expeditions would utilize the historic hut, which still stands today, that was constructed during Scott's first expedition.

A panoramic view of McMurdo Station.

Environmental stewardship is a cornerstone of USAP activities, and the logistics provided by McMurdo Station enable environmentally sound science to be conducted across Antarctica. All activities in Antarctica are governed by the international Antarctic Treaty, which reserves the region south of 60° S latitude for peaceful purposes and fosters international cooperation in scientific research. In October 1998 the Protocol on Environmental Protection to the Antarctic Treaty entered into force. This protocol requires that activities in Antarctica be planned and conducted to limit adverse environmental impacts. McMurdo Station's long-term environmental monitoring program, developed jointly by Texas A&M University and the University of Texas researchers, fulfills the protocol's requirements for monitoring the impact of ongoing activities.





GIS aided University of Texas marine biologists in determining the location of marine sampling sites in McMurdo Sound. They located sampling sites at specific depths along four transects across areas of known disturbances. A fifth control transect was located in an indisturbed area near the station. Sampling sites were determined by depth and by viewing relevant infrastructure overlaid on bathymetric contours, including the station's sewage outfall and seawater intake.

Because of the small spatial extent (meters or less) of much of the human impacts at McMurdo Station, careful consideration of geographic location is important in undertaking any environmental monitoring program. ArcGIS Desktop (ArcView and ArcInfo) and its ArcMap application were used extensively throughout the project's year-long planning phase and its three-year pilot phase, beginning in 1999, and continue to be used during implementation of the monitoring program beginning in 2003.

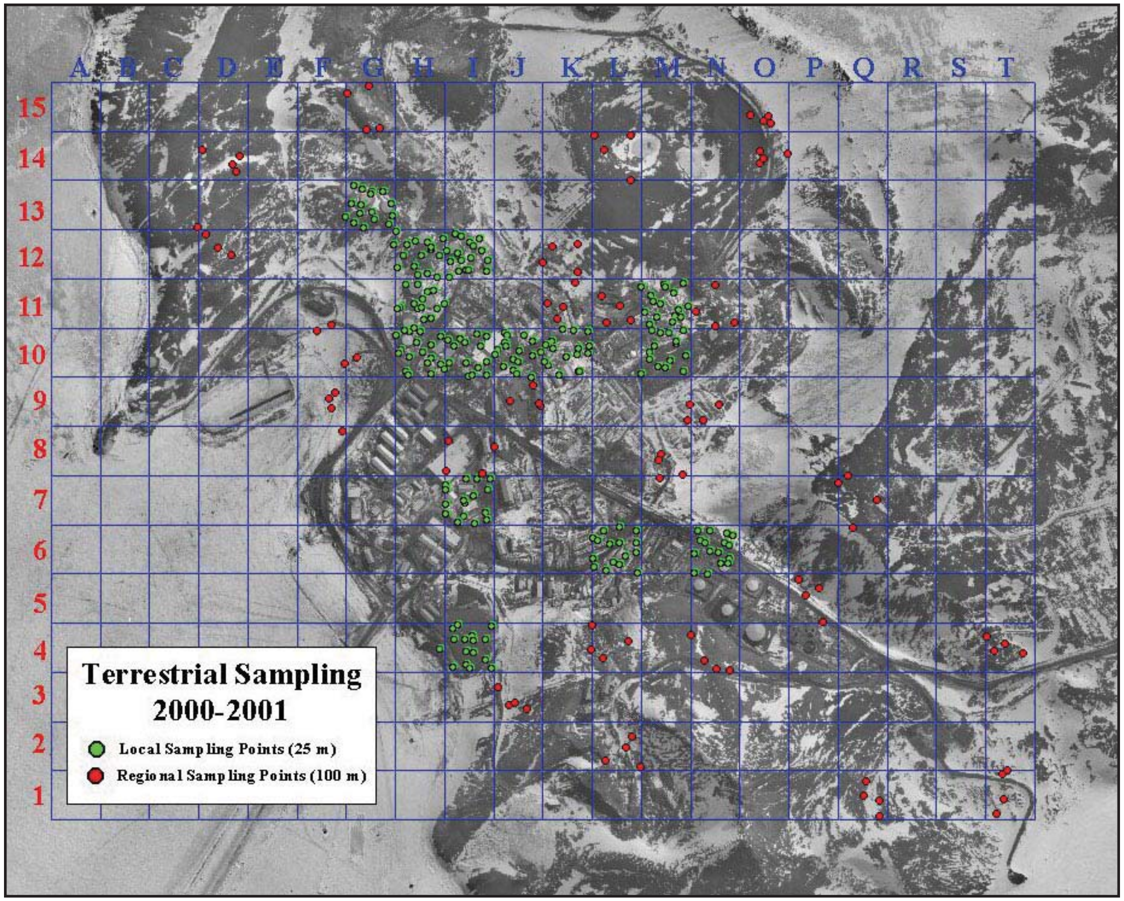
During the planning phase, researchers used ArcView to compile a spatially referenced database of historical environmental studies. Using ArcView to visualize the locations of known contamination and historical environmental sampling over station infrastructure maps and orthorectified aerial photographs aided greatly in developing strategies to sample the landscape surrounding and adjacent to the station.

The largest environmental contaminant at McMurdo Station is fuel, on which the entire USAP runs. Fuel spills, largely a legacy of former practices, have resulted in meter-sized areas of contamination. Researchers used ArcView and ArcInfo to design and test several stratified random sampling schemes capable of efficiently detecting changes in the overall levels of contamination at the station and to monitor changes at specific areas of concern. Nested sets of square and hexagonal sampling grids were created using ArcInfo and its ARC Macro Language (AML). Coarse 100 m grids enabled sampling across the entire station, while finer 25 m and 5 m grids allowed sampling of the heterogeneous patterns of contamination at impacted sites, such as around fuel tanks.

GIS helped assure the collection of a spatially random sample. Researchers randomly selected grid cells to sample and determined the sampling location within each cell through loose coupling of ArcInfo with statistical and other mathematical software packages. They navigated to the random sampling sites in the field using maps created in ArcView in conjunction with a differential GPS unit. Once a sampling site was located, they collected a surface sample and later geochemists at the Geochemical and Environmental Research Group (GERG) at Texas A&M University analyzed it for total petroleum hydrocarbons (TPH) and selected metals.

Using this GIS-enabled approach, nearly 2,000 terrestrial samples have been collected to date during four field seasons. This field collection program would not be possible without the GPS support and expertise provided for Antarctic research by UNAVCO, Inc. (www.unavco.org), a nonprofit organization that supports and promotes GPS and other high-precision geodetic techniques in the earth sciences.

ArcView, and more recently its ArcMap application, serves as the primary means of analyzing the spatial patterns of specific measured contaminants, such as TPH or lead. Maps produced by ArcMap are a primary vehicle for disseminating information to a wide range of audiences. Information dissemination is important as the monitoring program is designed to support environmental management and decision making.



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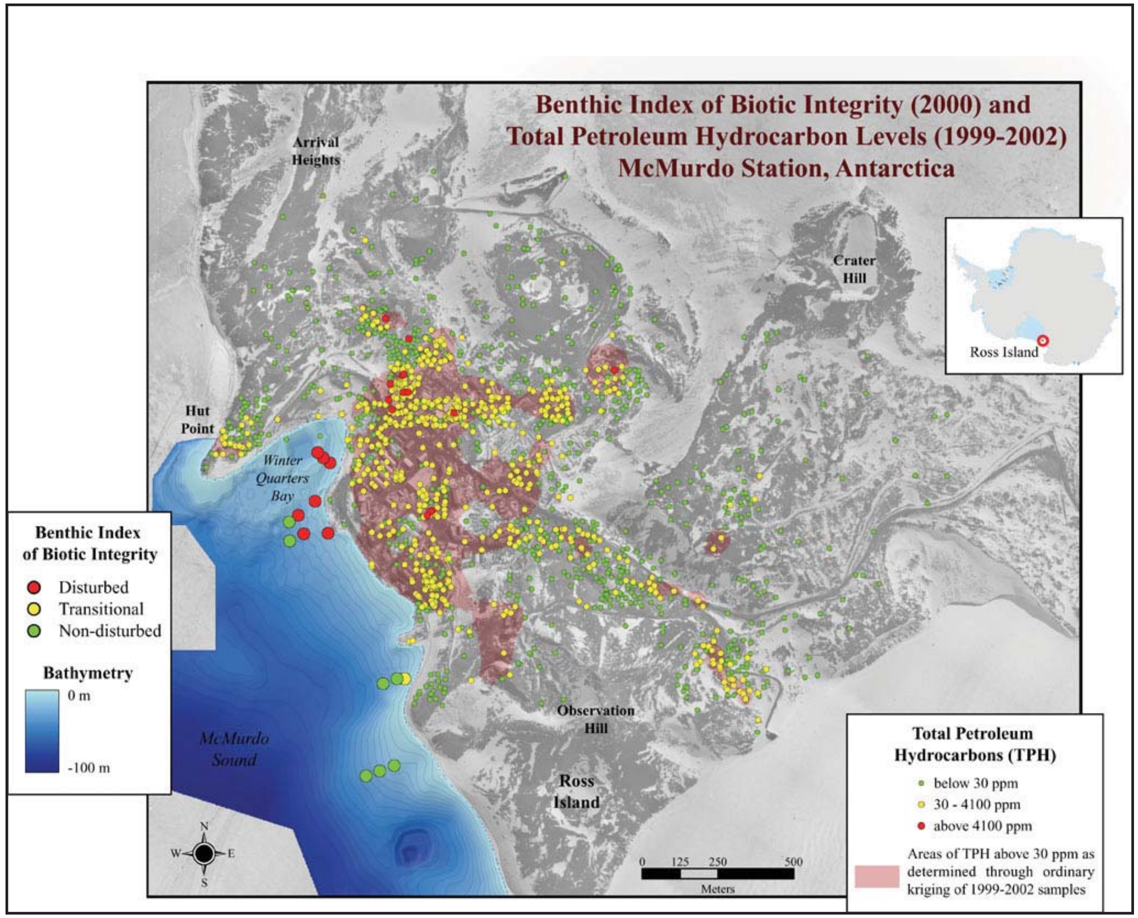
ArcView aided University of Texas marine biologists in determining the location of marine sampling sites in McMurdo Sound. They located sampling sites at specific depths along four transects across areas of known disturbances. A fifth control transect was located in an undisturbed area near the station. Sampling sites were determined by depth and by viewing relevant infrastructure overlaid on bathymetric contours, including the station's sewage outfall and seawater intake.

The sites are reoccupied each year to assess change over time in response to changes in station operations, such as a new sewage treatment plant, and to capture gradual long-term changes. At each marine site, divers from Raytheon Polar Services, the primary support contractor to USAP, collect sediment cores for community structure analysis, sediment chemistry, and toxicity. Sediment toxicity is analyzed on the station by University of Texas marine biologists using light producing bacteria (Microtox). The sediment cores and terrestrial samples are shipped back to Texas via cargo ship. At Texas A&M University, geochemists measure levels of TPH and polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and selected metals in the terrestrial and marine samples. University of Texas researchers use the community structure of organisms in the cores to compute a benthic index of biological integrity, which measures the ecological integrity of each marine site.

An extensive archive of aerial photography owned by the United States Geological Survey (USGS) exists for Antarctica, including McMurdo Station. Using the ArcGIS Desktop application ArcMap, researchers mapped footprints of buildings, fuel tanks, and roads from aerial photographs dating as far back as 1960. They created a disturbance history of the station by overlaying a hexagonal grid over the station and its immediate environs. The date of the aerial photograph recording the initial physical disturbance in each polygon was then identified in ArcMap. This mapping revealed that the majority of physical disturbance around McMurdo Station occurred within the first 15 years of the station's existence.



Levels of disturbance in McMurdo Sound near the station as measured by a Benthic Index of Biotic Integrity and Total Petroleum Hydrocarbon Levels measured at the station overlaid on an orthorectified aerial photograph and color-coded bathymetry. Most human inpact is confined to areas within a few hundred meters of the station.

ArcGIS will continue to play an important role in supporting McMurdo Station's long-term environmental monitoring program. By allowing a user's current position to be viewed over aerial photographs and station maps, mobile GIS technologies—such as ArcPad—will allow field sampling to be accomplished more efficiently. Moreover, GPS is currently being used to collect extensive location information about operational activities across USAP, including helicopter landing sites, fuel caches, and spills. As the quantity of this geolocated, environmentally relevant information increases, GIS will play an increasingly important role in environmental stewardship of United States activities in Antarctica.

Andrew Klein, Mahlon C. Kennicutt II, and Steve Sweet are with Texas A&M University, and Paul Montagna and Sally Applebaum are with the University of Texas. The project's Web site (www.gerg.tamu.edu/antarctica) is hosted by the Geochemical and Environmental Research Group at Texas A&M University.

(Reprinted from the Fall 2004 issue of *ArcNews* magazine)

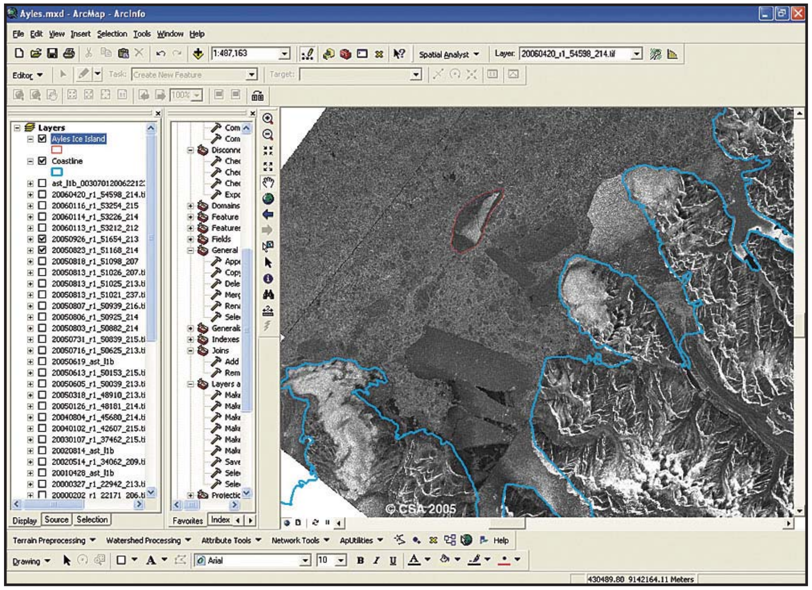
Mapping the Ayles Ice Shelf Break

GIS Tracks 33-Square-Mile Ice Island in the Arctic

Highlights

- Volume of ice loss calculated with GIS.
- ArcInfo helps visualize causes of the break.
- Unique "microbial mat" habitat also analyzed.

It was the Arctic ice shelf collapse heard around the world: this past New Year's weekend, the BBC, the Canadian Broadcasting Corporation, CNN, the *New York Times,* and other media organizations broke the story that the ancient Ayles Ice Shelf in Canada had cracked from its mooring in an Ellesmere Island fjord and floated into the Arctic Ocean.



Ayles ice island, delineated by a red polygon, broke from Ellesmere Island (outlined in blue) on August 13, 2005. The RADARSAT background images were processed by the Alaska Satellite Facility at the University of Alaska in Fairbanks.

The ice shelf calving was discovered by Laurie Weir of the Canadian Ice Service in September 2005 while she was comparing satellite images of the ice shelves. She contacted Luke Copland from the Laboratory for Cryospheric Research at the University of Ottawa in Canada, who launched a scientific investigation into what occurred. Though the news spread in some scientific circles and was reported at a conference, journalists did not catch word of the story for 15 months.

With the possible culprit being global warming, all eyes turned north, where the newly formed ice island sits safely—so far—in sea ice about 10 miles off Ellesmere. "Right now it's frozen in off the coast," says Derek Mueller, a geographer and postdoctoral researcher at the Geophysical Institute University of Alaska Fairbanks, who helped to investigate and write a paper about what happened to the 33-square-mile Ayles Ice Shelf.

Though the ice island has only traveled a short way since the August 13, 2005, incident and there's no obvious current danger to ships or oil drilling platforms, the chance of trouble ahead exists, Mueller says. "It could break away at any time and float further down to the south, and it would likely start breaking up as it floats," he states. "These ice islands will be tracked by the Canadian Ice Service so that ships will be warned," adding that the possibility exists, though slim near term, that the ice island could drift down toward the coast of Alaska with the Beaufort Gyre current and into shipping lanes and toward oil drilling operations. "Worst-case scenario, if it did hit one of the oil drilling platforms, it could cause a lot of damage," Mueller adds.

Though not enough evidence exists to blame global warming for the collapse of the Ayles Ice Shelf, Mueller says that what occurred is consistent with other signs of climate change in the Arctic. "Taken together, all of these signs are worrisome," he says.

Sizing Up the Ayles Ice Shelf

Having studied the ecosystems on the Ellesmere Island ice shelves as part of his Ph.D. research in biology, Mueller was invited to help investigate the Ayles Ice Shelf breakup and contribute to a paper the researchers were writing about the calving. In his work, through the university's ESRI campuswide site license, Mueller used ArcInfo software to create a map that helped researchers visualize the chain of events and learn how much ice was lost from the fjord on the north end of Ellesmere Island.

Eric Bottos from McGill University, Derek Mueller from the Geophysical Institute at the University of Alaska, and Alexandra Pontefract from McMaster University sample microbial mats on the Markham Ice Shelf (August 2005).
(Photo courtesy of Denis Serrazin).

"The break was visible, but what we wanted to know was, What was the size of the ice island when it broke away?" Mueller says, adding that mapping and analysis showed it shrank from about 41 square miles to 33 square miles. "Aside from the loss of the Ayles Ice Shelf, 20 percent of the nearby Petersen ice shelf was also lost just after August 13, 2005. And some multiyear landfast sea ice (MLSI) that had been there since the 1940s was lost from Yelverton Bay to the west of Ayles Fjord."

After georeferencing and projecting RADARSAT images (provided to the Alaska Satellite Facility by the Canadian Space Agency and its private partners) before and after the ice shelf breakup, Mueller imported the geographic TIFF (GeoTIFF) format into ArcInfo. With vector layers, such as coastline contour lines, from the Canadian government laid down, he traced polygons over the top of the RADARSAT images of the ice shelf taken at different times.

"Using GIS, I put down several images that I could flick back and forth showing where the ice was before any of the activity, calculated the square kilometers—the area of that polygon—then looked again and saw where ice wasn't located," he says. "Then we could essentially calculate the ice loss," which was about 54 square miles, according to Mueller.

A Moderate Resolution Imaging Spectroradiometer (MODIS) image of the Ayles Ice Shelf breaking away from Ellesmere Island (August 13, 2005, at 20:45 Coordinated Universal Time [UTC]). (Image courtesy of NASA.)

"GIS also helps interpret satellite images," Mueller states. "What is good about that method is you can keep those polygons and flick the image to another time. Sort of like a time machine, you can flick backward in time and forward in time and watch for changes. And if you have a polygon or a vector overlay in ArcInfo, then you can look for your border underneath and, if it alters over time, you know you've got a change."

In studying the Ayles Ice Shelf breakup, the researchers found that factors in addition to possible long-term climate changes likely contributed to the calving.

In addition to higher-than-usual temperatures that summer, Ellesmere Island was struck by strong winds, according to Mueller. "A lot of the multiyear landfast sea ice broke away from the shore—from the front of the Ayles Ice Shelf—and a lot of the sea ice was pushed away as well," he says. "That was caused by very strong winds pushing offshore and alongshore. Those winds pushed away the sea ice, and that allowed the ice shelf itself the freedom to move away."

Though the new ice island stayed put in the summer of 2006, Mueller says it's not stuck permanently. "It may last another year. It may last another few months. It's not necessarily stable ice."

Even in winter, the humongous chunk of ice could begin moving again. "It's fairly exposed to all the currents that are churning around in that area," Mueller says.

Mapping Ice Types

Mueller also used ArcInfo several years ago when he mapped ice types while studying microbial mats on the ice shelves. Microbial mats, often present in extreme environments, are this planet's oldest known ecosystems.

"I was interested in looking at cold-tolerant organisms in ecosystems that are ice dependent, he says, adding that "microbial mats composed of algae, microinvertebrates, and bacteria are commonly found on the surface of Arctic ice shelves. The ice shelves are a unique habitat for microbial mats, which can perhaps provide some clues as to what types of life existed when the planet was younger and how that life evolved."

In ArcInfo, he mapped the ice types, such as the marine "basement" ice and the meteoric or atmospheric iced firn, and also noted the sites where he took samples of microbial mats. Mueller will use that map to refer to as he continues studying the changes in the Arctic ice shelves in the years ahead.

"I'm looking for baseline information on the cryosphere—the cold parts of the earth—to look for changes due to climate warming." He adds. "Ice shelves may be a valuable indicator of climate change. When the ice shelves disintegrate, it represents a loss of habitat." He is concerned that the ice shelves may completely break up within his lifetime based on predicted warming of the Arctic.

"Working to preserve habitats and biodiversity is important," Mueller concludes. "These ice shelves may harbor some cold-adapted organisms that could be interesting for biotechnology. Or you might simply value the habitats that we are losing from our landscape."

(Reprinted from the Spring 2007 issue of *ArcNews* magazine)

Traditional Knowledge Meets New Tools

Eskimos and Ecologists Aided by Landfast Ice Mapping

The science of sea ice is an ancient discipline for indigenous people living north of the Arctic Circle. Ice science is a matter of survival for the Inupiat Eskimos in the northernmost regions of Alaska whose subsistence depends on hunting marine mammals, including whales, seals, walruses, and polar bears, and shorebirds. More than 7,000 Inupiat Eskimos live along the Beaufort Sea and Chukchi coast of the Arctic Ocean—the traditional lands along the North Slope. For thousands of years, these hardy subsistence hunters have made seasonal trips to the ice edge seeking fish and game. GIS is helping these people better understand and survive in an extreme environment, which is seeing the impacts of climate change in terms of coastal erosion, flooding, permafrost melting, increased intensity of storm events, and so forth.

April 26, 2004, a spring sea ice lead developed along the coast of the Inupiat village of Barrow, Alaska, which is the northernmost community in the United States. Near real-time SAR imagery is incorporated into a user-friendly Web interface for use by native hunters and sea ice researchers.

The Inupiats have a vast amount of traditional ecological knowledge passed on from generation to generation. This includes a wealth of terminology for ice and snow and the various conditions associated with them. Hunting parties hike across pressure ridges, sit by seal holes for days, set up temporary igloos to wait for bowhead whales to swim by them, and camp on areas of landfast ice. (The coastal landfast ice extension is sea ice that forms and is often grounded by pressure ridges and remains attached to the coast for much of the winter.) To survive in this region, the people must understand the signs that indicate changes in the environment. For example, they need to know that a shift of wind velocity or a change in the sea current's direction may cause a land extension of ice to break off the coast, which has the potential to strand hunting parties or crush houses.

For the last century, western scientists have studied this frozen region of the world hoping to learn more about climate, light, polar ice caps, astronomy, the atmosphere, and so on. The study of landfast ice and pack ice is important for understanding ecology, climate change, minerals management, and navigation. Indigenous people have much to offer western researchers in the understanding of ice science. The National Science Foundation (NSF) is funding a program known as the Human Dimensions of the Arctic System that helps researchers and Inupiats develop a method of integrating traditional knowledge with modern scientific findings. GIS technology has proven to be an excellent tool in cross-cultural communication for discussions that synthesize both forms of ecological knowledge.

Allison Graves Gaylord, founder of Nuna Technologies in Homer, Alaska, is part of a team of researchers who received funding from NSF to develop the methodology for incorporating traditional ecological knowledge and western science to study sea ice. Because of global warming, the Arctic pack ice is thinning and coastal communities are more vulnerable to storms and dangerous ice events. A landfast ice extension may extend several hundred meters or kilometers from the coast and act as a platform for both traditional subsistence hunting activities and sea ice research. The sea ice environment is dynamic and even landfast ice can be hazardous and can break into drifting ice floes. Using ArcGIS Desktop software (ArcInfo, ArcView), Gaylord georectifies satellite imagery from the Canadian Space Agency and European Space Agency. She incorporates additional information about Inupiat hunting camps and trails as data layers.

Gaylord explains, "Since 2000, I have acquired near-real-time satellite imagery of Synthetic Aperture Radar (SAR) sensors. SAR works both day and night, through darkness and clouds, and produces excellent data about ice. People in the community are very excited about being able to see these images. The Inupiat people say that the ice conditions have become less predictable. The animals behave differently, sometimes migrating at different times and sometimes staying longer. Marine mammals typically travel with the polar pack ice. In recent years, the pack ice has retreated far offshore during the summer and fall months. Polar bears lingered at Point Barrow for weeks while the pack ice remained far offshore. The ice is thinner and less stable. Ice conditions erode earlier in the spring and set up later in the fall. Therefore, landfast ice is not getting grounded and lacks its normal stability. It is dangerous to be out on it." The traditional knowledge of the Inupiat people is challenged by impacts of global warming, which makes the Arctic environment less predictable.

A GIS-enabled Web site, built with ArcIMS, is used to distribute sea ice information to enhance the safety of the community of native hunters and sea ice researchers. This site, called the Barrow Area Information Database—Internet Map Server (BAID-IMS), is designed to enhance logistics and research planning efforts supported by the Barrow Arctic Science Consortium. Scientists, land managers, educators, and the local community use BAID-IMS to access spatial information pertaining to terrestrial, marine, freshwater, and atmospheric research in the Barrow area.

Gaylord says, "The BAID-IMS Web site has been a huge success. It is a resource available to local residents and researchers that are doing work in Barrow. Many sea ice specialists consider it to be a model application for the emerging Arctic GIS initiative. Another project we are hoping to get funded soon is a portal that connects research nodes across the Arctic through ArcIMS technology. Many of the nodes are near native communities similar to Barrow. Web applications can provide access to high-resolution satellite imagery, as well as information about historic and current research activity, infrastructure, landownership data, etc. This would be the beginning of developing an Arctic Spatial Data Infrastructure."

The Minerals Management Service (MMS), a bureau in the U.S. Department of the Interior, is also interested in the dynamics of landfast ice. MMS in the Alaska region is a federal agency that has a mission to manage the mineral resources of the Alaskan Outer Continental Shelf in an environmentally sound and safe manner. It is tasked with finding a way to provide the opportunity to explore for petroleum and still preserve the environment and the lifestyle of the people living adjacent to its coast. Naturally, MMS is interested in Nuna Technologies' research efforts and has funded the company to conduct further research in the region.

For example, MMS needs to know how spring leads and moving ice packs interact. The seaward limit of stable landfast ice defines where spilled oil might pool under the ice and where fast ice conditions apply to the design and operation of offshore facilities. This landfast ice also defines the furthermost landward boundary of possible whale routes during the springtime migration period.

Nuna Technologies has teamed with sea ice specialists from the Geophysical Institute of the University of Alaska to map the average monthly shoreward landfast ice extent. GIS is also used to process datasets to summarize the spatial distribution of spring leads. ArcGIS grids and shapefiles are used to show monthly distribution of the shoreward landfast ice across the Alaskan Beaufort Sea to the Canadian McKenzie Delta. The extent and stability of the landfast ice along this stretch of coast is being analyzed. Remote sensing imagery, specifically Radarsat synthetic aperture radar and advanced very high-resolution radiometer data, has been analyzed for the time period between 1993 and 2004. This data will be compared with the university's archived data from the 1970s and 1980s.

The information from this study of both temporal and spatial aspects of landfast ice is the foundation for improving the MMS oil spill risk analysis. The study meets an ongoing need for future sales policy, oil spill contingency planning, and National Environmental Impact Act analysis.

More Information

For more information, visit Nuna Technologies at www.nunatech.com.

(Reprinted from the Summer 2006 issue of *ArcNews* magazine)

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