Geodetic Support to the National Science Fountation Office of Polar Programs Arctic Sciences

2007 Annual Report

UNAVCO

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Submitted by

Bjorn Johns
UNAVCO, Inc.
6350 Nautilus Drive
Boulder, Colorado
80301
www.unavco.org/polar

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Cover photo: Abel Brown from the Ohio State University, awating pick-up after installing GPS staion TIMM on Timmiariit Island in southeast Greenland.

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Summary

UNAVCO is the National Science Foundation's and NASA's pre-eminent national facility for earth science applications of the Global Positioning System (GPS) and complimentary equipment including LiDAR and related power and communications systems. The range of services provided to the National Science Foundation's Office of Polar Programs Arctic Sciences Section (NSF-OPP/ARC) includes equipment, training, project planning, field support, proposal assistance, technical consultation, data processing, and data archiving on a year-round basis. Permanent station network support services are also provided, from the initial engineering and installations through operations, maintenance, and data archival and distribution. Sustaining engineering activities are ongoing to meet the technical challenges such as providing robust telemetry and power systems at remote high-latitude locations. Resources and expertise from the other core UNAVCO support areas, 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 are leveraged to apply state-of-the-art technologies at a reasonable cost.

The ongoing Major Research Infrastructure (MRI) funded engineering effort *Development of a Power and Communication System for Remote Autonomous GPS and Seismic Stations in Antarctica* was applied to the immediate needs of the Greenland POLENET (GNET) project. Tasks were rescheduled to provide "alpha" systems to the GNET project which was funded with minimal time for engineering, procurement, fabrication, and shipping activities prior to the field season. As a result the GNET project was the first user of MRI developed field kits, and 23 systems were installed in August and September 2007 (cover photo). UNAVCO now offers standardized power and communication system kits for rapid deployment and robust data collection, including attention to long-term operation and maintenance issues. "Beta" systems were recently fielded in Antarctica for the Antarctic POLENET project, and after a few remaining improvements mature field systems will be provided for the GNET 2008 field season. The MRI engineering effort is now focused on these minor system improvements, updated documentation, and new designs to meet the challenges of operating year-round in extreme cold of the Antarctic Polar Plateau or high altitude Greenland.

UNAVCO has received support for a second MRI proposal, *Acquisition of a Terrestrial Laser Scanning System For Polar Research,* and purchased a terrestrial laser scanner (TLS) LiDAR system for NSF-OPP funded research support. An Optech ILRIS 3D system was purchased at the end of the year, and operational support capability will be built up during 2008 with pilot projects in Antarctica and Iceland. This survey instrument is complimentary to the suite of GPS equipment already available, allowing for much higher spatial density surveys of short distances. Considerable demand is expected, for applications such as soil surface mapping, quantification of landforms, and change detection of slopes, rock glaciers, and glaciers.

Sixteen Principal Investigator based Arctic projects encompassing a range of applications were supported during 2007 (Figures 1 and 2). Five infrastructure and operational projects were also supported, including training users of the Barrow and Summit Camp DGPS systems, providing equipment for Greenland skiway surveys, adding GPS-met capability to the base station in Atqasuk, Alaska, and providing hardware upgrades for the Toolik Field Station GPS system. Table 1 summarizes projects supported, and Appendix A provides more detailed descriptions of the individual projects. The UNAVCO web site (www.unavco.org/polar) provides comprehensive and historical information related to Polar Programs support.

Figure 1 - Alaska research project locations in 2007.

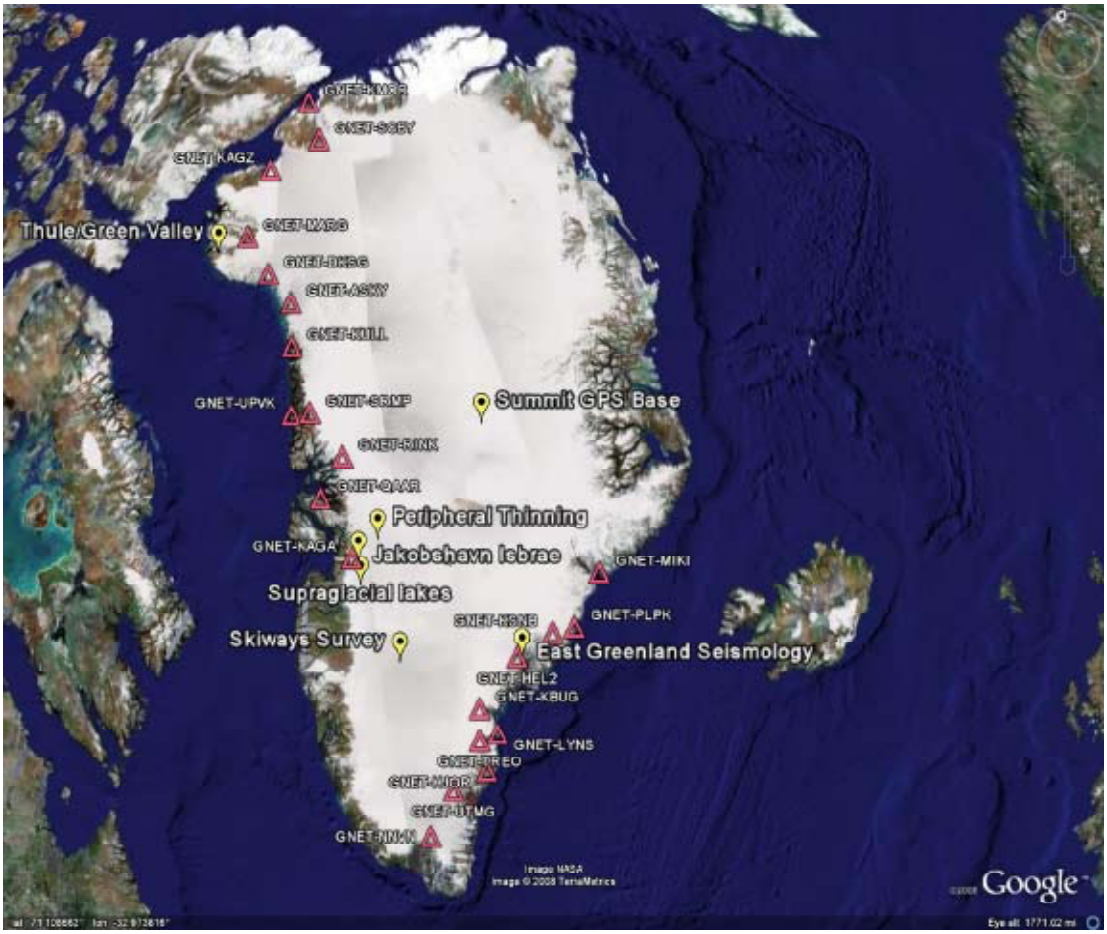


Figure 2 - Greenland research project locations in 2007.

Table 1 - 2007 Support Provided

Project	Funding Source	Point of Contact	Eqp Loan	Quantity Receivers	Field	Training	Data Archived	Data processed
Alaska:								
Arctic Tundra	DEB-0516326	Ted Schurr	X	2				
Atqasuk GPS Base	ARC-UNAVCO CA	Bjorn Johns	X	1			X	
Barrow Biocomplexity	ARC-0421588	Craig Tweedie	X	1				
Barrow Traditional	ARC-0641623	Richard Beck	X	1				
BASC GPS Base	ARC-UNAVCO CA	Glenn Sheehan	X	3	X	X	X	X
Beringia	ARC-0454997	Craig Tweedie	X	2				
Circumpolar Active	ARC-0352958	Frederick Nelson	X	3				
Denali Summit Survey	PI internal	Michael Loso	X	1				
Juneau Icefield	PI internal	Scott McGee	X	4	X	X		
McCall Glacier	ARC-0229705	Matt Nolan	X	4	X	X	X	X
STEEP	EAR-0409426	Jeff Freymueller	X	6			X	
Toolik Field Station	ARC-UNAVCO CA	Andrew Balser	X	2				
Greenland:								
East Greenland	PI internal	Meredith Nettles	X	15				
Jakobshavn Isbrae	ARC-0531075	Martin Truffer	X	6				
Peripheral Thinning	NASA NNG06GA83G	Tom Neumann	X	10				
POLENET (GNET)	ARC-0632320	Michael Bevis	X	23	X	X	X	
Skiways Survey	VECO	Jeff Scanniello	X	2				
Summit GPS Base	ARC-UNAVCO CA	Bjorn Johns	X	2		X	X	X
Supraglacial Lakes	ARC-0520077	Sarah Das	X	5	X			
Thule/Green Valley	ARC-0221606	Ron Sletten	X	4	X	X	X	X
Other:								
Sperry Glacier	ARC- 0454789	Joel Harper				X		

Science Support

The UNAVCO Facility provides GPS project management, equipment and field engineering support for principal investigator projects and for installing, operating and maintaining continuous GPS networks world-wide. UNAVCO also undertakes new technology development and evaluation of commercially available products for research applications, and archives GPS data and data products for future applications. The following highlights some of the resources and capabilities available for science project support:

- Expertise in program and project management, field engineering, technical support, and training
- Equipment and laboratory facilities for maintaining repairing, testing, and deploying equipment
- Systems integration and software development capabilities for custom applications
- Formal systems for property management, import/export, shipping and logistics; grant administration, project financial management, tracking, and reporting; established processes and procedures for supporting scientific research

These capabilities are drawn upon to provide support tailored to the needs of Arctic research projects as summarized below.

Science Advisory Committee

The Polar Networks Science Committee has been established and includes members of the polar GPS and seismic communities:

Terry Wilson, Ohio State University – Chair
Doug Wiens, Washington University - Vice-Chair
Sridhar Anandakrishnan, Pennsylvania State University
Rick Aster, New Mexico Tech
Carol Raymond, Jet Propulsion Laboratory
Bob Smalley, University of Memphis

This committee allows for the direct participation of the polar science community in UNAVCO as a consortium that provides them with considerable resources in the era of large polar GPS networks such as POLENET. This committee, which reports to both the IRIS and UNAVCO Board of Directors is expected to 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. The committee membership is expected to evolve to provide better representation of Arctic investigators.

Training

Flexible options for field team training include training before deployment to the field, training in the field, and direct field engineering support during the project. The level of training is tailored to the experience of each research group. Training was provided in Boulder for Summit Camp staff to familiarize them with the new GPS survey system, and refresher training was provided in Barrow for several users of the GPS system at the Barrow Arctic Science Consortium (BASC). Project specific training was also provided for five other science projects as noted in Table 1.

Field Support

Field support is provided to groups that desire technical assistance for their geodetic GPS surveys. Direct field support was provided for the Barrow GPS system maintenance, and for the GNET, Greenland Supraglacial Lakes, Juneau Icefield Research Program, McCall Glacier and Thule/Green Valley field projects. Remote technical support is also provided via telephone, email, and documentation on the web.

Data Processing

Post-processing of differential GPS data is required to achieve millimeter to centimeter level precision, and UNAVCO supports data processing for field projects using Trimble TGO software and the Canadian Spatial Reference System on-line data processing service, and the EarthScope/Plate Boundary Observatory data analysis system may be used to generate daily positions and position timeseries for permanent station data collected on the North American tectonic plate. Precipitable water vapor data can also be determined from GPS permanent station data using the University Corporation for Atmospheric Research (UCAR) COSMIC program's GPS-met analysis capabilities. This season data processing support was provided for the McCall Glacier and Thule/Green Valley projects. In addition, GPS position timeseries are provided for GNET station KAGA, Summit Camp, and Barrow, and GPS-met data are produced for Atqasuk, Barrow, and Summit Camp.

Data Archiving

All GPS data handled by UNAVCO are archived at the Boulder archive to ensure data safeguarding and future accessibility. The data are organized by project name and year in an open access, searchable on-line database. 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 immediately after project completion.

Education and Outreach

Broader Impacts in the education and outreach arenas for UNAVCO's Polar support include three main areas: an internship for a student underrepresented in STEM fields through the RESESS program (Research Experiences in Solid Earth Science for Students) , work toward an Active Earth Display highlighting the UNAVCO community's Arctic and Antarctic research, and, in 2007, planning for UNAVCO's participation in the Polar-highlighted 2008 annual meeting of the SACNAS (Society for the Advancement of Chicanos and Native Americans in Science).

Ezer Patlan, an undergraduate geophysics major from the University of Texas at El Paso, did a 10 week research internship in the summer of 2007 under the supervision of UNAVCO engineer Seth White (Figure 3). Ezer presented the results at the end-of-summer RESESS/SOARS colloquium in Boulder and as a poster presentation at the 2007 SACNAS meeting: *Development of a Power and Communication system for Remote Autonomous GPS and Seismic Stations in Antarctica.*

Figure 3 - Ezer Patlan with UNAVCO polar engineer and project mentor Seth White working on a polar remote power and communcation system.

IRIS has developed a kiosk-based interactive 'museum' exhibit called *Active Earth Display.* UNAVCO has taken the lead in planning and implementation of a polar research exhibit in collaboration with IRIS and with the POLENET project at Ohio State. This will be finalized during 2008.

For the fourth year, in 2008 UNAVCO will sponsor a student field trip prior to the main national SACNAS meeting. POLENET PI Terry Wilson will collaborate with UNAVCO in a theme of climate change for the Utah meeting. We began these plans in 2007.

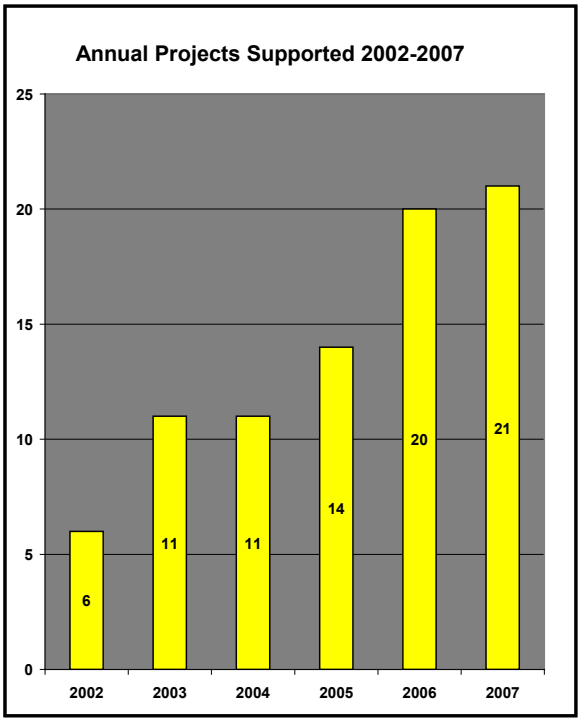
Equipment and Technology

GPS Equipment Pool

GPS equipment is available for geodetic surveying, mapping, and permanent station applications. Thirty seven new Trimble geodetic survey receivers were purchased (3 R7, 1 R8, and 33 NetRSs (25 for GNET including KAGA)) for a total of seventy NSF-OPP Arctic Sciences receivers in the UNAVCO pool:

Eight of these receivers are deployed long-term at Atqasuk, Barrow, Summit Camp, and Toolik Field Station, and 18 are deployed as part of the GNET network (Table 2). The equipment at the remaining five GNET sites was paid for by the University of Luxemburg and the Danish National Space Center. Eleven additional receivers from the UNAVCO pool were provided for project support throughout the field season to meet high-precision GPS demands from the

Arctic research community (Figures 4 and 5). Ancillary equipment such as data processing software, solar panels, batteries, chargers, tribrachs, tripods, and cables is also provided.



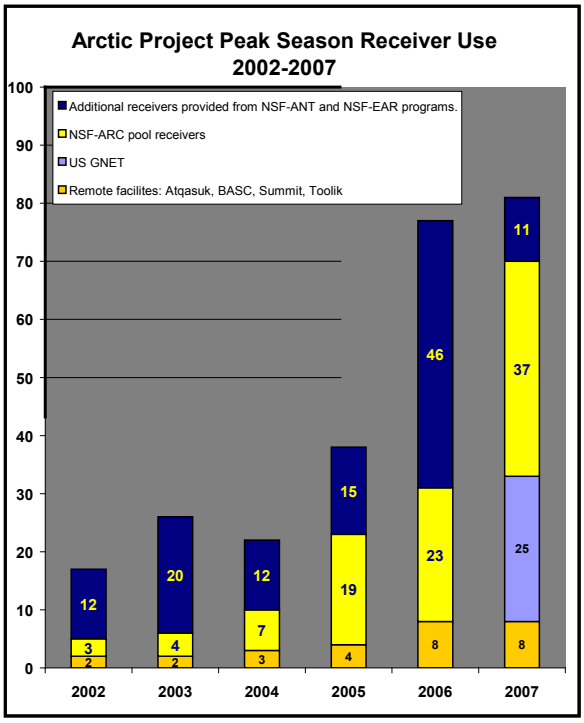


Figure 4 (left) - Support to Arctic research projects continues to grow.

Figure 5 (right) - Demand for receivers continues to increase with more research projects deploying larger number of receivers for ice dynamics and bedrock geodesy measurements in Greenland, and new receiver acquisition continues in response to this trend.

Table 2 – Equipment Deployed Long Term at Remote Facilities

Location	GPS receivers	Radio modems	Other equipment (value > $1000)
Atqasuk ARM Facility	1 TNL NetRS		
Barrow Arctic Science Consortium	1 TNL NetRS 1 TNL R8 1 TNL R7	1 TNL HB450 2 PC RFM96-2W	2 TSC2 survey controllers
Summit Camp	1 TNL NetRS 1 TNL R7	1 TNL HB450	1 TSC2 survey controller 1 Vaisala WXT510 metpack
Toolik Field Station	1 TNL NetRS 1 TNL 5700	1 PacCrest LPB Base 3 PacCrest RFM96W Rovers 1 PC RFM96-35W	1 TSC2 survey controller
GNET	18 NetRS	17 Iridium	

LiDAR

UNAVCO has received support for the MRI proposal *Acquisition of a Terrestrial Laser Scanning System For Polar Research* and purchased a terrestrial laser scanner (TLS) LiDAR system for NSF-OPP funded research support. An Optech ILRIS 3D system was purchased at the end of the year, and operational support capability will be built up during 2008 with pilot projects in Antarctica and Iceland. This survey instrument is complimentary to the suite of GPS equipment already available, allowing for much higher spatial density surveys of short distances. Considerable demand is expected, for applications such as soil surface mapping, quantification of landforms, and change detection of slopes, rock glaciers, and glaciers.

Techology Development

The ongoing MRI funded engineering effort *Development of a Power and Communication System for Remote Autonomous GPS and Seismic Stations in Antarctica* was leveraged to rapidly respond to the engineering, manufacturing, fabrication, and field support demands for the IPY POLENET-GNET project. Tasks were rescheduled to provide “alpha“ systems to the GNET project which was funded with minimal lead time prior to the field season. As a result the GNET project was the first user of MRI developed field kits, and 23 systems were installed in August and September 2007. Beyond the GNET project, these systems are in use on several different projects in the Antarctic including POLENET. UNAVCO now offers standardized power and communication system kits for rapid installation and robust data collection, including attention to long-term operation and maintenance issues. GPS data retrieval using the Iridium short burst data (SBD) service was also tested in a project with Alberto Behar of the Jet Propulsion Laboratory, Mark Fahnestock of the University of New Hampshire, and Martin Truffer of the University of Alaska Fairbanks. While this system was reasonably successful, it is not as versatile or reliable as direct modem dial-up which remains preferable for UNAVCO’s GPS data retrieval. However, this proof of concept project demonstrated the feasibility of SBD data retrieval should the topic become relevant in the future due to the Iridium air-time cost structure or the need for real-time data. The polar technology project website, www.unavco.org/polartechnology, provides a community resource and includes technical reports and detailed information on individual components and systems for users interested in adopting any of the products from this MRI funded effort.

Features of the MRI developed systems include:

- Solar panels and wind turbines for power
- Scalable battery bank size to accommodate various logistical capabilities and power requirements
- Small aircraft transportable
- Rapid set-up requiring a few hours of ground time rather than remote camping or multiple visits
- Ruggedized for the extreme polar environment
- Iridium communications for up to 1Mb/day data retrieval
- Scalable Iridium data download hub at UNAVCO, with GPS data delivery directly to archive
- Available to community as kits from UNAVCO

Atqasuk GPS Base Station

The Atqasuk, Alaska GPS station was upgraded to include a met pack to provide GPS meteorological data. The upgrade was funded by the DOE Atmospheric Radiation Measurement (ARM) Program, and the GPS-met data products are produced by the University Corporation for Atmospheric Research (UCAR). Station information, including access to GPS and met data, is available on the station web page at www.unavco.org/polar.

The main purpose of this base station (ATQK) is to provide a local source of geodetic quality differential corrections for GPS data post-processing of surveys in the Atqasuk area on the Alaska North Slope. The station is located at the ARM Climate Research Facility (ACRF) which provides security, power, and Ethernet communications. The Trimble NetRS receiver is operated remotely by UNAVCO specifically for users who have requested base GPS data in Atqasuk similar to that provided by UNAVCO and the Barrow Arctic Science Consortium in Barrow. The station runs continuously and data are available to the public from UNAVCO. Higher sample rate data are also recorded on the receiver in hourly files, and are made available to users as needed. All data are available via the Internet, and there is no need for users to have physical access to the receiver.

Figure 6 (left) – Installation of an MRI system field kit on Mt. Erebus, Antarctica, with GPS and met sensors.
Figure 7 (right) – GNET site at Kap Agassiz in northwest Greenland with auxiliary battery boxes and solar panels.

Barrow Differential GPS System

Two Trimble real-time kinematic (RTK) differential GPS (DGPS) rover systems are available for dedicated use at the Barrow Arctic Science Consortium (BASC) to meet the surveying needs of researchers working at BASC. UNAVCO provides year-round technical support to users of this system and maintains a web page with the relevant system technical information, while BASC provides the day to day operational support including equipment scheduling and issue. To ensure the continued success of the Barrow system to local science users, UNAVCO staff makes annual maintenance/training visits, often in conjunction with related project requests. In April field engineers Thomas Nylen and Marianne Okal visited Barrow and replaced the Trimble 5700 rover system was replaced with a more compact Trimble R8 system, and provided on-site training to BASC staff. System information, including access to GPS data, is available on the station web page at www.unavco.org/polar.

Summit GPS Base System

A permanent GPS base station and rover system is maintained at Summit Camp with real-time kinematic (RTK) surveying capability. The system consists of a continuously operating base receiver and a roving receiver with ancillary equipment. UNAVCO provides training to Summit science techs on demand, is available for year-round technical support to users of this system, and maintains a web page with the relevant system technical information. In addition to providing precision mapping and topographic surveying capability, the system also allows measurement of ice motion and yield data for atmospheric studies. Pressure, temperature, humidity, and column water vapor data derived from GPS are available on-line from UCAR. Station information, including access to GPS and met data, is available on the station web page at www.unavco.org/polar.

Toolik Field Station Differential GPS System

A permanent GPS base station and rover system is maintained is maintained at the Toolik Field Station to meet the surveying needs of researchers working in the vicinity of Toolik Lake on the north side of Alaska's Brooks Range. The real-time capability increases the system versatility in proximity of the station (for example it allows for stakeouts of pre-determined points), while the post-processing capability using Trimble Geomatics Office software extends the system radius to over 100km from the station. This year the base receiver, survey controller, and base station transmitter all needed repair and UNAVCO provided replacement units/upgrades. All other support was handled by the GIS/GPS staff at Toolik Field Station.

GNET

The POLENET Greenland IPY project (GNET) is an international effort led by Michael Bevis of the Ohio State University to install approximately fifty continuous GPS stations around the Greenland perimeter to apply bedrock geodesy to measure the response to past and present day ice sheet mass change (Figure 8). The US NSF funded portion of this project provides for 38 stations (including the UNAVCO led site KAGA). Most of the sites are remote and rely on solar and wind power and satellite data retrieval. Data management is provided by UNAVCO, and an Iridium based download system allows for full data retrieval from the remote stations, with on-line access at facility.unavco.org/data. Stations situated in villages will be upgraded to internet connectivity in 2008 and are currently downloaded as the opportunities arise. Figure 9 and Table 3 show the network and status at the end of 2007.

Figure 8 - Thomas Nylen of UNAVCO completes the antenna installation at GPS station KAGA above the Jakobshavn Gletscher/Kangia Icefjord.

2007 was the first year of field installations, and UNAVCO provided engineering design, procurement, shipping and field support with very little lead time. Field engineer Thomas Nylen took the lead on the field deployment portion project which resulted in 23 stations being installed during August and September, while other UNAVCO staff also spent several months assisting with the planning, preparation, and field activities. The entire GNET 2007 project was an international group effort that also included significant efforts by OSU, the Danish National Space Center (DNSC), the University of Luxemburg, and Veco Polar Resources.

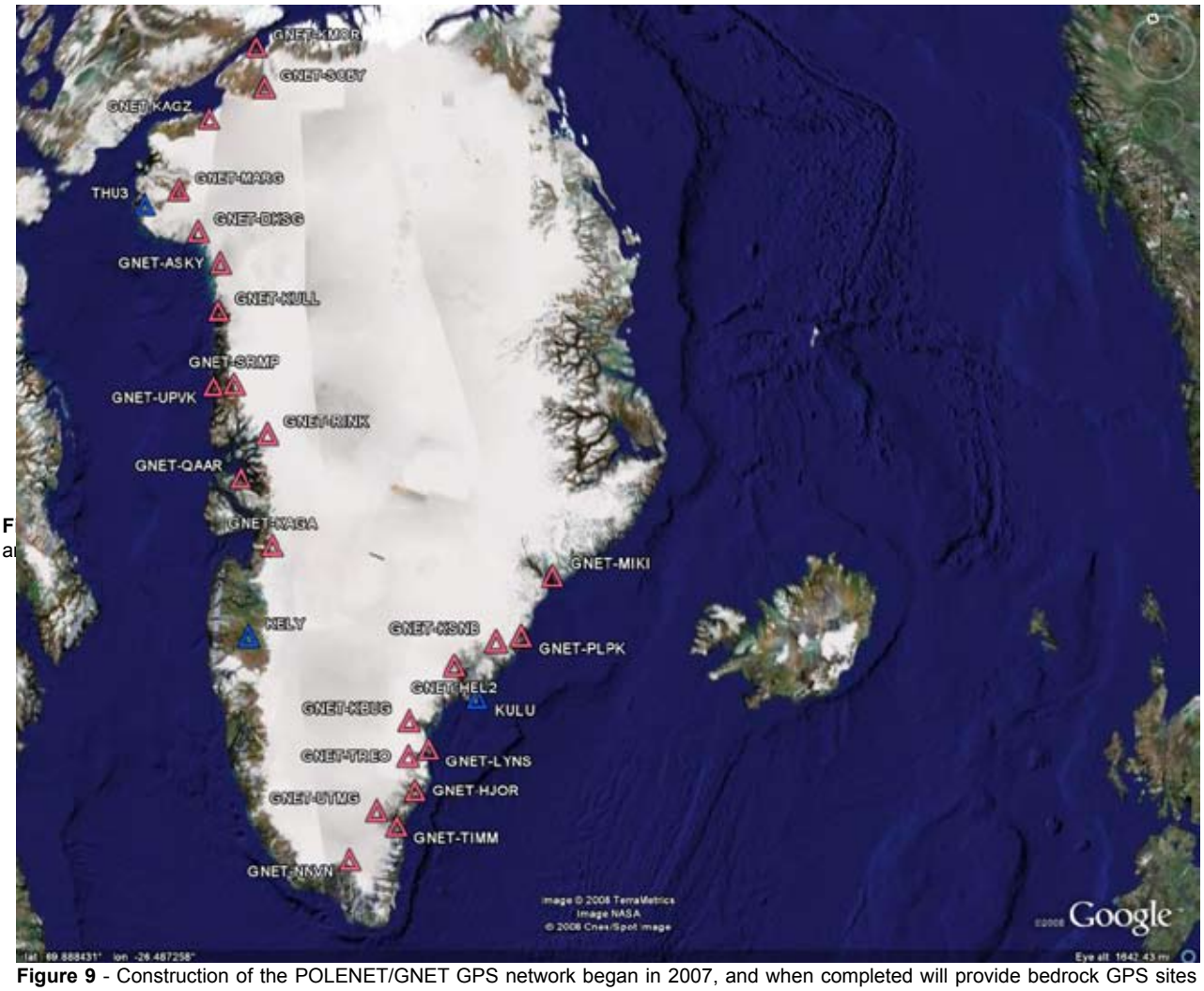


Figure 9 - Construction of the POLENET/GNET GPS network began in 2007, and when completed will provide bedrock GPS sites around the entire circumference of Greenland.

Table 3 - GNET network status as of 31 December 2007

Site	Agency	Village/remote	Status 31 December 2007
MIKI	OSU	Remote	Operational, but buried in snow. Maintenance planned to raise Iridium antenna.
PLPK	OSU	Remote	Operational
KSNB	OSU	Remote	Operational
HEL2	OSU	Remote	Operational
KBUG	U. Lux	Remote	Operational
LYNS	U. Lux.	Remote	Operational
TREO	U. Lux	Remote	Operational
HJOR	U. Lux	Remote	Operational
UTMG	OSU	Remote	Down since Sept. 07 – maintenance TBD
TIMM	OSU	Remote	Operational
NNVN	OSU	Remote	Down since Sept. 07 – maintenance TBD
KAGA	UNAVCO	Remote	Operational
QAAR	OSU	Village	Needs communication upgrade
RINK	OSU	Remote	Operational
UPVK	DNSC	Village	Needs communication upgrade
SRMP	OSU	Remote	Operational
KULL	OSU	Village	Needs communication upgrade
ASKY	OSU	Remote	Down since Nov. 07 – maintenance TBD
DKSG	OSU	Remote	Operational
MARG	OSU	Remote	Operational
KAGZ	OSU	Remote	Operational
SCBY	OSU	Remote	Down since Nov. 07 – needs power system upgrade, maintenance TBD
KMOR	OSU	Remote	Operational

Future Plans

The following activities are planned to improve geodetic support to the community:

1. 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. Possible solutions include hosting community courses, establishment of a community processing center where new users can work through their data with expert assistance present, and contracting automated processing services to accompany the archival of continuous data.

2. UNAVCO has received support for the MRI proposal *Acquisition of a Terrestrial Laser Scanning System For Polar Research* and purchased a terrestrial laser scanner (TLS) LiDAR system for NSF-OPP funded research support. An Optech ILRIS 3D system was purchased at the end of the year, and operational support capability will be built up during 2008 with pilot projects in Antarctica and Iceland. This survey instrument is complimentary to the suite of GPS equipment already available, allowing for much higher spatial density surveys of short distances. Considerable demand is expected, especially for soil surface mapping, quantification of landforms, and change detection of slopes, rock glaciers, and glaciers.

Appendix A - Detailed Summary of Support Provided

Alaska

Arctic Tundra Thermocarst (Ted Schurr – University of Florida Gainesville)

Two receivers were provided to accurately measure microtopographical changes that have occurred as permafrost has thawed and thermokarst has developed. This project studies the carbon balance of Arctic tundra in response to permafrost thawing, using radiocarbon to detect the loss of old carbon.

Atqasuk GPS Base (Bjorn Johns – UNAVCO)

UNAVCO operates a GPS receiver in Atqasuk, Alaska. This year the station was upgraded to include a met pack to provide GPS meteorological data. The upgrade was funded by the DOE Atmospheric Radiation Measurement (ARM) Program, and the GPS-met data products are produced by the University Corporation for Atmospheric Research (UCAR). Station information, including access to GPS and met data, is available on the station web page at facility.unavco.org/project_support/polar/atqasuk/atqasuk.html.

The main purpose of this base station (ATQK) is to provide a local source of geodetic quality differential corrections for GPS data post-processing of surveys in the Atqasuk area on the Alaska North Slope. The station is located at the ARM Climate Research Facility (ACRF) which provides security, power, and Ethernet communications. The Trimble NetRS receiver is operated remotely by UNAVCO specifically for users who have requested base GPS data in Atqasuk similar to that provided by UNAVCO and the Barrow Arctic Science Consortium in Barrow.

Barrow Biocomplexity (Walter Ochel – San Diego State University)

A dedicated rover receiver system was provided for this project which examines how biological and physical processes interact to control carbon uptake, storage and release in Arctic tundra ecosystems and how the self-organizing nature of these interactions varies across multiple spatial and temporal scales. A semi-permanent RTK repeater, set up at the tramway computer building, provides differential corrections from the Barrow base.

Barrow Traditional Knowledge (Wendy Eisner – University of Cincinnati)

A dedicated rover receiver system was provided for this project which compares measurements with traditional knowledge.

BASC GPS Base (Glenn Sheehan – Barrow Arctic Science Consortium)

Two Trimble real-time kinematic (RTK) differential GPS (DGPS) rover systems are available for dedicated use at the Barrow Arctic Science Consortium (BASC) to meet the surveying needs of researchers working at BASC. UNAVCO provides year-round technical support to users of this system and maintains a web page with the relevant system technical information, while BASC provides the day to day operational support including equipment scheduling and issue. To ensure the continued success of the Barrow system to local science users, UNAVCO staff makes annual maintenance/training visits, often in conjunction with related project requests. In April field engineers Thomas Nylen and Marianne Okal visited Barrow and replaced the Trimble 5700 rover system was replaced with a more compact Trimble R8 system, and provided on-site training to BASC staff (Figure 10). System information, including access to GPS data, is available on the station web page at facility.unavco.org/project_support/polar/barrow/barrow.html.

Figure 10 - Bryan Thomas, IT Manager at BASC, was recently trained on the Trimble equipment. Here, he is seen conducting a PPK survey of one of the power lines at the Barrow Environmental Observatory site.

Bench Glacier (John Bradford - Boise State University)

This project is studying water storage and routing within glaciers, and a new model of glacier hydrology. Five receivers were provided for kinematic GPS control for GPR surveys and for geodetic precision measurements of glacier motion. Training and consultation were also provided prior to the field project.

Beringia (Craig Tweedie – University of Texas El Paso)

Two receivers were provided to conduct static and kinematic field surveys at multiple sites in the Beringian Arctic. The project objective is to determine the impact of decadal time scale land cover change on plot to landscape-level carbon flux at multiple sites throughout the Beringia region.

Circumpolar Active Layer Monitoring Network - CALM (Frederick Nelson – University of Delaware)

UNAVCO provided three GPS receivers and data processing software. This was the seventh season this project used GPS to measure seasonal elevation changes in the permafrost active layer on the Alaskan North Slope.

Denali Summit Survey (Michael Loso – Alaska Pacific University)

A single GPS receiver was provided to supplement other research in case a summit bid was possible. While this did not happen, it was requested to support the National Park Service obtain new and high precision GPS coordinates for the elevation of North America's highest peak.

Juneau Icefield Research Program (Scott McGee – JIRP)

Figure 11 - Scott McGee, JIRP's head surveyor, measures the position of a point on the Lemon Glacier.

Four RTK receivers and field engineering support was provided for a pilot project to explore the possibility of providing annual support to the Juneau Icefield Research Program in Alaska. JIRP was established in 1946 and is an annual glaciological research and educational program. Its goal for the past 62 years and into the future is to investigate and monitor the geology, ecology, glaciology, and meteorology of the Juneau Icefield, near Juneau, Alaska. Glacier survey work on the Icefield has been accomplished using theodolites and EDMs, and beginning in 1992, survey-grade GPS. The goal of the survey program is to determine and monitor annually the temporal and spatial velocity distribution of the glaciers on the Juneau Icefield, and to determine surface height changes of the glaciers and relate this information to the mass balance regime. Other GPS-related activities include topographic mapping of glaciers and bedrock outcrops and to provide GPS support for allied geology, botany, geophysics, and meteorology projects (Figure 11). Since this program is not NSF funded, cost recovery would be required for sustainable UNAVCO support in future seasons.

McCall Glacier (Matt Nolan – University of Alaska, Fairbanks)

Mass balance measurements, surface velocities, cross-section profiles and continuous topography of McCall Glacier were made using real-time kinematic (RTK) surveys (Figure 12). The mass balance profiles were first measured in the 1990s with an airborne laser survey. These same points were re-occupied to determine vertical changes. The original network of velocity stakes was installed in 2003 and since then has been measured twice a year. Field support and four Trimble 5700/R7 receivers were provided, and one additional receiver was left over the previous winter to determine late season flow variations. The research on the glacier is part of a multiyear project funded by the National Science Foundation's Freshwater Initiative to study the

Figure 12 - Jason Geek measures surface topography of McCall Glacier in the Brooks Range, Alaska.

hydrologic regimes of the several rivers flowing from the Brooks Range. Previous mass balance measurements on the glacier have been made during the International Geophysical Year in 1957-58, the International Hydrological Decade in 1969-1975 and the latter half of the 1990s. Because of this history, McCall Glacier has the longest monitoring record of any glacier in Arctic Alaska.

St. Elias Erosion/Tectonics Project (STEEP) (Jeff Freymueller – University of Alaska, Fairbanks)

The St. Elias Erosion/Tectonics Project (STEEP) is a multidisciplinary project to address the tectonics of the St. Elias Range, Alaska, and the linkage between tectonism and erosion in major orogenic belts. This project received funding from both NSF-EAR and NSF-OPP, and UNAVCO provided six receivers for the 2007 season.

Toolik Field Station Differential GPS System (Andrew Balser - University of Alaska, Fairbanks)

A permanent GPS base station and rover system is maintained is maintained at the Toolik Field Station to meet the surveying needs of researchers working in the vicinity of Toolik Lake on the north side of Alaska's Brooks Range. The real-time capability increases the system versatility in proximity of the station (for example it allows for stakeouts of pre-determined points), while the post-processing capability using Trimble Geomatics Office software extends the system radius to over 100km from the station. This year the base receiver, survey controller, and base station transmitter all needed repair. UNAVCO provided replacement units/upgrades, and repaired and returned the failed units to the community pool. All other support was handled by the GIS/GPS staff at Toolik Field Station.

Greenland

East Greenland Seismology (Meredith Nettles - Lamont-Doherty Earth Observatory)

Fifteen receivers were provided to study glacier-earthquake mechanisms. The receivers were deployed on Helheim Glacier in southeast Greenland, and collected high-rate data to measure deformation associated with "glacial earthquakes." These events have been detected only in the past few years using global seismic data, which place only limited constraints on the process. The campaign was funded mainly by PI internal funds, with a data processing component funded by NSF-OPP. UNAVCO support was provided using NSF-EAR and NSF-OPP resources.

Jakobshavn Isbrae (Martin Truffer – University of Alaska Fairbanks)

Six receivers were provided for this project which aims at making a quantitative assessment of ocean freshwater contributions from the Greenland Ice Sheet. One component of this is to assess the discharge of ice from the large outlet glaciers. While the NSF funded activity has no field work component, a companion project funded through NASA is for directly measuring changes in flux of the biggest outlet glacier in West Greenland. The UNAVCO provided GPS receivers were for conducting continuous measurements of ice flow on the main glacier to assess short term variations, as well as shorter repeat point measurements to assess the long term evolution.

Peripheral Thinning (Tom Neumann – University of Vermont)

This project is studying the role of meltwater on the peripheral thinning of the Greenland ice sheet. Ten Trimble R7 receivers were provided for this project's final field season to measure ice dynamics. This project was funded by the NASA Oceans and Ice program and UNAVCO support was via a sub-award from the University of Vermont.

POLENET (GNET) (Michael Bevis – Ohio State University)

The POLENET Greenland IPY project (GNET) is an international effort led by Michael Bevis of the Ohio State University to install approximately fifty continuous GPS stations around the Greenland perimeter to apply bedrock geodesy to measure the response to past and present day ice sheet mass change. The US NSF funded portion of this project provides for 38 stations (including the UNAVCO led site KAGA). Most of the sites are remote and rely on solar and wind power and satellite data retrieval. Data management is provided by UNAVCO, and an Iridium based download system allows for full data retrieval from the remote stations, with on-line access at facility. unavco.org/data. Stations situated in villages will be upgraded to internet connectivity in 2008 and are currently downloaded as the opportunities arise.

2007 was the first year of field installations, and UNAVCO provided engineering design, procurement, shipping and field support with very little lead time (Figure 13).

Field engineer Thomas Nylen took the lead on the field deployment portion project which resulted in 23 stations being installed during August and September, while other UNAVCO staff also spent several months assisting with the planning, preparation, and field activities. The entire GNET 2007 project was an international group effort that also included significant efforts by OSU, the Danish National Space Center (DNSC), the University of Luxemburg, and Veco Polar Resources.

Figure 13 - Field engineer Marianne Okal at Doecker Smith Gletscher site DSGK. The system is powered by four 90W solar panels and two Forgen 500 wind turbines. For year-round continuous operation.

Skiways Survey (Jeff Scanniello – Veco Polar Resources)

UNAVCO provided an RTK base, rover, survey controller, and support for the use of the GPS system at Summit Camp for stakeout surveys of Summit and Raven camp skiways.

Summit GPS Base (Bjorn Johns - UNAVCO)

A permanent GPS base station and rover system is maintained at Summit Camp with real-time kinematic (RTK) surveying capability. The system consists of a continuously operating base receiver and a roving receiver with ancillary equipment. UNAVCO provides training to Summit science techs on demand, is available for year-round technical support to users of this system, and maintains a web page with the relevant system technical information. In addition to providing precision mapping and topographic surveying capability, the system also allows measurement of ice motion and yield data for atmospheric studies. Pressure, temperature, humidity, and column water vapor data derived from GPS are available on-line from UCAR. Station information, including access to GPS and met data, is available on the station web page at facility.unavco.org/project_support/polar/summit/summit.html.

Supraglacial Lakes (Sarah Das – Woods Hole Oceanographic Institute)

This project uses geophysical field measurements and remote sensing to investigate the role of Greenland's supraglacial lakes in delivering melt water to the ice sheet's bed and in modulating ice flow on short time scales. Recent results demonstrate a correlation between ice velocity and surface melt draining through moulins to the bed, which may provide a mechanism for rapid response of the Greenland Ice Sheet to climate change. Supraglacial lakes are one of the critical links between surface melting and enhanced basal flow, have the potential to rapidly respond to future climate change, and are the focus of the research project. Five receivers, solar power systems, and enclosures were provided for a 27 month continuous deployment. The enclosure boxes were built to also accommodate the seismic data logger system provided by IRIS. A brief maintenance visit was made this by UNAVCO staff, combined with the KAGA installation.

Thule-Green Valley (Jeff Welker – University of Alaska Anchorage)

The ICYLANDS project quantifies the coupling of the carbon and water cycles and the interacting physical, chemical, and biological processes that control carbon exchange between cold, dry terrestrial ecosystems and the atmosphere. One of the main goals of this project is looking at carbon cycling by studying both the ecology and soil chemistry of Arctic ecosystems. UNAVCO provided field engineering support and four GPS receiver systems for: (1) measuring fixed points and (2) delineation of watershed boundaries and periglacial features (Figure 14). Bolts that were installed in 2005 to measure the downslope movement of non-sorted stripes and solifluction lobes in Green Valley were re-measured to

Figure 14 - UNAVCO engineer Seth White sets up GPS base receiver at Green Valley solifluction site, near Thule, Greenland.

obtain solifluction velocity vectors. These measurements are the first GPS-based study of soil evolution in the high-Arctic, and centimeter-level displacements of several diverse soil features were demonstrated. These are the most pervasive periglacial forms in the high-Arctic and their formation is the primary mechanism by which soil organic carbon is brought to depth, and potentially brought up from depth at a later date.

Other

Sperry Glacier (Joel Harper – University of Montana)

This project is part of concurrent measurement of ice-surface velocity and hydrologic conditions of small mountain glaciers, and measures ice-surface velocity at two locations on Sperry Glacier, Montana. UNAVCO provided remote technical support and training.