GNSS SUPPORT TO THE NATIONAL SCIENCE FOUNDATION

OFFICE OF POLAR PROGRAMS
ANTARCTIC PROGRAM

2005-2006 SEASON REPORT

UNAVCO
6350 NAUTILUS DRIVE
BOULDER, CO  80301
GNSS Support to the National Science Foundation
Office of Polar Programs
Antarctic Program

2005-2006 Season Report
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Submitted by
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Thomas Nylen
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Cover photo: UNAVCO engineer Seth White upgrading the power system at the Cape Roberts continuous GPS site.
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Summary

UNAVCO provides year-round support for scientific applications of the Global Navigation Satellite Systems (GNSS)
1 to the National Science Foundation’s Office of Polar Programs (NSF/OPP) Antarctic Program. This support includes pre-season planning, field support, and post-season follow-up, as well as development work for supporting new applications. The UNAVCO web site (facility.unavco.org) provides comprehensive and historical information related to UNAVCO support to NSF/OPP.

A “satellite” facility is staffed at McMurdo Station, Antarctica during the austral summer research season, providing a full range of support services including Global Positioning System (GPS) equipment, training, project planning, field support, system fabrication (new this season), technical consultation, data processing, and data archiving. Twenty-six projects received support in 2005/2006 as requested prior to the field season, and two additional projects were added during the field season (Figure 1). Table 1 summarizes Antarctic projects using UNAVCO support, while Appendix A provides more detailed discussions of individual projects.

The 2005/2006 saw a significant increase in permanent station activity, in response to a request by NSF for UNAVCO to provide a more cost effective and standardized “one stop shopping” for GPS, power, and communication systems. This season, five existing continuous stations received substantial upgrades, one new station was installed at the WAIS Divide camp, and a semi-permanent test platform for development purposes was set up at the base of Observation Hill at McMurdo Station. A section of this report is dedicated to long-term continuous data collection and network support.

A new Polar Services group was also formed during the summer of 2005 to better align the program resources with the technical and logistical needs of the polar research community. This group is managed by Bjorn Johns and also includes Thomas Nylen and Seth White who both joined with considerable Antarctic research support experience. The mission of the group is to provide high precision GNSS systems and related equipment, with technical support specifically tailored to polar project and network requirements. Resources and expertise from the other core UNAVCO support areas are leveraged, including NSF-EAR investigator support, NASA-Global GNSS Network (GGN) operations, the EarthScope/Plate Boundary Observatory facility construction and operation, and the UNAVCO community data archive.

1. GNSS refers to all modern satellite navigation systems, including GPS, the Russian GLONASS, and the emerging European Galileo systems. While UNAVCO’s support continues to be based on GPS, new hardware is beginning to incorporate the reception of other signals and we expect this trend to continue as new products emerge on the market.
Figure 1: Project locations with UNAVCO support during the 2005-2006 field season. Figure provided by Jessica Walker, Raytheon Polar Services Company (RPSC).
### Table 1: 2005-2006 Antarctic Support Provided

<table>
<thead>
<tr>
<th>Project</th>
<th>Point of Contact</th>
<th>Support Effort (%)</th>
<th>Eqp. Loan</th>
<th>Field Support</th>
<th>Training</th>
<th>Data Archived</th>
<th>Data processed</th>
<th>Preseason Request</th>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>2</td>
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<td>Yes</td>
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<td>I-205</td>
<td>Voigt</td>
<td>10</td>
<td>Yes</td>
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<td>Cool Robots</td>
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<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Science Support

Training
UNAVCO offers flexible options for field team training, including training before deployment to the field, training in the field, and data processing training as needed after data have been collected. The level of training is tailored to the experience of each research group. For the 2005/2006 season most training was provided at McMurdo Station or in the field, but training was also provided before the field season to several groups at UNAVCO’s Boulder facility. Participants of a general training course in August included members of I-163 (Raymond), I-190 (MacAyeal), and I-277 (Fricker).

Field Support
Three UNAVCO engineers were present at McMurdo Station during the main body season. The primary responsibilities of the field engineers are managing the large equipment pool, providing technical support to field projects, and supporting infrastructure such as the McMurdo GPS base station system, the South Pole reference station AMU2, and the Mount Erebus and TAMDEF continuous station networks. Training is also provided to the Raytheon Polar Services Company (RPSC) science technicians on maintaining these systems over the winter. Pre-season support was also provided to I-163, I-190, I-277 in the form of equipment and technical assistance.

Data Processing
Post-processing of differential GPS data is necessary to achieve the centimeter level precision required for most projects. UNAVCO supports field data processing using Trimble Geomatics Office commercial software and the Canadian Spatial Reference System on-line data processing service, and many groups are trained to process their data in the field to ensure data quality before pull-out. UNAVCO also continues to provide post-season data processing support using commercial software, on-line data processing services, and referrals for advanced post-processing requirements.

Data Archiving
All GPS data handled by UNAVCO are archived, both locally at McMurdo Station and at the UNAVCO Boulder archive, to ensure data safeguarding and future accessibility. Antarctic data are sorted by project event number and Antarctic field season. UNAVCO archiving services are available to all NSF sponsored geodetic GPS projects—not just those directly supported by UNAVCO—and all investigators are encouraged to archive their data soon after project completion. Metadata from all UNAVCO-supported Antarctic projects are accessible on-line by field season and project event number.

Data collected to geodetic standards are archived by site name and precise site coordinates, and site descriptions are readily available on-line. As this database of precise GPS coordinates continues to grow, future projects benefit by having pre-established geodetic control in their field study areas.

Equipment
Science Pool
Seventy-seven geodetic quality dual-frequency receivers from the UNAVCO pool (15 Trimble NetRS, 34 Trimble R7, 17 Trimble 5700, five Trimble 4700, one Trimble 4800, and five Trimble 4000 SSE/SSI) were provided for Antarctic support throughout the field season. All necessary ancillary equipment, such as data processing software, solar panels, batteries, chargers, tribrachs, tripods, and cables, was also provided.

The receiver pool is upgraded and expanded annually to better meet the extended GPS deployment needs. Prior to the field season, eight new Trimble R7 GPS campaign receivers were purchased, bringing the total U.S. Antarctic Program (USAP) pool to 58 units. To meet the full demands of opposite peak field seasons, equipment from the OPP-Arctic and USAP pools are shared.

2. Bjorn Johns (10/05-12/05), Thomas Nylen (10/05-12/05), and Seth White (10/05-02/06).
### Table 2: USAP Receivers in the UNAVCO Equipment Pool

<table>
<thead>
<tr>
<th>Receiver model</th>
<th>Qty</th>
<th>Features and Applications</th>
<th>Average age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trimble 4000</td>
<td>1</td>
<td>Front panel display for field programming and ease of use and educational value. One receiver is retained for training applications, while the seven other receivers were provided to researchers on permanent loan.</td>
<td>8 yrs</td>
</tr>
<tr>
<td>Trimble 4700</td>
<td>4</td>
<td>Robust receiver for short term data collection and kinematic surveys where a handheld survey controller is used. These continue to be fully subscribed every field season.</td>
<td>7 yrs</td>
</tr>
<tr>
<td>Trimble 5700</td>
<td>17</td>
<td>Modern low power, high memory receiver suited for both short term and continuous data collection.</td>
<td>4 yrs</td>
</tr>
<tr>
<td>Trimble R7</td>
<td>25</td>
<td>Same as the 5700, but also capable of tracking the new L2C GPS signal.</td>
<td>2 yrs</td>
</tr>
<tr>
<td>Trimble NetRS</td>
<td>11</td>
<td>State-of-the-art reference station receiver with computer and web browser interface, well suited for continuous data collection applications.</td>
<td>2 yrs</td>
</tr>
</tbody>
</table>
Long-term Continuous Data Collection and Network Support

A substantial increase in remote permanent station and network support activities was provided for the 2005-2006 season. This work is a continuation of development activities initiated a year earlier, and it has resulted in engineering, network operations, and data management support with several new systems deployed or upgraded as detailed below. UNAVCO now offers a centralized source for Antarctic permanent station equipment and the associated technical expertise for successful deployment and robust data collection, including attention to long-term operation and maintenance issues and ensuring that system configurations and data management meet global standards. However, significant technical challenges also remain to enable year-round operation and data retrieval of remote autonomous systems envisioned for future geophysical research initiatives. Meeting these challenges requires a focused engineering effort, and UNAVCO, together with the Incorporated Research Institutions for Seismology (IRIS), recently submitted a Major Research Infrastructure (MRI) development proposal to team with the Antarctic GPS and seismology scientists to design and build the next generation power and communication system for autonomous polar station operation.

The following highlights the accomplishments over the past year to address emerging requirements for developing and supporting remote permanent GPS stations including coordination with the science community, hardware testing, system development and design, station upgrades, new installations, and improved facilities for support of remote/permanent station and network initiatives:

1. **Supply, maintenance, and support system for station components such as solar power systems, batteries, enclosures, mounting hardware, and antenna monuments.** Researchers can request such items directly from UNAVCO along with GPS equipment through the RPSC Support Information package (SIP) process. The equipment is made available on the ice, and spares are on hand for field contingencies. The benefit to the overall program is time and cost savings from the economy of scale of consolidated purchases, a pool approach for re-use of equipment after individual projects are completed, and familiarity of the system design by UNAVCO staff in the field.

2. **Lab and field test facilities.** An environmental test chamber with a -70C to +70C temperature range is available at UNAVCO, and two nearby field sites (Marshall and Niwot Ridge) allow for “back-yard” field testing. The Marshall site (Figure 2) was used extensively for Iridium system testing prior to the field season. The Niwot Ridge site is located at 11,600 feet on the continental divide at the University of Colorado Mountain Research Station facility, and is subject to extreme winds, spindrift, and rime icing. Infrastructure at the site provides current and historical meteorological data, a web camera, and internet access. Wind turbine testing at this site is planned for the 2006-2007 winter season.

A new GPS testbed (Figure 3) was also installed on Observation Hill at McMurdo Station. This station is intended to accommodate prototypes for future deep-field permanent installations and serve as a platform for testing systems before deployment to remote sites. This facility enables the testing of new receivers, power and communication systems, and structural hardware year-round in extreme conditions while within close range of McMurdo support. During summer 2005-2006, all three permanent stations in the Trans-Antarctic Mountains were first tested here before deployment. Currently, this facility houses two receiver systems inside separate enclosures, with the goal of evaluating the effect of different thermal insulation on system performance during the dark winter months. Telemetry from both of these sites is through the Truncated Cones repeater site back to McMurdo, to replicate true field installations. Temperature, voltage, and power consumption data are also being recorded at the site to allow more in-depth analysis of the performance of each system.
3. Proposal for resources to design and build the next generation power and communication system for autonomous polar station operation. UNAVCO, together with IRIS, recently submitted a Major Research Infrastructure (MRI) development proposal Collaborative Research: Development of a Power and Communication System for Remote Autonomous GPS and Seismic Stations in Antarctica to team with the Antarctic GPS and seismology scientists to design and build the next generation system for autonomous polar station operation. The power and communication units built would form the nucleus of a new IRIS/UNAVCO equipment pool, and would allow the science community to achieve the first long-duration deployment of continuously recording GPS and seismic stations across the Antarctic continent proposed to commence during the International Polar Year (2007-2009). The goals of the proposal are to use the latest power and communication technologies, linked with the collective experience and expertise of the science community and facility staff, to 1) design, integrate, and test a scalable power and communication system optimized for ease of deployment and reliable multi-year operation in severe polar environments; and 2) provide an initial pool of these systems for deployment and testing in science experiments.

The technical requirements guiding the system design are driven by the needs of the research community, including year-round, continuous operation and real-time delivery of as much data as technically feasible. A robust power module would consist of two parts – one based on solar panels and sealed lead acid (SLA) batteries for summer operation, and one for winter operation that incorporates advanced battery technologies and wind turbines. A three-tiered approach for communication and data retrieval would be adopted that includes: a) radio modems/radio repeaters to connect directly to the internet via local area networks where stations are close to permanent bases, b) a commercial Iridium satellite-based connection for GPS, state-of-health, limited seismic data retrieval, and system control, and c) onboard memory to allow for data uploads during maintenance or opportunity visits (possibly including flyovers and wireless data transmission). Custom environmental enclosures will accommodate thermal and wiring requirements. The system would be deployable from light aircraft in no more than two missions per station and with a three person field team.

4. Iridium satellite modems for remote GPS data downloading. For the most remote sites, Iridium satellite communications provide the most practical means for data retrieval. The system is low power, provides global coverage, and uses a non-directional antenna that eliminates the need to align the antenna in the field. Hardware and software testing continues for robust field applications. A proof-of-concept system is currently operating in Antarctica at the TAMDEF Fishtail Point remote GPS site (Figure 4), with daily data recovery direct to the UNAVCO archive. The Iridium system has performed well since the December 2, 2005 installation, and daily data files are still being retrieved as of mid June 2006. Current Iridium development is aimed at reducing the system power requirements for better performance through the winter months.

5. Iridium system download hub established. A computer at UNAVCO is dedicated to downloading remote Iridium field sites. Currently this computer retrieves data from the TAMDEF site at Fishtail Point and from local Iridium development and testing deployments. An arctic deployment near Jakobshavn Isbrae, Greenland is planned for August 2006 and will also be downloaded through this hub.

6. Dedicated Polar shop facility and staging area. The UNAVCO office in Boulder recently acquired 500 square feet of additional space (Figure 5) devoted exclusively to design, fabrication, testing, and storage of GPS systems.
for use in the polar regions. This workspace includes a complete stock of tools and hardware, and represents a significant increase in capability to meet the growing needs of the scientific community for robust, rapidly deployable, year-round GNSS systems.

7. Trans-Antarctic Mountains (TAMDEF) network sites upgraded. In support of G-079 TAMDEF (Wilson), three permanent stations in the Trans-Antarctic Mountains were upgraded (Figure 6). The sites at Fishtail Point, Mount Fleming, and Cape Roberts all received additional batteries and/or solar power capacity for mid-winter operation, and their power systems were repaired and streamlined. New receivers and permanent antenna monuments were also installed at each site. The ethernet radio link at Mount Fleming was replaced by a serial system, and a new serial radio link was installed at Cape Roberts.

Data retrieval from these two sites is through the Truncated Cones repeater site on Mt. Erebus. This repeater was installed during 2004-2005, and was changed from ethernet to serial communications in 2005-2006. (The Fishtail Point site, which is not within line of sight from McMurdo Station or the Mt. Erebus repeater, relies on an Iridium satellite modem system for data downloading.)

Before deployment to the field, all three receiver, power, and communication systems were tested at the Observation Hill test facility at McMurdo Station. Data are downloaded daily and delivered directly to the UNAVCO data archive (Figure 7). A major storm damaged the Mt. Erebus repeater on June 1, 2006, with winds over 150 knots. As a result, remote data retrieval from Mt. Fleming and Cape Roberts is no longer possible, but the sites have sufficient memory for continued data collection. Damage assessment, repair, and data recovery are a priority tasking for October 2006.

8. Winter continuous data collection on Taylor Glacier. Three winterover systems were designed, built, and installed for the I-139 (Hallet) study of seasonal variations in mechanics of dry-land glacier calving. These systems include solar power, batteries, power management, and receiver systems, and represent an upgrade on the six receiver systems which were successfully deployed on the Kamb Ice Stream during winter 2004. This design has since been refined further, with improved systems currently deployed in Greenland (Figure 8).
9. Permanent station installed at WAIS Divide Camp. UNAVCO installed a community GPS base station at the WAIS Divide camp in November 2005 (Figure 9) to support local GPS projects and provide a consistent time series for the duration of the camp. This base station at the camp was used by several science groups during the summer season including the I-163 (Raymond) deep radar project. The I-345 (Tulaczyk) and I-288 (Gogineni) projects also used data from this station for use in their work near the WAIS Divide camp. The Trimble NetRS receiver is connected via a wireless ethernet link to a publicly available computer at the camp. Although it currently functions as a summer-only site, it may be upgraded for winterover operation if requested by the WAIS community. Publicly available data are archived at UNAVCO.

10. Installation of a new South Pole GPS base station. The South Pole GPS station was upgraded to a new system that both meets the U.S. Geological Survey (USGS) data requirements and is standardized for UNAVCO operation and maintenance support. Publicly available data are archived at UNAVCO, the Crustal Dynamics Data Information System (CDDIS), and the Scripps Orbit and Permanent Array Center (SOPAC) with minimal latency. This system was installed on the new elevated station. A frequency doubler was also provided for the rubidium reference frequency standard, and a second receiver is staged on station as a spare. The new Trimble NetRS receiver is connected directly to the internet, and can be accessed and operated remotely, resulting in a substantial time savings for the South Pole Research Associate.

11. MCM4 McMurdo GPS base station upgraded with new receiver. UNAVCO maintains a real-time kinematic (RTK) GPS system at McMurdo which allows for centimeter level surveys in real-time in the immediate vicinity of McMurdo Station. The GPS base station is in Building 71 at Arrival Heights, and differential corrections from this receiver are broadcast from a radio transmitter on Crater Hill. During the 2005-2006 season, this receiver was replaced with a Trimble NetRS receiver MCMD, which is connected directly to the internet and accessible from the UNAVCO facility in Boulder and over the local area network. In addition to the RTK functionality, this receiver also collects a 15 second and 2 Hz sample rate data for geodetic applications. The 15 second data are available from the UNAVCO archive, and serve as a backup to the MCM4 data distributed by NASA. The high rate data are available on request and are held for 30 days. The system was used by B-518 (Kennicutt) for navigating to sample locations for an environmental impact assessment in the McMurdo vicinity. The DGPS repeater (Figure 10) in the Dry Valleys was decommissioned since this part of the system was obsolete.

12. Expanded McMurdo equipment staging facilities. The Crary Lab is an excellent base of operations for UNAVCO, but as the UNAVCO support role continues to grow so does the on-ice space requirements. Both the volume of equipment handled as well as the stock and inventory requirements that accompany continuous GPS station installation and maintenance highlight the need for larger workspace and additional storage. A complete set of shop tools was also added to the UNAVCO inventory for better on-ice fabrication, installation, and maintenance support. For the 2006-2007 season, UNAVCO has requested more dedicated shop space for system preparation and assembly, and also plans to acquire a dedicated outside storage container for materials and supplies that would otherwise occupy shared lab space. The long-term desire still remains to obtain dedicated space at McMurdo Station, rather than space that must be formally requested in the RPSC Support Information Package every year.
13. **Facilitated community cooperation and communication.** Coordination amongst interested stakeholders, including project scientists, UNAVCO, the USGS, IRIS, and NSF is essential for successful and cost effective deployment, maintenance, and operation of future Antarctic GPS and seismic networks that extend beyond the immediate science needs of a single project. GPS efforts to date have been very project specific, in terms of both principal investigators and geographic study areas. Several meetings were held to address community coordination for large GPS and seismic network proposals, including a Washington D.C. workshop and side meetings at the American Geophysical Union and European Geosciences Union conferences. Proposals were recently submitted to NSF for the IPY Polar Earth Observing Network (POLENET) project, with UNAVCO slated to provide leadership for the technical support requirements.

14. **Increased level of cooperation with IRIS.** UNAVCO and IRIS enjoy a solid working relationship, and recently together submitted the MRI proposal which will lead to significant future collaboration in developing remote GPS and seismic systems. Co-locating GPS and seismic equipment is becoming more common within the Polar research community in general, and UNAVCO, with IRIS assistance, recently provided enclosure and power systems to accommodate both sensors for research on the Greenland ice cap. The recently submitted IPY POLENET proposal also reflects substantial IRIS-UNAVCO cooperation to provide systems with maximum commonality.
Future Plans

The following activities are planned to improve all aspects of continuous data collection and network support:

1. **Develop a standardized system design.** Standard GPS, power, and communication systems at remote GPS installations are essential for efficient maintenance and operations. UNAVCO has a long history of all aspects of GPS network operations and is putting considerable effort into applying this experience to Antarctic applications where the ability to deploy stations with a minimum number of flights and ground time is paramount. A prototype Antarctic remote site is being built near Boulder to speed up the development cycle, and will be deployed at the Niwot Ridge test site for evaluation under winter conditions. It also serves as a test bed for systems integration, and as an opportunity to validate a design before committing to deploy it in Antarctica. These component-level development and testing activities are expected to facilitate the convergence on a standard system design should a large scale network project such as POLENET be funded.

2. **Continue Iridium data retrieval development efforts.** Iridium/GPS integration efforts to date have been successful in providing a robust system to download full GPS data from the most remote locations. However, there are still challenges that UNAVCO will continue to pursue, including reducing the system power requirements and applying the short burst data (SBD) mode for improved efficiency.

3. **Pursue development activities as outline in the development proposal Collaborative Research: Development of a Power and Communication System for Remote Autonomous GPS and Seismic Stations in Antarctica.** This proposal outlines a detailed technology development plan that will benefit future remote Antarctic GPS installations. UNAVCO’s intent is to proceed within the constraints of available resources.

4. **Support the creation of a UNAVCO Polar Advisory Committee.** A Polar–focused advisory committee would benefit the Polar science community with direct participation in UNAVCO as a consortium that provides them with considerable resources. Such a committee is seen to be necessary should a large Antarctic network initiative come to fruition, and it was included in the management plan of the MRI proposal. Such a committee could also coordinate input from the science/research community regarding Polar networks and science requirements, advise and engage on Polar GPS and proposal initiatives, and assist with the development of acquisition proposals for Polar remote station components and systems.

5. **Explore long-term solutions for advanced data processing support.** The commercial data processing software supported by UNAVCO works well for new users and smaller projects. However, several projects could benefit from using more rigorous and adaptable academic data processing software. Proficiency in such software requires regular use, and UNAVCO is well positioned to work with the science community to develop a solution that relies upon community expertise to reduce barriers to entry for new users. A possible solution would be the establishment of a community processing center, where new users can work through their data with expert assistance present.

6. **Monitor terrestrial laser scanning (TLS) technology for Antarctic applications.** UNAVCO, together with the emerging LIDAR community, are developing a proposal for the acquisition of tripod based LIDAR units for PI community and EarthScope applications. Such units have the potential to augment GPS surveys for applications such as high precision surface mapping and stability monitoring. As UNAVCO gains experience with this emerging technology, its suitability for Antarctic applications will be evaluated.
Appendix A - Detailed Summary of Support Provided

G-049 (David Harwood)

The ANDRILL project will retrieve sediment cores from the surface underlying the Ross Sea and the Ross Ice Shelf which will compliment the data record obtained from previous cores. During the 2005-2006 season a camp was established on the sea ice in McMurdo Sound. The group performed acoustic soundings of the ocean floor along two 15-km transects with the goal of locating a secondary drill site if the sea ice at their primary drill site (farther north) is unsuitable for drilling during the 2006-2007 season. UNAVCO surveyed shothole locations (Figure 11) and provided a two-week continuous measurement of sea ice motion at the camp site.

B-050 (Kenneth Smith)

UNAVCO provided a geodetic receiver for precise positioning of the Laurence M. Gould while imaging icebergs of varying size in the NW Weddell Sea. The digital imaging project used shipboard acoustics, radar, and sonar, to estimate the aerial extent, submerged area and contours of icebergs.

G-052 (Jerry Mullins)

The South Pole GPS station was upgraded to a new system that both meets USGS data requirements and is standardized for UNAVCO operation and maintenance support. Publicly available data are archived at UNAVCO, the Crustal Dynamics Data Information System (CDDIS), and the Scripps Orbit and Permanent Array Center (SOPAC) with minimal latency. This system was installed on the new elevated station. A frequency doubler was also provided for the rubidium reference frequency standard, and a second receiver is staged on station as a spare. The new Trimble NetRS receiver is connected directly to the Internet, and can be accessed and operated remotely, resulting in a substantial time savings for the South Pole Research Associate.

G-057, G-058 (Ralph Harvey)

The Antarctic Search for Meteorites (ANSMET) field team performed local stop-and-go kinematic surveys of meteorite locations, allowing the meteorite spatial data to be used in their GIS database. This year’s campaign involved a systematic search in the Miller Range as well as an exploratory search in ice fields near the Allan Hills. UNAVCO provided five Trimble 4000 receivers, data archiving, and base station coordinates using the Canadian Spatial Reference System precise-point-positioning (CSRS-PPP) automated data processing service. Ownership of the GPS receivers and associated hardware was transferred to the group during the season.

B-068 (Brenda Hall)

Dr. Hall’s group spent the 2005-2006 field season locating and excavating elephant seal remains along the Scott Coast. These remains were discovered during a previous geologic field campaign, and will yield information about the extent and habits of the seals in this area which they no longer inhabit. Climate records will also be extracted from the remains. UNAVCO provided training, one receiver which the group used to mark the exact locations of their finds, and provided data processing using data from the TAMDEF ROB4 continuous base station at Cape Roberts.

G-076 (Jaakko Putkonen)

Dr. Putkonen’s group is using cosmogenic dating methods to determine past ice dynamics within the McMurdo Dry Valleys. UNAVCO provided two Trimble R7 base receivers and a Trimble 4700 roving receiver to measure the locations of pins in boulders on gelifluction flows within the valleys. These pins were installed during the 2004-2005 season, and were remeasured to determine flow rates of these features. Training and data processing support were also provided.
**G-079 (Terry Wilson)**

Dr. Wilson’s group is studying the crustal motions around the Ross Sea area associated with glacio-isostatic adjustment (uplift or subsidence resulting from unloading or loading of crust by glaciers) and with active rifting of the Terror rift system. This group’s application demands the highest precision possible with GPS. UNAVCO provided 15 Trimble 5700/R7 GPS receivers for campaign measurements and three receivers (Trimble NetRS, 5700, and R7) for winter-over sites. Additionally, UNAVCO worked with the G-079 team members (Figure 12) to substantially upgrade these three continuously operating sites. Upgrades included additional battery banks, increased solar power capacity, improved power control systems, and installation of more robust monumentation. The telemetry of these sites was also improved. Serial radio links were installed at the Cape Roberts and Mount Fleming sites, with telemetry to McMurdo via a repeater at Truncated Cones on Mt. Erebus. The site at Fishtail Point received an upgraded Iridium modem system. Communications systems for these three winterover stations were thoroughly tested at the newly-installed test platform at McMurdo prior to deployment to the field.

**G-081 (Philip Kyle)**

Dr. Kyle requested UNAVCO support for both campaign and permanent station GPS activities on Mt. Erebus to measure the deformation of the volcano caused by the migration of magma. Two Trimble 4700 receivers were provided to the field team for mapping activities and campaign occupations. UNAVCO also continued involvement in maintenance of the permanent GPS network on Erebus. The Trimble NetRS at site CONZ was replaced, modifications were made to its ethernet data link, and the power system was improved. The Trimble R7 receiver at Abbott Peak (Figure 13) was retrieved and downloaded, then replaced by another Trimble R7 for operation during winter 2006. Data from the seven telemetered Erebus permanent stations are downloaded daily to McMurdo Station, and transferred to the UNAVCO data archive where they are on-line and publicly available. GPS data collected since 1999 show displacements on the order of millimeters per year.

**I-139 (Bernard Hallet)**

Taylor Glacier is an outlet glacier of the East Antarctic Ice Sheet that terminates in Taylor Valley. The I-139 field team deployed an array of instruments at the glacier’s terminus to better understand the dynamics of dry-land calving. Instruments include cameras, meteorological sensors, strain gauges, tilt sensors, thermistors, seismometers, and GPS receivers to observe and record calving events and measure air and ice conditions and strain within small networks (Figure 14). UNAVCO provided one Trimble 5700 base station and two Trimble 4700/5700 rovers for kinematic surveying of geographical features during ground penetrating radar (GPR) transects and static surveying of four strain arrays, optical surveying sites and other measurement locations. Three additional Trimble 5700 systems (one base station, two on the glacier) were installed near the terminus for continuous measurements during the summer and one hour daily measurements during the winter. UNAVCO provided field support, data processing, and data archiving during the first part of the summer season. Two Trimble 5700s, field support, data processing, and data archiving were also provided for a late-season resurvey of the strain networks.
I-163 (Charles Raymond)

The field team used ice-penetrating radar to detect spatial variations of ice crystal alignments over a wide area near the West Antarctic Ice Sheet (WAIS) divide, which separates ice flow toward the Ross and Amundsen Seas. Since ice crystal orientations reveal the history of ice flow in the region, these data will be of great interest to the upcoming WAIS divide drilling project. UNAVCO provided four Trimble 5700 receivers for use in tracking the paths traversed by the radar sled as well as occupying newly-installed strain grids in several key locations. A continuously-operating base station was also installed at the WAIS Divide camp for use by I-163 as well as other science groups operating in the area. Formal training was also provided at UNAVCO for Dr. Kenichi Matsuoka prior to the field season.

I-186 (Ted Scambos)

Dr. Scambos’ group deployed to the Antarctic Peninsula to monitor a large iceberg as it drifts northward. The disintegration process of such an iceberg is thought to be similar to that of an ice shelf disintegrating due to a warmer climate, and thus will yield information about climate-related evolution of the Peninsula region. UNAVCO supplied three Trimble R7 campaign systems and training for this study.

I-190 (Douglas McAyeal)

Nine Trimble R7 receivers, training, and data processing assistance were provided to measure the motion of icebergs and the propagation of a rift which is separating the ‘Nascent berg’ from the rest of the Ross ice shelf. One of these receiver systems was also left on iceberg C-16 to track its motion during the winter months. UNAVCO also supported an I-190 side project which monitored ice motions near the sea ice runway (Figure 15) during aircraft operations.

I-191 (Karl Kreutz)

The 2005-2006 season was the second field season of this ice coring project on the Clark and Commonwealth Glaciers in the Dry Valleys. Data from these cores will be used to understand climate variability during the past 2000 years. UNAVCO support included three receiver systems, field surveying, and data processing for measurement of two strain grids which were installed last season around the drill sites. These repeat surveys yielded ice motion used for interpretation of the ice cores.

I-205 (Sridhar Anandakrishnan)

The third season of the TIDES project involved high frequency motion surveys of the Bindschadler and MacAyeal Ice Streams. It was found in previous seasons that ocean tides exert strong influence on the behavior of these ice streams, although individual ice streams respond in dramatically different ways to tidal forcing. Improved knowledge of ice-stream behavior will contribute to researchers’ ability to assess the potential for rapid ice-sheet change affecting global sea levels. Approximately 30 receivers were deployed during the season on the ice streams as well as two supporting studies of motion of the Byrd and Mullock Glaciers. UNAVCO provided 24 campaign systems (14 R7, 10 NetRS) for this project. Also, the three Mullock Glacier systems were deployed by UNAVCO personnel (Figure 16).

B-211 (Peter Doran)

A drilling camp was established at Lake Vida by B-211 which utilized new drilling technologies to retrieve samples from this pristine ice-covered lake. After the camp was removed, UNAVCO accompanied a member of the team to obtain a precise coordinate for the borehole location. A base station was set up, however the borehole could not be re-located because of melting and refreezing of the lake ice surface.
B-268 (Michael Gooseff)

Dr. Gooseff’s group is taking a coordinated hydrologic, biogeochemical, and molecular microbial approach to studying the characteristics of the aquatic-terrestrial transition zones in the Dry Valleys of Antarctica. UNAVCO supplied one 5700 base receiver and one 4700 roving system for mapping of wetted zones and sampling sites. Training at McMurdo was also provided.

I-277 (Helen Fricker)

UNAVCO provided six Trimble 5700 receivers for velocity measurements of the Amery Ice Shelf. Training in Boulder and equipment loan prior to the field season was also provided for familiarization prior to the field season. This multi-year study is centered around observations of an active rift system at the front of the ice shelf. To avoid substantial shipping costs and importation paperwork, the receivers were left in Hobart, Australia for use again next season.

O-283 (Chuck Stearns)

UNAVCO provided a Trimble 4800 receiver/antenna, training, data processing, and data archiving to the Automated Weather Station field team in an ongoing effort to produce accurate site elevations used in climate models. These surveys are conducted as “opportunity surveys” during scheduled maintenance visits to the AWS sites.

B-300 (Yu-Ping Chin)

Dr. Chin’s group is focusing on Pony Lake at Cape Royds to study dissolved organic matter in an environment lacking higher plants. During the 2005-2006 season, several surveys were performed by the field team using one base and one roving system for kinematic surveying of the lake boundary, sample sites, and other features. For one survey, a UNAVCO engineer accompanied the group to collect and process the data.

I-345 (Slawek Tulaczyk)

The I-345 project aims to determine whether Kamb Ice Stream in the West Antarctic Ice Sheet is in the process of restarting, and to understand the mechanism enabling or preventing surging depending on their findings. During the 2005-2006 season, the field team retrieved four winter-over systems which had been built by UNAVCO during 2004-2005 and installed by the science group that year. UNAVCO also provided six campaign systems (three R7, three 5700) for use in surveying strain grid arrays near the former UPC campsite. GPS data from the WAIS Divide base station (Figure 17) was also used by I-345.

G-411 (Bernard Hallet)

This project examined the role of glacier dynamics in determining glacial sediment yields through a combination of techniques and resources from glaciology and marine geology. Three receivers were provided for short-term rapid static surveys on two glaciers in Chilean Patagonia. Ancillary equipment and data processing support were also provided for the project which was staged from the Nathaniel B. Palmer research vessel.

B-421 (Diane McKnight)

As part of the McMurdo Dry Valleys LTER project, this group is concerned with long-term monitoring of glacier-fed streams, primarily in the Taylor and Wright Valleys. In 2005-2006, UNAVCO performed surveys of two primary study sites near Lake Fryxell. The extents of Huey Creek and Von Guerard Stream were mapped, and locations of sample sites along the streams were captured. Data processing was provided.

B-426 (Peter Doran)

The positions of ablation stakes on lakes Fryxell, Hoare, and Bonney were measured to determine motion of surface ice on these perennial frozen lakes. Kinematic surveys of the surface of Canada Glacier were also completed during ground penetrating radar (GPR) transects. The purpose of the transects were to measure the elevation of the bed below the glacier. UNAVCO provided field support, two Trimble geodetic receivers, data processing, and data archiving.

Figure 17: The GPS base station at WAIS Divide camp serves several projects working on the West Antarctic Ice Sheet.
T-513 (Charles Booth)

The T-513 group operates a network of ultraviolet radiation sensors in the polar regions, including one station at Arrival Heights near McMurdo. UNAVCO support was requested to obtain accurate coordinates for the instrument's optical collector and a survey of visual obstructions in the instrument's field of view. While RPSC surveyors ultimately performed the survey, UNAVCO personnel had previous experience working with T-513 and assisted in specifying the exact survey requirements.

B-518 (Mahlon Kennicutt)

Dr. Kennicutt's group is working to determine the temporal and spatial scales of human disturbance in the McMurdo vicinity. The group used a real-time kinematic (RTK) GPS system for measurements of sample locations. The McMurdo base station established and maintained by UNAVCO, MCMD, was used for real-time corrections.

Cool Robots (Laura Ray)

The Antarctic plateau is a unique location to study the upper atmosphere at high magnetic latitudes, providing a stable environment for sensitive instruments that measure the interaction between the solar wind and the earth's magnetosphere, ionosphere, and thermosphere. This project focuses on the design and fabrication of a lightweight mobile robot that enables deployment of instrument networks in Antarctica. One can envision deploying multiple robots from the South Pole to desired locations on the plateau for long- or short-term observation, and retrieving or repositioning the robot network through Iridium-based communication. Potential missions include deploying arrays of magnetometers, seismometers, radio receivers and meteorological instruments, measuring ionosphere disturbances through synchronization of GPS signals, using ground-penetrating radar (GPR) to survey crevasse-free routes for field parties, and conducting glaciological surveys with GPR. UNAVCO provided one geodetic GPS receiver as a science payload for prototype testing at Summit Camp, Greenland.

NBP Anderson Cruise (Jerry Bucher)

UNAVCO provided a DGPS base system for a near-shore marine geophysical survey. Additional equipment, including FreeWave serial radios, a solar array, and data processing software was also provided.

RPSC (Brennen Brunner)

UNAVCO supports additional in-season requests from science groups as well as the NSF support contractor on an availability basis. During 2005-2006, the field safety team requested a two-day campaign to measure flow velocity of the Erebus Ice Tongue. UNAVCO provided two receiver systems, field support, and data processing.