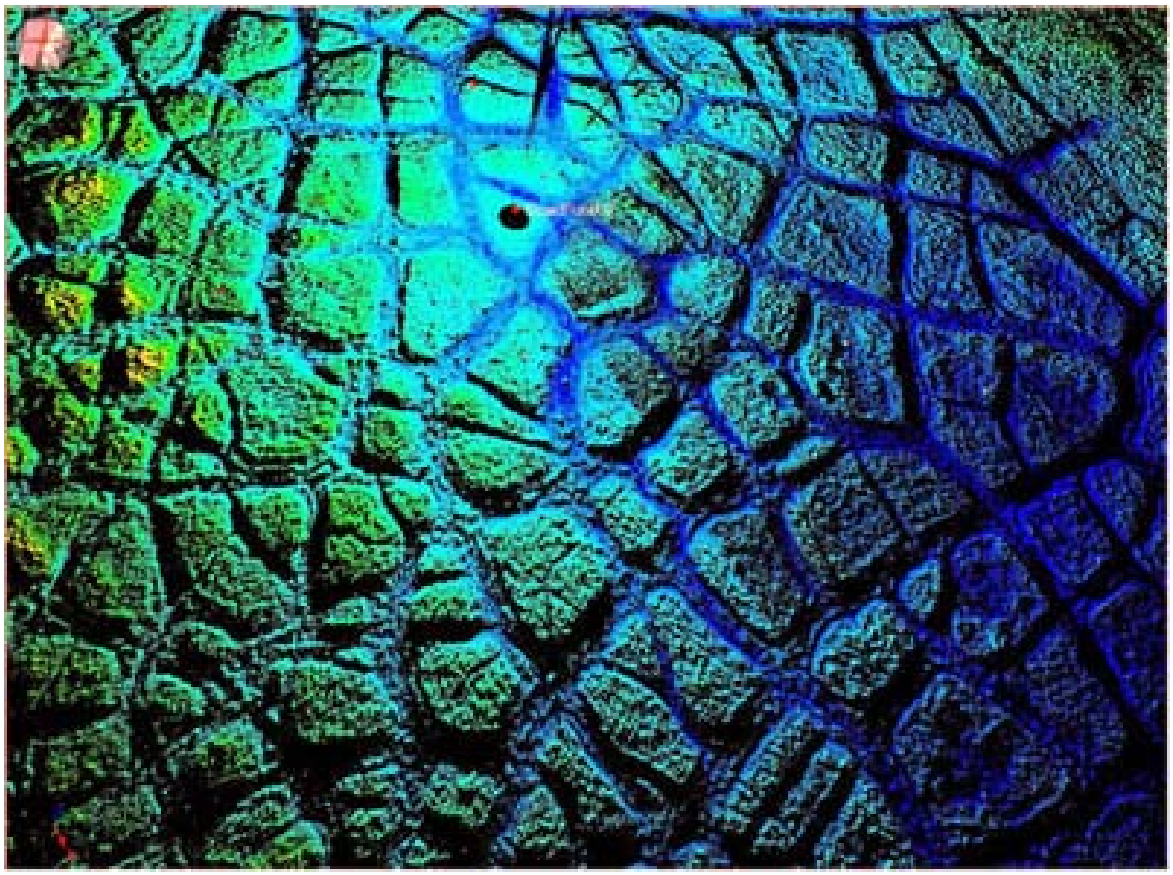
Geodetic Support to the National Science Foundation Office of Polar Programs Arctic Sciences



2010 Annual Report

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

2010 Annual Report

January 26, 2011

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through EAR-0735156- UNAVCO Community and Facility Support:
Geodesy Advancing Earth Science Research

Cover photo – A geo-referenced LiDAR image of the tundra landscape in Barrow clearly defines the polygonal features. The color scale represents true elevation and allows us to see larger-scale landscape features.

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Summary

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 operation, and the UNAVCO community data archive are leveraged to apply state-of-the-art technologies at a reasonable cost.

In 2010 the scope of Polar activities at UNAVCO effectively outgrew the Cooperative Agreement, and a new proposal, Enhanced Support for GPS Networks and Terrestrial Laser Scanning in Polar Regions (ANT-1053220) was awarded. This award includes funds for enhanced core UNAVCO Facility support in two primary areas. The first is network engineering to support the ~100 station continuously operating GPS receivers installed in Greenland (GNET) and in Antarctica (POLENET). The second is polar support for Terrestrial Laser Scanning.

Twenty two Principal Investigator based Arctic projects encompassing a range of applications were supported during 2010 (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.

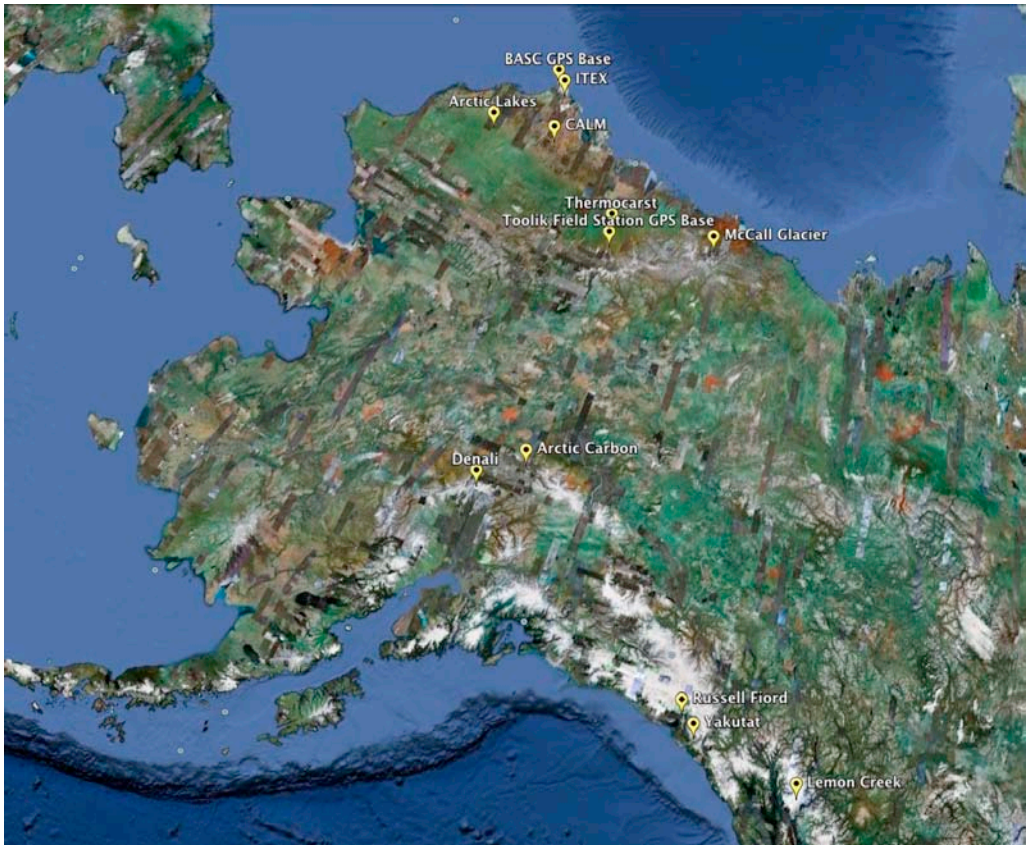


Figure 1 – Alaska research project locations in 2010.

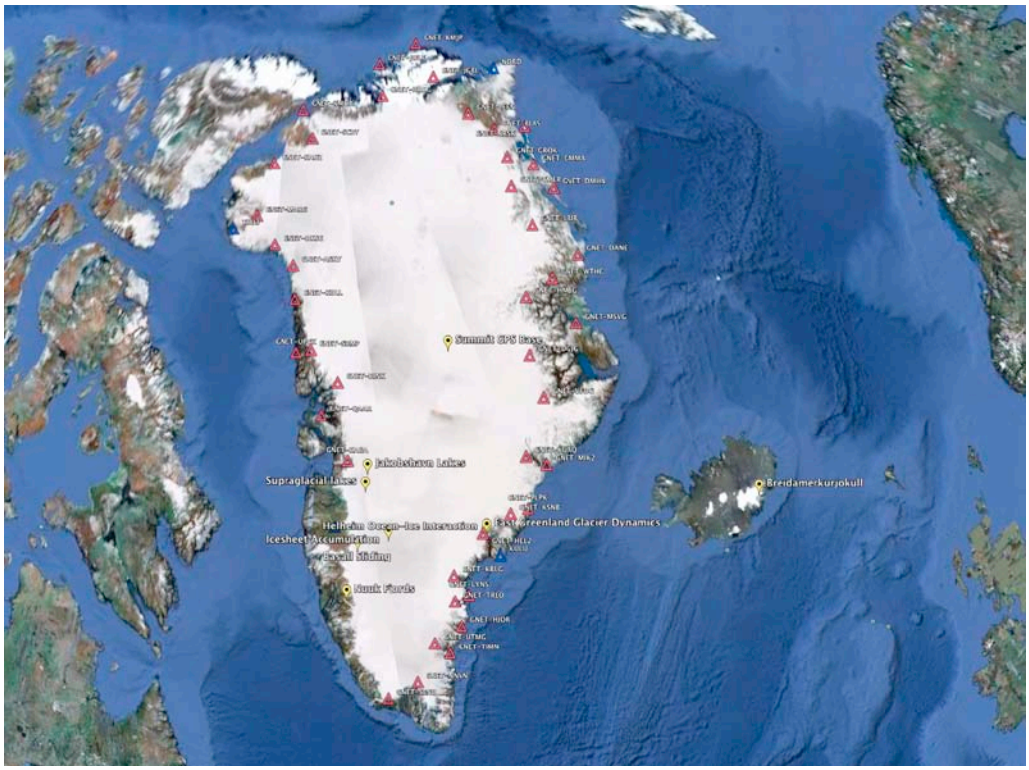


Figure 2 – Greenland and Iceland research project locations in 2010.

Table 1 – 2010 Projects Supported

Project	Funding Source	Point of Contact	Eqp Loan	Quantity Receivers/TLS	Field Support	Training
Alaska:						
Arctic Carbon	ARC- 0747195	Ted Schurr	X	2		
Arctic Lakes	ARC-0713903	Ken Hinkel	X	2		
Barrow ITEX SAON	ARC-0856628	Craig Tweedie	X	2 + TLS	X	X
BASC GPS Base	ARC-UNAVCO CA	Glenn Sheehan	X	3	X	X
CALM	ARC-0856421	Nikolay Shiklomanov	X	2 + TLS	X	X
Denali	ARC-0713974	Karl Kreutz	X	2		
Lemon Creek Glacier	PI internal	Andrew Fountain	X			
McCall Glacier	ARC-0229705	Matt Nolan	X	4		
Russell Fiord	ARC-0949775	Dan Lawson	X	7		
Thermocarst	ARC-0806341	Mike Gooseff	X	TLS		X
Toolik Field Station GPS Base	ARC-UNAVCO CA	Jason Stuckey	X	2		
Toolik Field Station LiDAR	ARC-UNAVCO CA	Jason Stuckey	X	TLS		
Yakutat	ARC-0806463	Roman Motyka	X	10		
Greenland:						
Basal Sliding	ARC-0909495	Joel Harper	X	3		X
East Greenland Glacier Dynamics	ARC-0710891	Meredith Nettles	X	3	X	
Greenland Meltwater	ARC-0909454	Ginny Catania	X			X
Helheim Glacier-Ocean-Ice Interaction	ARC-0806393	David Holland	X	Power system		
Icesheet Accumulation	ARC-0909499	Rick Forster	X	4		
Jakobshavn Lakes	ARC-0907178	Sridhar Anandakrishnan	X	8		
Nuuk Fjords	ARC-0909552	Martin Truffer	X	10		
POLENET-GNET	ARC-0632320	Michael Bevis	X	40	X	
Summit GPS Base	ARC-UNAVCO CA	Bjorn Johns	X	2		X
Supraglacial Lakes	ARC-0520077	Sarah Das	X	4		
Other:						
CALM-Cherskii	ARC-0856421	Nikolay Shiklomanov	X	3		
Iceland Breidamerkurjokull	ARC-0806163	Ian Howat	X	13		

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 courses from UNAVCO's Short Course Series and Workshops were relevant to polar investigators:

GPS Data Analysis and Modeling Using GAMIT/GLOBK/DEFNODE

16-19 November 2010
University of Miami, FL
This workshop will combine GPS data processing and analysis using the GAMIT/GLOBK software with modeling of secular and time-dependent motion of GPS stations using DEFNODE. Participants will be expected to have exercised the software on their own before the workshop and should bring laptops with the software installed or with remote access to their own labs. The format will include both presentations and one-on-one tutoring using the participants' own data.
Instructors: Bob King, MIT; Rob McCaffrey, Portland State; Tim Dixon and Shimon Wdowinski, Miami.

TLS: Terrestrial Laser Scanning (Ground-Based LiDAR) Methods and Applications in Geologic Research and Education

October 30, 2010, 8am-5pm
Geolocial Society of America 2010 Annual Meeting, Denver, CO
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. Limited financial support is available for students. For more information and to register, visit the GSA 2010 Short Course Website.
Instructors: John Oldow, University of Texas at Dallas; Carlos Aiken, University 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. 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 now members to provide better representation of Arctic investigators. Current membership is:

Doug Wiens, Washington University - Chair
Carol Raymond, Jet Propulsion Laboratory – Vice Chair
Sridhar Anandakrishnan, Pennsylvania State University
Mark Fahnestock – University of New Hampshire
Erik Ivins, Jet Propulsion Laboratory
Meredith Nettles – Columbia University
Mike Ritzwoller – University of Colorado
Leigh Stearns – University of Kansas

Equipment and Technology

GPS Equipment Pool

GPS equipment is available for geodetic surveying, mapping, and permanent station applications. One new Trimble NetR9 geodetic receiver was were purchased, and one was lost on project for a total of 89 NSF-OPP Arctic Sciences receivers in the UNAVCO pool (Table 2). (Two more USAP owned receivers were also lost on Arctic projects in 2010, and three additional receivers will be procured in 2011 to replenish the pool.)

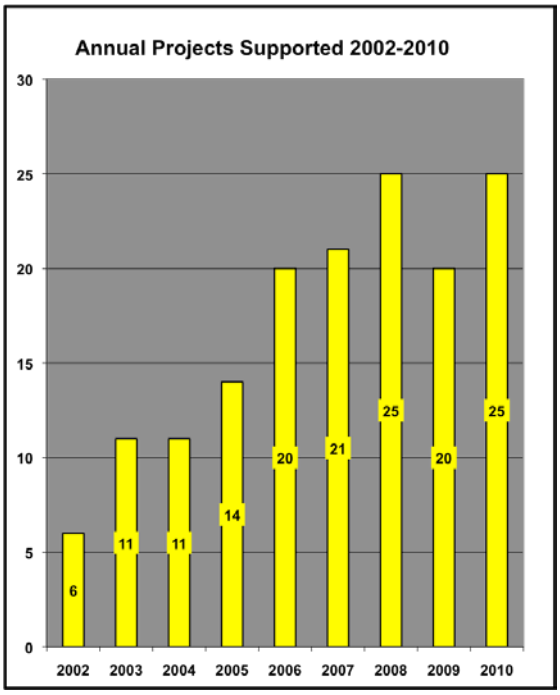
Eight of these receivers are deployed long-term at Atqasuk, Barrow, Summit Camp, and Toolik Field Station, and 38 are deployed as part of the US portions of the GNET network (Table 3). The equipment at the remaining six GNET sites was paid for by the University of Luxemburg and the Danish Technical University (DTU). Forty three 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, tribrachs, tripods, and cables is also provided.

Table 2 – Arctic Equipment Pool

Item	Qty	Features and Applications	Average Age (yr)
Trimble 5700	7	Low power, high memory receiver suited for both short term and continuous data collection.	9
Trimble R7	19	Same as the 5700, but also capable of tracking the new L2C GPS signal.	7
Trimble R8	1	1 TNL HB450	4
Trimble NetRS	61	Reference station receiver with computer and web browser interface, well suited for continuous data collection applications.	4
Trimble NetR8	1	Reference station receiver with computer and web browser interface, well suited for continuous data collection applications.	
LiDAR scanner	1	Optech ILRIS 36D Terrestrial laser scanner	3

Table 3 – 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 PC LPB Base 3 PC RFM96W Rovers 1 PC RFM96-35W	1 TSC2 survey controller
GNET (OSU+UNAVCO)	38 NetRS	36 Iridium	



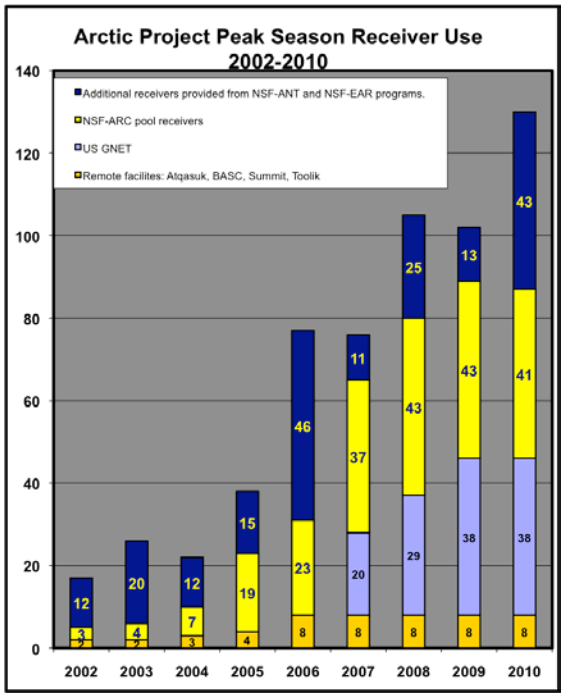
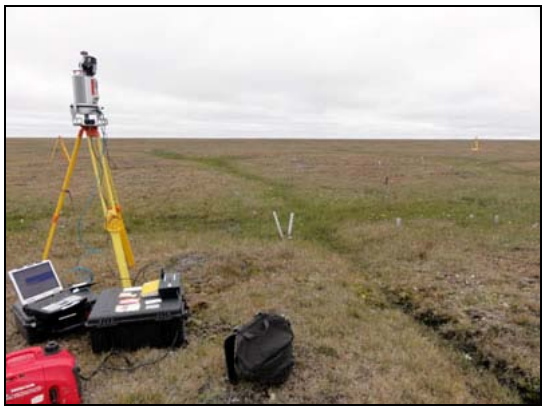


Figure 3 (left) – Current level of resources allow for support to 20-25 Arctic research projects per year.

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 2010 the scope of Polar activities at UNAVCO effectively outgrew the Cooperative Agreement, and a new proposal, Enhanced Support for GPS Networks and Terrestrial Laser Scanning in Polar Regions (ANT-1053220) was awarded. This award includes funds for 0.5 FTE support to Arctic LiDAR projects. Four separate PI LiDAR projects were supported in Alaska as noted in Table 1.



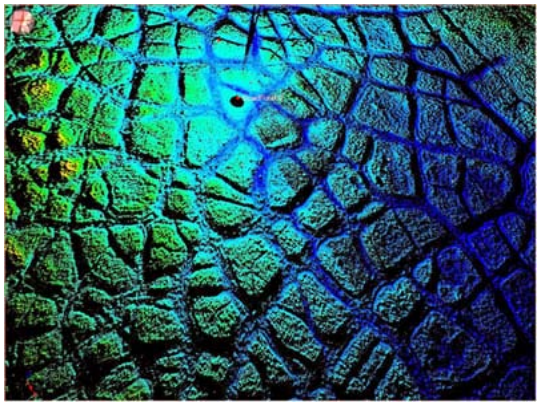


Figure 5 (left) – Scanning in the Barrow Environmental Observatory on a typical day in Barrow. The green linear features are water-logged cracks in the earth that will freeze and expand in the winter, creating ice wedges. From the Circumpolar Active Layer Monitoring Network (N. Shiklomanov).

Figure 6 (right) – A geo-referenced LiDAR image of the tundra landscape in Barrow clearly defines the polygonal features. The color scale represents true elevation and allows us to see larger-scale landscape features.

Technology Development

Remaining funds from the completed MRI project Development of a Power and Communication System for Remote Autonomous GPS and Seismic Stations in Antarctica were used to issue a subcontract to Xeos Technologies to develop a scalable and instrument independent Iridium Router-based Unrestricted Digital Internetworking Connectivity (RUDICS) based communications for geodetic GNSS networks and other sensors. Enhanced features include the ability to host standard "network appliance" devices using the Ethernet interface and TCP/IP protocol, improved bandwidth, reduced power consumption, cold hardening, and improved system control. Two systems were delivered and field testing is currently in progress.

The proposal Enhanced Support for GPS Networks and Terrestrial Laser Scanning in Polar Regions includes 0.5 FTE for network engineering to support the ~100 station continuously operating GPS receivers installed in Greenland (GNET) and in Antarctica (POLENET). Part of this effort is for sustaining engineering activities specifically for the requirements to transition from development activities to an operational role in supporting the polar autonomous GPS networks, provide a systematic approach to keeping up with ever changing technologies, and make the MRI developed systems available to the broader community. Specific efforts in 2010 included improving the IT infrastructure of the Iridium communication hub at UNAVCO, working with Xeos technologies on the subcontracted RUDICS development activities mentioned above, improved system grounding at remote sites, and testing the "plateau" wind turbine system in a windier "margin" environment.

Atqasuk GPS Base Station

The Atqasuk, Alaska GPS station continued to operate without any major attention or 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. Field engineer Seth White 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. (The on-site management of this system will change in 2011.)

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 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 a LiDAR instrument was also provided to the TFS GIS staff, who handled all local support.

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 7). 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 7 and Table 4 show the UNAVCO supported network and status at the end of December 2010.

In 2010 there were no NSF-sponsored GNET field logistics. However, seven sites in the northwest and ten sites in the southeast received maintenance visits using DTU logistical support. UNAVCO provided the necessary equipment, shipping to Greenland (with CH2MHill Polar Services support), and remote technical support. Seth White also provided field support for the northwest effort based out of Thule.

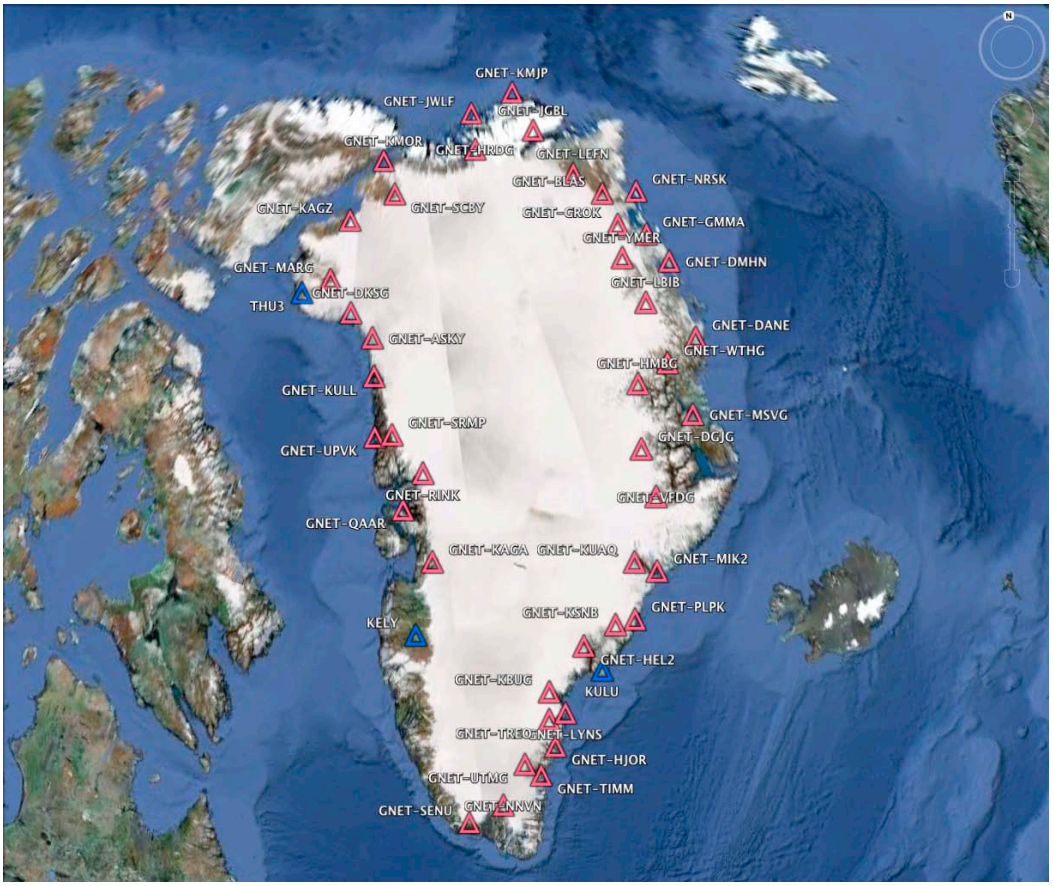


Figure 7 – The POLENET/GNET network. Seventeen sites received maintenance in 2010 using DTU logistics and UNAVCO technical support.

Table 4 – GNET network status as of 31 December 2009

Site ID and health	Site "owner"	Communication link	Status 31 December 2010
MIK2	OSU	Iridium	Operational
KUAQ	OSU	Iridium	Comms link intermittent
PLPK	OSU	Iridium	Operational
KSNB	OSU	Iridium	Operational
HEL2	U. Lux	Iridium	Operational
KBUG	OSU	Iridium	Operational
LYNS	OSU	Iridium	Operational
TREO	OSU	Iridium	Operational
HJOR	OSU	Iridium	Operational
UTMG	OSU	Iridium	Station rebuild required.
TIMM	OSU	Iridium	Operational
NNVN	U. Lux	Iridium	Operational but a rebuild is recommended.
SENU	OSU	Iridium	Operational
KAGA	UNAVCO	Iridium	Operational
QAAR	OSU	None	Data download by DTU
RINK	U. Lux	Iridium	Operational
UPVK	DTU	None	Data download by DTU
SRMP	U. Lux	Iridium	Operational
KULL	OSU	None	Data download by DTU
ASKY	OSU	Iridium	Comms link down since Mar. 2010, maint. planned in 2011.
DKSG	OSU	Iridium	Operational but a power system upgrade is required.
MARG	OSU	Iridium	Operational
KAGZ	OSU	Iridium	System down since Nov. 2010 – power system upgrade required.
SCBY	OSU	Iridium	System down since Nov. 2009 – maintenance required.
KMOR	OSU	Iridium	Operational
HRDG	OSU	Iridium	Modem answers, but no comms to receiver since Oct. 08
JWLF	OSU	Iridium	Comms link down since Sep. 08, SIM card is disabled,
KMJP	OSU	Iridium	Operational but comms upgrade required.
JGBL	OSU	Iridium	Operational

LEFN	OSU	Iridium	System down since Feb. 2010 – maintenance required.
BLAS	OSU	Iridium	Operational
NRSK	OSU	Iridium	Operational but comms upgrade required.
GROK	OSU	Iridium	Operational
GMMA	OSU	Iridium	Operational
YMER	OSU	Iridium	Operational
DMHN	DTU	None	Operational
LBIB	OSU	Iridium	Operational
DANE	OSU	Iridium	Operational
WTHG	OSU	Iridium	Operational
HMBG	OSU	Iridium	Operational
MSVG	OSU	Iridium	Operational
DGJG	OSU	Iridium	Operational
VFDG	OSU	Iridium	Operational
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.		

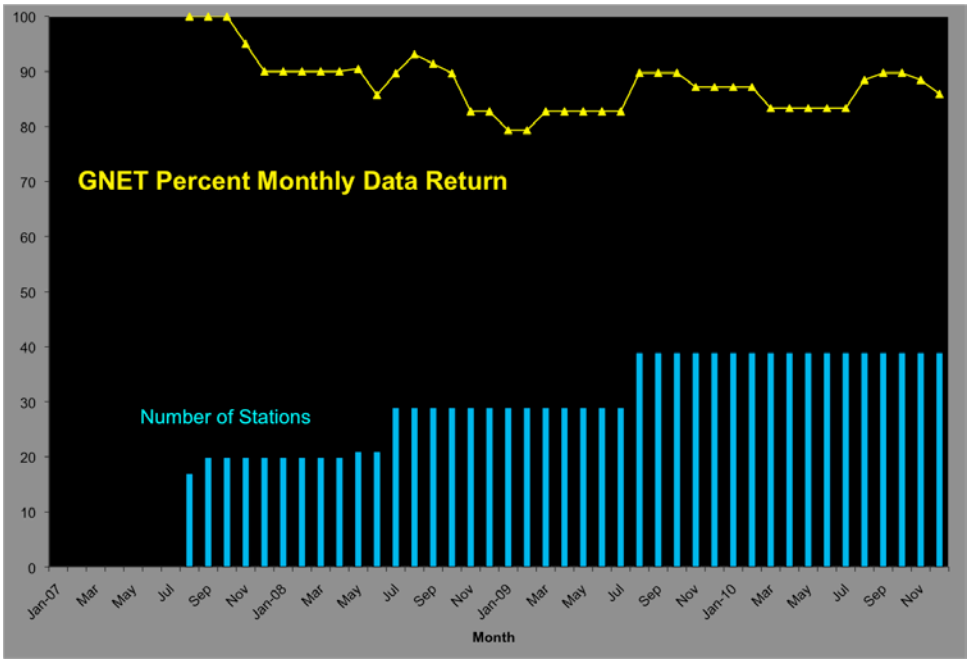


Figure 8 - GNET data return from remote stations with Iridium communications through 2010 shows consistent 80-90% data return.

Appendix A - Detailed Summary of Support Provided

ALASKA:

Arctic Carbon (Ted Schuur – 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 were provided.

Barrow ITEX-SAON (Craig Tweedie – University of Texas at El Paso)

Two GPS receivers, a LiDAR instrument, field support, and data processing support were provided to conduct repeat surveys to assess organic matter accumulation and ground heave at Barrow.

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. Field engineer Seth White 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. (The on-site management of this system will change in 2011.)

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

This was the tenth season this project used GPS to measure seasonal elevation changes in the permafrost active layer on the Alaskan North Slope. UNAVCO provided two GPS receivers, a LiDAR instrument, field support, and data processing support.

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. Two receivers were provided to profile the ice surface and measure ice flow velocities for determining flow vectors at each research site.

Lemon Creek Glacier (Andrew Fountain – Portland State University)

Two receiver enclosure cases were provided in support of this glaciology project.

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.

Russell Fiord (Dan Lawson - CRREL)

One POLENET style cGPS system was provided as a long term base station on Haenke Island, and 6 GPS systems were provided for ice dynamics measurements on Hubbard Glacier. One Arctic R7 systems was lost in the field and is not likely to be recovered.

Thermocarst (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 a pre-season training and a LiDAR instrument to PIs Mike Gooseff (Penn State) and Ben Crosby (Idaho State), 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 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 a LiDAR instrument was also provided to the TFS GIS staff, who handled all local support.

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:

Basal Sliding (Joel Harper – University of Montana)

Pre-season training and three geodetic GPS receiver systems, rugged weatherproof enclosures, and power systems for continuous measurement of ice velocity near boreholes on the Greenland ice sheet.

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 season the remaining equipment was retrieved upon project completion.

Greenland Meltwater (Ginny Catania – University of Texas, Austin)

This project studies the thinning of marginal regions of the Greenland Ice Sheet. This season a GNET style power system was provided for a bedrock base station. The kit included a geodetic quality monument to allow the data to be used for rebound measurements and augmentation of GNET.

Helheim Glacier-Ocean-Ice Interaction (David Holland – New York University)

This season extra parts including batteries were provided to upgrade the system provided in 2009 . his system uses both solar and wind power 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.

Icesheet Accumulation (Rick Forster – University of Utah)

Four GPS receiver systems were provided to collect snow accumulation data using GPS and GPR from a snowmachine traverse. The transect is designed to fill the accumulation data "void" between 2000 m and the ELA. The project goals are to constrain the magnitude, inter-annual variability and spatial variability of accumulation on the Southeast Greenland Ice Sheet below 2000 m.a.s.l. through calibration of the Polar MM5 and Polar WRF using newly obtained field data in Southeast Greenland.

Jakobshavn Lakes (Sridhar Anandakrishnan – Pennsylvania State University)

Eight GPS receiver systems were provided in support of this project. CReSIS aims at developing better technology and models for understanding changes in the polar ice sheets. In support of this goal Penn State University (PSU, Co-PIs Sridhar Anandakrishnan and Richard Alley) conducted geophysical fieldwork in Greenland in summer 2010, including active seismic experiments on Jakobshavn to examine basal conditions

and a synoptic scale GPS deployment around supraglacial lakes in the vicinity of Jakobshavn Isbrae in order to examine the total speedup along the margin and determine how far deformation from a single supraglacial lake drainage propagates and its net effect. The GPS data will be combined with high resolution remote sensing data (worldview 0.5 m resolution data) to serve as ground control for speckle-tracking velocity analysis and repeat digital elevation model construction from stereoscopic imagery before and after drainages to examine lasting deformation caused by these drainages.

Nuuk Fjords (Martin Truffer – University of Alaska, Fairbanks)

Five summer only and five year-round GPS receiver systems were provided. This project leverages and extends an existing o ceanographic investigation into changing fjord conditions at Godthabsfjorden by adding an interior fjord scope to the oceanographic measurements. It will also provide documentation of glacier flow variability and recent patterns of change of the main glacier entering the fjord, Kangiata Nunata Sermia (KNS), and provides an otherwise unavailable look at the interactions at the interface between a rapidly changing outlet glacier system and the changing marine system that is likely pacing the ice.

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 (Figure 7). 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 7 and Table 4 show the UNAVCO supported network and status at the end of December 2010.

In 2010 there were no NSF-sponsored GNET field logistics. However, seven sites in the northwest and ten sites in the southeast received maintenance visits using DTU logistical support. UNAVCO provided the necessary equipment, shipping to Greenland (with CH2MHill Polar Services support), and remote technical support. Seth White also provided field support for the northwest effort based out of Thule.

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:

CALM-Cherskii - (Nikolay Shiklomanov – University of Delaware)

A request for local survey infrastructure to benefit NSF funded researchers working at the Cherskii field station in Siberia was made by the CALM project. To accommodate this need, and two avoid the complications of import and export to and from Russia, three of the oldest systems in the UNAVCO pool (Trimble 4700s) were provided to the project PI with the understanding that UNAVCO does not expect them back in the equipment pool. The receivers are no longer compatible with the newer standards and were becoming a support liability to UNAVCO.

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. This was a repeat deployment as a follow-up to hardware problems in 2009.