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

2009 Annual Report

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Geodesy Advancing Earth Science Research

Cover photo – the GNET geodetic network was completed in 2009 with 44 station installations supported by UNAVCO.
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UNAVCO is the National Science Foundation'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.

Development activities of the MRI funded engineering effort Development of a Power and Communication System for Remote Autonomous GPS and Seismic Stations in Antarctica focused on minor refinements and final documentation. This project was completed in September 2009 and 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. 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.

In 2007 UNAVCO received MRI funding for the 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 was built up during 2008 with pilot projects in Antarctica, Iceland, and the US. In 2009 projects were supported with a better understanding of the complexities involved, and the current challenge is building the level and depth of technical expertise required to support a growing number of users.

Seventeen Principal Investigator based Arctic projects encompassing a range of applications were supported during 2009 (Figures 1 and 2). Three infrastructure and operational projects were also supported, including training users of the Barrow and Summit Camp DGPS systems, and providing technical support 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 2009.

Figure 2 – Greenland, Iceland, and Finland research project locations in 2009.
### Table 1 – 2009 Projects Supported

<table>
<thead>
<tr>
<th>Project</th>
<th>Funding Source</th>
<th>Point of Contact</th>
<th>Eqp Loan</th>
<th>Quantity Receivers</th>
<th>Field Support</th>
<th>Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arctic Carbon</td>
<td>ARC-0516326</td>
<td>Ted Schurr</td>
<td>X</td>
<td>2</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Arctic Lakes</td>
<td>ARC-0713903</td>
<td>Ken Hinkel</td>
<td>X</td>
<td>2</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Barrow BAID</td>
<td>ARC-0454996</td>
<td>Craig Tweedie</td>
<td>X</td>
<td>1</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>BASC GPS Base</td>
<td>ARC-UNAVCO CA</td>
<td>Glenn Sheehan</td>
<td>X</td>
<td>3</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CALM</td>
<td>ARC-0856421</td>
<td>Nikolay Shiklomanov</td>
<td>X</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denali</td>
<td>ARC-0713974</td>
<td>Karl Kreutz</td>
<td>X</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juneau Icefield Research Program</td>
<td>PI internal*</td>
<td>Scott McGee</td>
<td>X</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>McCall Glacier</td>
<td>ARC-0229705</td>
<td>Matt Nolan</td>
<td>X</td>
<td>4</td>
<td></td>
<td></td>
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<tr>
<td>Snownet</td>
<td>ARC-0632133</td>
<td>Matthew Sturm</td>
<td>X</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermocarst</td>
<td>ARC-0806341</td>
<td>Mike Gooseff</td>
<td>X</td>
<td>LiDAR</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Toolik Field Station GPS Base</td>
<td>ARC-UNAVCO CA</td>
<td>Jason Stucky</td>
<td>X</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yakutat</td>
<td>ARC-0806463</td>
<td>Roman Motyka</td>
<td>X</td>
<td>10</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Greenland:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>East Greenland Glacier Dynamics</td>
<td>ARC-0710891</td>
<td>Meredith Nettles</td>
<td>X</td>
<td>8</td>
<td></td>
<td></td>
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<tr>
<td>Helheim Glacier-Ocean-Ice Interaction</td>
<td>ARC-0806393</td>
<td>David Holland</td>
<td>X</td>
<td>Power system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>POLENET-GNET</td>
<td>ARC-0632320</td>
<td>Michael Bevis</td>
<td>X</td>
<td>40</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Store Glacier</td>
<td>NASA NNX06AE31G</td>
<td>Ian Howat</td>
<td>X</td>
<td>Tripod</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Summit GPS Base</td>
<td>ARC-UNAVCO CA</td>
<td>Bjorn Johns</td>
<td>X</td>
<td>2</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Supraglacial Lakes</td>
<td>ARC-0520077</td>
<td>Sarah Das</td>
<td>X</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iceland Breidamerkurjokull</td>
<td>ARC-0806163</td>
<td>Ian Howat</td>
<td>X</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland -SCENOP</td>
<td>ARC-0631230</td>
<td>Ezra Zubrow</td>
<td>X</td>
<td>2</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
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 worldwide. New technology development and evaluation of commercially available products for research applications is undertaken as needed, and GPS data and data products are archived 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.

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 camp 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 as noted in Table 1.

The following course from UNAVCO’s Short Course Series and Workshops was relevant to polar investigators:

INTERFACE Workshop: Recent Developments in the Methods and Applications of Terrestrial Laser Scanning (Ground-based LiDAR) in Geologic Research and Education

October 16, Geological Society of America Annual Meeting 2009, Portland, OR. This workshop will provide faculty, students, and professionals with the basic principles of Terrestrial Laser Scanning (TLS), aka ground-based LiDAR, workflows and best practices for the acquisition and processing of TLS data, an overview of various TLS platforms, and examples of science and education applications. This one-day workshop will consist of lectures and hands-on application of TLS equipment and data processing. TLS provides very high-resolution images over relatively small areas, is relatively inexpensive to acquire, and has been used successfully to support a wide range of geoscience investigations from outcrop mapping to deformation monitoring. Instructors: John Oldow and Carlos Aiken, Univ. of Texas at Dallas; David Phillips, UNAVCO.

Field Support

Field support is provided to groups that desire technical assistance for their geodetic GPS surveys. Direct field support was provided as noted in Table 1. 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, GAMIT/GLOBK/TRACK (see above), and the Canadian Spatial Reference System on-line data processing service. 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. 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.

Science Advisory Committee

The Polar Network Science 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. In 2009 the committee expanded adding two new members to provide better representation of Arctic investigators. Current membership is:

Doug Wiens, Washington University - Chair
Terry Wilson, Ohio State University – Vice-Chair
Sridhar Anandakrishnan, Pennsylvania State University
Rick Aster, New Mexico Tech
Mark Fahnestock – University of New Hampshire
Meredith Nettles – Columbia University
Carol Raymond, Jet Propulsion Laboratory
Bob Smalley, University of Memphis
**GPS Equipment Pool**

GPS equipment is available for geodetic surveying, mapping, and permanent station applications. Four new Trimble NetRS geodetic survey receivers were purchased (3 for GNET) for a total of 89 NSF-OPP Arctic Sciences receivers in the UNAVCO pool (Table 2).

Eight of these receivers are deployed long-term at Atqasuk, Barrow, Summit Camp, and Toolik Field Station, and 38 are deployed as part of the US portions of the GNET network (Table 3). The equipment at the remaining six GNET sites was paid for by the University of Luxemburg and the Danish Technical University (DTU). Thirteen 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 3 and 4). Ancillary equipment such as data processing software, solar panels, batteries, chargers, tripods, and cables is also provided.

**Table 2 – Arctic Equipment Pool**

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>Features and Applications</th>
<th>Average Age (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trimble 5700</td>
<td>7</td>
<td>Low power, high memory receiver suited for both short term and continuous data collection.</td>
<td>8</td>
</tr>
<tr>
<td>Trimble R7</td>
<td>20</td>
<td>Same as the 5700, but also capable of tracking the new L2C GPS signal.</td>
<td>6</td>
</tr>
<tr>
<td>Trimble R8</td>
<td>1</td>
<td>1 TNL HB450</td>
<td>3</td>
</tr>
<tr>
<td>Trimble NetRS</td>
<td>61</td>
<td>State-of-the-art reference station receiver with computer and web browser interface, well suited for continuous data collection applications.</td>
<td>3</td>
</tr>
<tr>
<td>LiDAR scanner</td>
<td>1</td>
<td>Optech ILRIS 36D Terrestrial laser scanner</td>
<td>2</td>
</tr>
</tbody>
</table>

**Table 3 – Equipment Deployed Long Term at Remote Facilities**

<table>
<thead>
<tr>
<th>Location</th>
<th>GPS receivers</th>
<th>Radio modems</th>
<th>Other equipment (value &gt; $1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atqasuk ARM Facility</td>
<td>1 TNL NetRS</td>
<td>1 TNL HB450, 2 PC RFM96-2W</td>
<td>2 TSC2 survey controllers</td>
</tr>
<tr>
<td>Barrow Arctic Science Consortium</td>
<td>1 TNL NetRS, 1 TNL R8, 1 TNL R7</td>
<td>1 TNL HB450</td>
<td>2 TSC2 survey controller, 1 Vaisala WXT510 metpack</td>
</tr>
<tr>
<td>Summit Camp</td>
<td>1 TNL NetRS, 1 TNL R7</td>
<td>1 TNL HB450</td>
<td>1 TSC2 survey controller</td>
</tr>
<tr>
<td>Toolik Field Station</td>
<td>1 TNL NetRS, 1 TNL 5700</td>
<td>1 PC LPB Base, 3 PC RFM96W Rovers, 1 PC RFM96-35W</td>
<td>1 TSC2 survey controller</td>
</tr>
<tr>
<td>GNET (OSU+UNAVCO)</td>
<td>38 NetRS</td>
<td>36 Iridium</td>
<td></td>
</tr>
</tbody>
</table>
Figure 3 (left) – Current level of resources allow for support to 20-25 Arctic research projects per year.

Figure 4 (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.

**LiDAR**

In 2007 UNAVCO received MRI funding for the 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 was built up during 2008 with pilot projects in Antarctica, Iceland, and the US. In 2009 projects were supported with a better understanding of the complexities involved, and the current challenge is building the level and depth of technical expertise required to support a growing number of users.
Figure 5 (left) – The degraded landscape in the bottom left corner of the photo is one of the thermokarst sites that were scanned near Toolik Field Station (Mike Gooseff PI) to determine the rate of degradation, as well as providing topographical information that may help researchers.

Figure 6 (right) – Researchers Ben Crosby and Sarah Godsey set up a scan amidst a sea of mosquitoes.

**Technology Development**

Development activities of the MRI funded engineering effort *Development of a Power and Communication System for Remote Autonomous GPS and Seismic Stations in Antarctica* focused on minor refinements and final documentation. This project was completed in September 2009 and 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. The polar technology project website, [www.unavco.org/polartechnology](http://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

The development activities of the power and communications development MRI project have been pushed by the need to concurrently field systems for GNET and POLENET. In this third and final year a system design review meeting was held to solicit feedback from community experts who have not been intimately involved in the design process. The results of this review are included as Appendix B.
Atqasuk GPS Base Station

The Atqasuk, Alaska GPS station continued to operate without any major attention of field visits. 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.

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 June field engineer Joe Pettit visited Barrow to perform system maintenance and provide on-site training to science and 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, year-round technical support to users of this system, and 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 provides data for atmospheric studies. Station information, including access to GPS 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 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 all local 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 (Figures 7 and 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 are managed by GNET Danish collaborator Danish Technical University (DTU) and are currently downloaded as the opportunities arise. Figure 8 and Table 4 show the UNAVCO supported network and status at the end of December 2009.

Figure 7 – Station GROK in northeast Greenland (installed in 2008) received an opportunity maintenance visited to apply the 2009 standard system configuration.

2009 was the third and final year of field installations, and UNAVCO provided, procurement, shipping and field support. Field engineer Thomas Nylen took the lead on the planning, preparation, and field deployment portion of the project which resulted in 11 stations installed in August. Two stations installed in northeast Greenland in 2008 were also upgraded to the slated system configuration. The entire GNET 2009 project was an international group effort that also included significant efforts by OSU, DTU, and CH2M-Hill Polar Services.
Figure 8 – Construction of the POLENET/GNET GPS network was completed in 2009, with 11 stations added along the east coast completing the bedrock cGPS network around the entire circumference of Greenland.

Table 4 – GNET network status as of 31 December 2009

<table>
<thead>
<tr>
<th>Site ID and health</th>
<th>Site “owner”</th>
<th>Communication link</th>
<th>Status 31 December 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIK2</td>
<td>OSU</td>
<td>Iridium</td>
<td>Operational</td>
</tr>
<tr>
<td>KUAQ</td>
<td>OSU</td>
<td>Iridium</td>
<td>Comms link down</td>
</tr>
<tr>
<td>PLPK</td>
<td>OSU</td>
<td>Iridium</td>
<td>Operational</td>
</tr>
<tr>
<td>KSNB</td>
<td>OSU</td>
<td>Iridium</td>
<td>Operational</td>
</tr>
<tr>
<td>HEL2</td>
<td>U. Lux</td>
<td>Iridium</td>
<td>Operational</td>
</tr>
<tr>
<td>KBUG</td>
<td>OSU</td>
<td>Iridium</td>
<td>Modern answers, but no comms to receiver since Dec. 08</td>
</tr>
<tr>
<td>LYNs</td>
<td>OSU</td>
<td>Iridium</td>
<td>Comms link down Jul. 08, SIM card is disabled</td>
</tr>
<tr>
<td>TREG</td>
<td>OSU</td>
<td>Iridium</td>
<td>Operational</td>
</tr>
<tr>
<td>HJOR</td>
<td>OSU</td>
<td>Iridium</td>
<td>Operational</td>
</tr>
<tr>
<td>UTMG</td>
<td>OSU</td>
<td>Iridium</td>
<td>Comms link down since Sep. 07, SIM card is disabled,</td>
</tr>
<tr>
<td>TIMM</td>
<td>OSU</td>
<td>Iridium</td>
<td>Operational</td>
</tr>
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<td>Status</td>
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<td>OSU</td>
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</table>
Green Station is operational with real-time data retrieval.

Yellow Station is most likely collecting data, but without communications we can not be certain.

Red A site visit is required to resume data collection.

Table 4 and Figure 9 illustrate good performance of a network that was deployed in parallel with a technology development effort (the MRI funded engineering effort Development of a Power and Communication System for Remote Autonomous GPS and Seismic Stations in Antarctica). Lessons were learned along the way, and the mature systems installed in 2009 are also the output product of the MRI development project. In addition, these systems were deployed after thorough burn-in testing, something that was not possible in previous seasons due to inadequate lead time. This includes standard GPS receiver QC checks, testing the built up system board (GPS receiver, Iridium data modem, and power control components) in the UNAVCO environmental chamber when destined for extreme cold locations, and performing a “burn-in” test to capture infant mortality cases and allow for corrective action if problem components are identified. For future deployments, adequate lead time and staff time will need to be built into project planning, or the decision made to proceed with the acceptance of greater risk. This was not possible for the 2007 and 2008 seasons due to insufficient lead times.

Figure 9 - GNET data return from remote stations with Iridium communications through 2009 shows consistent 80-90% data return as the network was built over three field seasons.
Appendix A - Detailed Summary of Support Provided

ALASKA:

Arctic Carbon (Ted Schurr – University of Florida Gainesville)

Two receivers and training at UNAVCO were provided to accurately map field site topography for the project goal to measure the carbon balance of Arctic tundra in response to permafrost thawing.

Arctic Lakes (Ken Hinkel – University of Cincinnati)

This project studies changes in lake dynamics on the Arctic coastal plain of North America over the past half century. Two GPS receivers and training were provided.

Barrow BAID-IMS (Craig Tweedie – University of Texas at El Paso)

The Barrow Area Information Database and Internet Map Server (BAID-IMS) is designed to help scientist, land managers, educators and the local community access spatially relevant information for northern Alaska. A dedicated rover RTK receiver system and training in Barrow were provided to University of Texas at El Paso students and technicians to collect information on current and historical research sites and infrastructure which will be hosted in BAID-IMS.

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 June field engineer Joe Pettit visited Barrow to perform system maintenance and provide on-site training to science and BASC staff. System information, including access to GPS data, is available on the station web page at www.unavco.org/polar.

Circumpolar Active Layer Monitoring Network - (Nikolay Shiklomanov – University of Delaware)

This was the nineth season this project used GPS to measure seasonal elevation changes in the permafrost active layer on the Alaskan North Slope. UNAVCO provided three GPS receivers.
**Denali (Karl Kreutz – University of Maine)**

The goal of this project is to assess snow chemistry and ice flow dynamics at two research sites on glaciers in Denali National Park to locate a suitable site for extraction of a surface to bedrock ice core. Three receivers were provided to profile the ice surface and measure ice flow velocities for determining flow vectors at each research site.

**Juneau Icefield Research Program (Scott McGee – JIRP)**

Four RTK receivers were provided 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. Since this program is not NSF funded, JIRP covered the incremental costs of UNAVCO support.

**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. 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. Four receivers and RTK ancillary equipment were provided. The research on the glacier is part of a multiyear project funded by the National Science Foundation's Freshwater Initiative to study the 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.

**SnowNet (Matthew Sturm – University of Alaska, Fairbanks)**

One PPK GPS receiver provided for surveying needs accompanying LiDAR measurements in the Imnavait Creek watershed. The SnowNet project aims to better understand Arctic precipitation and snow cover trends.

**Thermokarst (Michael Gooseff – Pennsylvania State University)**

Alaska’s North Slope area is characterized by the surface “active layer” of tundra that thaws during the summer season, while the underlying permafrost remains frozen year-round. Thermokarst is a land feature that develops when this active layer separates from the permafrost, creating distinctive slumps, gullies, and hollows. As the climate in the Arctic changes, there is increasing report of thermokarst incidence. UNAVCO provided Terrestrial Lidar (TLS) support to PIs Mike Gooseff (Penn State) and Ben Crosby (Idaho State) for the duration of the summer, with the goal of measuring rates of degradation and characterizing the parameters that dictate when and where thermokarst will occur.
Toolik Field Station Differential GPS System (Jason Stuckey - University of Alaska, Fairbanks)

A permanent GPS base station and rover system 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 all local support was handled by the GIS/GPS staff at Toolik Field Station.

Yakutat Glacier (Roman Motyka - University of Alaska, Fairbanks)

UNAVCO provided 10 GPS receivers, 3 year-round power systems, and Iridium communications for a site near the glacier calving front for this study of the interplay between surface mass balance, glacier flow, bed geometry, and terminus dynamics of Yakutat Glacier.

GREENLAND:

East Greenland Glacier Dynamics (Meredith Nettles - Lamont-Doherty Earth Observatory)

Outlet glaciers on the perimeter of the Greenland Ice Sheet continuously feed fresh water into the Atlantic Ocean at the zone where the cryosphere, hydrosphere, and atmosphere meet, a highly complex and insufficiently understood area. A large-scale remote sensing project was recently developed by a group of researchers from Lamont-Doherty Earth Observatory, Harvard University, the University of Maine, and the Institute for Space Sciences in Barcelona, Spain, with the aim of using GPS to better determine the dynamics of the glacial flow of these outlet glaciers. UNAVCO provided support for both the development and field portions of the project.

This study focuses on Helheim and Kangerdlugssuaq glaciers, which are located on the South-East coast of Greenland and together drain approximately 8% of the Greenland Ice Sheet. The project proposed to install 30 single-frequency (L1) GPS receiver systems equipped with radio communications on each glacier for a 15-month period from June of 2008 through August of 2009. The data are stored locally at each receiver site and transmitted to one of six nearby dual-frequency GPS sites located on stable rock out-crops above the glaciers. Each rock-site will be equipped with a small computer to manage communications and store all incoming data, and with satellite (Iridium) communications that will transmit all data back to UNAVCO. The dual-frequency data recorded at the rock sites were used to obtain space and time corrections for the L1 ice data.

While the US and Spanish researchers developed the software, firmware, and communications portions of the project, UNAVCO created designs for and fabricated both the L1 ice-site enclosures and dual-frequency rock-site stations. Six dual-frequency receivers and power systems were provided for the fixed rock sites adjacent to the glaciers, and the L1 units were deployed and operated at both Kangerlugssuaq and Helheim Glaciers. Data were retrieved via an Iridium download computer at UNAVCO, where it was picked up by the science team for processing.
Helheim Glacier-Ocean-Ice Interaction (David Holland – New York University)

One MRI developed power system kit, using both solar and wind power, was provided as the power source for the project’s weather station. Power and weather monitoring sensors and displays provided by Dr. Holland's group provides an opportunity for close monitoring of the engineering data related to the power system performance.

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 are managed by GNET Danish collaborator Danish Technical University (DTU) and are currently downloaded as the opportunities arise. Figures 8, 9 and Table 4 show the network and status at the end of December 2009.

2009 was the third and final year of field installations, and UNAVCO provided, procurement, shipping and field support. Field engineer Thomas Nylen took the lead on the planning, preparation, and field deployment portion of the project which resulted in 11 stations installed in August. Two stations installed in northeast Greenland in 2008 were also upgraded to the slated system configuration. The entire GNET 2009 project was an international group effort that also included significant efforts by OSU, DTU, and CH2M-Hill Polar Services.

Store Glacier (Ian Howat – Ohio State University)

A tribrach and tripod were provided for this project for a base station set-up adjacent to Store glacier.

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, year-round technical support to users of this system, and 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 provides data for atmospheric studies. Station information, including access to GPS data, is available on the station web page at www.unavco.org/polar.

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. The deployment of four receivers from UNAVCO was extended for another year of data collection, and one of the Trimble R7 units was swapped with a Trimble NetRS to provide better over-winter performance.
OTHER:

Iceland Breidamerkurjokull (Ian Howat – Ohio State University)

Thirteen receivers were provided for continuous GPS surveys of ice motion at Breidamerkurjokull to observe sliding and force budget dynamics. These systems included solar power systems and enclosures. Unfortunately solar charge regulator failures at three of the sites compromised the data set, and a repeat deployment is planned for March 2010.

Finland SCENOP (Ezra Zubrow – Ohio State University)

SCENOP seeks to identify cross-cultural regularities and differences in human responses to rapid environmental change in prehistory. By collecting and analyzing archaeological and paleo-environmental data from two widely separated but environmentally comparable circumpolar paleo-estuaries, the Yli-li area of Northern Finland and the Wemindji area of James Bay in Quebec. Specifically, SCENOP examines ecological and human transitions between fully marine, estuarine, and fully terrestrial conditions in both regions under study in the context of shoreline displacement. Two GPS receivers were provided for precise mapping of the artifacts, the site locations and elevations, and the prehistoric shorelines at the Finland research site.
Appendix B – MRI Design Review Committee Report

Major Research Instrumentation Project:
Development of a Power and Communication System for Remote Autonomous GPS and Seismic Stations in Antarctica

Review Committee Report

March 13, 2009

The review committee met with Bjorn Johns and Seth White of UNAVCO at the offices of UNAVCO in Boulder, Colorado on March 12 and 13, 2009. The committee was directed by Renee Crain of NSF to assess the performance of UNAVCO on the Polar Service’s NSF/OPP Major Research Instrumentation (MRI) Project. Specifically the committee was directed to answer the following questions:

1. Is UNAVCO at the leading edge of polar system designs for the target applications?
2. Is the project meeting stated deliverables and milestones?
3. How does the product measure up to the grant award size?
4. Are there other relevant field-tested designs that should be applied to this design?
5. Are there major issues with the design?
6. Are there minor but correctable issues that can be addressed in the design?
7. Evaluate the list of issues and planned corrective actions – are evolving design changes, failures and lessons learned being addressed effectively?

The committee met for a total of twelve hours during which UNAVCO presented a technical design overview and current status. There were many technical discussions during and after the presentation. The committee was encouraged by UNAVCO to ask questions and to dig as deeply as necessary to answer the above questions. We found the UNAVCO representatives to be informative and forthcoming.

The following are the unanimous findings of the committee.

- Is UNAVCO at the leading edge of polar system designs for the target applications?

The MRI system is at the leading edge of polar field system technology.

The committee is not aware of any competitive designs that would provide better performance or lower cost. While there are recent technologies such as rechargeable lithium ion batteries that would improve the MRI system, these technologies are not yet suitable for polar environments.

There are indications that the Trimble Net/RS receiver, which is central to the MRI design, will be discontinued sometime in the next year. The MRI system also needs to evolve in order to deal with this type of component obsolescence.
• Is the project meeting stated deliverables and milestones?

As listed in Section 4, Project Milestones in the proposal, the project has met the early milestones by the date of this review and the Year 3 milestones have either been completed or are on track for timely completion.

• How does the product measure up to the grant award size?

The committee was favorably impressed with the quality of the MRI design considering the amount of the grant. NSF received true value for its investment.

• Are there other relevant field-tested designs that should be applied to this design?

The committee is not aware of any field-tested designs that could be applied at this time. However, there are some new technologies that may be suitable for the MRI system in the foreseeable future. As they develop, these new technologies (advances in GPS receivers, more efficient solar cells, wind turbines, microcontrollers, communications, and battery technology) should be investigated and tested in order to keep the MRI system at the leading edge.

• Are there major issues with the design?

The committee found no major design issues. However, we strongly recommend that a watchdog timer be incorporated in all new systems and retrofitted to existing systems as they are serviced. It is the experience of the committee that, due to complex system components and interactions, undetected sporadic bugs will exist in fielded systems. The watchdog timer serves as a last line of defense and is considered good design practice.

• Are there minor but correctable issues that can be addressed in the design?

Most of the minor but correctable issues have already been addressed. The unresolved issues are being properly tracked and addressed. Improved documentation and user training would reduce future problems. UNAVCO is on track to complete the documentation and user training procedures by the end of the MRI grant period. The committee recommends that an independent third party review the final documentation.

• Evaluate the list of issues and planned corrective actions – are evolving design changes, failures and lessons learned being addressed effectively?

The review committee discussed each issue in detail and concurred with most of the proposed solutions. In addition, the committee offered several corrective action recommendations. The committee agrees that UNAVCO has been approaching these issues in a systematic and effective manner.

Given the time and funding constraints, UNAVCO has done a good job developing the MRI system. The committee agrees that the level of reliability achieved by the MRI system in this early stage of development is acceptable.

It is unreasonable to expect the first version of a polar field system to be perfect. All potential problems cannot be anticipated. Due to field site remoteness, identifying the source of a problem could take several years. We recommend that MRI system development continue in order to improve reliability and keep it on the leading edge of technology.
Review Committee:
The committee members have extensive experience designing and field testing polar instrumentation systems.

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