UNAVCO Facility and Community

Annual Progress Report for FY2002

Submitted to:

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National Science Foundation
Division of Earth Sciences

Under:
Proposal No. EAR-9910789
Cooperative Agreement No. ATM-9732665
Scientific Program Order No. 2 (EAR-9903413)

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11 October 2002

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1.0 Introduction

This has been an important and exciting milestone year for the UNAVCO community with the establishment of UNAVCO, Inc., and a banner year for the UCAR/UNAVCO Facility in Boulder, Colorado, and associated community initiatives. Following incorporation as a Colorado non-profit in 2001, UNAVCO, Inc. received its first National Science Foundation (NSF) award in April 2002 to support the independent operation of UNAVCO, Inc. and to conduct important pre-Plate Boundary Observatory (PBO) and EarthScope activities. UNAVCO, Inc. headquarters was established in early October 2002, including a financial management, personnel, procurement, and program management team capable of operating ongoing UNAVCO activities. UNAVCO has worked with the community to develop a draft PBO proposal that is available for comment at: http://www.unavco.org/research_science/publications/proposals/pbo/pbo.html. In early December, UNAVCO, Inc., on behalf of PBO, will join with the Incorporated Research Institutions for Seismology (IRIS) for USArray and Stanford University on behalf of the San Andreas Fault Observatory at Depth (SAFOD) community in submitting to NSF a collaborative proposal for EarthScope. In January 2003, the community will submit a follow-on proposal for future independent operation of the UCAR/UNAVCO Facility and other community support activities. Assuming the successful review of these proposals in the spring of 2003, the NSF and UNAVCO, Inc. will negotiate a Cooperative Agreement in summer 2003 for future operations, including the Facility and the PBO component of EarthScope.

The UCAR/UNAVCO Facility continued its critical work in support of NSF solid Earth sciences principal investigators using Global Positioning Systems (GPS) in FY2002. A total of 21 agent projects involving equipment loans, 12 campaign projects with engineering support, and 22 new permanent GPS installations were supported in the last year. A total of 14.8 Gbytes of campaign data was added to the UNAVCO archive along with 111.3 Gbytes of continuous data from permanently installed GPS stations. Additional Coast Guard Continuously Operating Reference Station (CORS) stations were upgraded to geodetic quality standards. The SuomiNet network of real time GPS-based atmospheric monitoring stations was upgraded from 17 to 60 stations, many of them with geodetic quality monuments. The post-Nisqually Earthquake GPS network installed in 2001 was upgraded with equipment provided by NSF to UNAVCO to form a community post-earthquake response pool. A proposal to upgrade the community pool of GPS equipment was successfully reviewed by the community with an award from NSF to UNAVCO, Inc. imminent. Current plans for support of NSF-funded GPS projects with equipment, field engineers, technology development, and data archiving show another strong year of activity by the community for 2003.

2.0 UNAVCO Facility Activities for FY2002

2.1. Permanent Station Support

Permanently installed, continuous GPS stations have played a growing role in solid-Earth science studies over the last few years. Although permanent installations are more expensive than episodic campaign surveys, they provide site motions at the highest precision and are especially suited to observing volcanic, postseismic, or other deformation transients. The Facility provides complete permanent station support including proposal and budget preparation, site reconnaissance, installation and operation of stations, ongoing maintenance including daily monitoring of network performance and data quality checking and archiving. The service provided by the Facility is scalable and can be quickly tailored to a Principal Investigator's (PIs) experience level. Unique services provided by the Facility include a single point of contact for all NSF permanent station installation and troubleshooting questions, an up-to-date permanent station database including data flow diagrams, individualized weekly network status reports emailed to PIs and collaborators, and a data archive that actively pushes data files to investigators via anonymous ftp.

For FY2002, the Facility provided in-field installation support of 22 new continuous GPS stations and monitored more than 200 stations on a daily basis (Table 2-1). Facility engineers also performed critical in-field maintenance for more than 30 problem stations. These stations are located worldwide, often in remote areas with limited communication and on-site support. In the office, Facility engineers also provided technical support to PIs who were installing their own networks. As part of the network monitoring and trouble-shooting effort, a UNAVCO network engineer monitors daily data volumes for all stations for which UNAVCO has primary oversight responsibility. If a station shows low data volumes, the engineer logs onto the station host computer and checks connections, station logs, and tracking files. The engineer troubleshoots the problem, determines the cause of data loss, and attempts to correct the problem to restore normal data flow from the station. Corrective actions include logging on to remote station computers and receivers to fix problems, contacting local site representatives, exchanging equipment, and making engineering site visits. Once the problem is resolved, a maintenance report is logged into the permanent station database at UNAVCO, and a report is forwarded to the PI and the project collaborators.

Table 2-1. GPS Stations Installed and Monitored by UNAVCO in FY2002.

Network Name (Funding)	# Stations	Field Visits	Field Work Done (Recon R, Maint M(#), Install I(#)	Data Flow Monitoring	Remote Troubleshooting	Computer Maintenance	Software Tests/Upgrades	Hardware Tests	Shipping/Customs	General Support	# of Stations Archived	PI	Engineer Hours (estimates)				Comments
													Pre-project	In-field	Post-project	General S.	
Dual Frequency Networks																	
Alaska (NSF)	8	1	R, I(2)	x	x	x	x	x	x	x	5	Freymueller	40	140	10	45	Trained USGS/AVO personnel on installation of short-braced monuments. **New Installations:** Two monuments installed.
Antarctica (NSF)	1			x	x	x	x	x	x	x	1	Kyle				10	
Arenal/Costa Rica (NSF, NASA)	3			x	x	x				x	3	Dixon, Schwartz				5	In-office remote monitoring only.
BARGEN (NSF, DOE, NASA)	50			x	x	x	x	x	x	x	50	Wernike, Davis				250	Shipping, trouble-shooting, testing, etc. No UNAVCO FE field visits in FY02. Extensive testing of cellular/internet device.
Carribean - Nevis/St. Kitts (NSF)	0		R					x	x	x	0	Mattioli	40	80	8	5	Recon Only. No stations installed.
Central Asia (NSF, NASA)	8			x	x	x	x	x	x	x	8	Hager, Herring				25	POL2: Upgraded to Ashtech Z-12. RTNT download. Equipment shipment.
DIVE (NASA, NSF)	2			x	x	x	x	x	x	x	2	Miller				25	General troubleshooting. Changed sample rate at one site.
Ethiopia (NASA)	2			x							2	Bilham					No data coming in.
Galapagos (NSF)	2	2	R,I(2)	x	x	x	x	x	x	x	6	Geist	110	90	30	40	**New Installations** - GV01,GV02
Greenland (NASA,NSF)	3	2	M(3)	x	x	x	x	x	x	x	1	Wahr, Stowers	80	140	25	40	**Maintenance Trip** - KULU: Upgraded computer to dial-up internet connection. **KELY, THU1:** Replaced receiver and general maintenance
Guererro Coast (NSF)	1			x	x	x	x	x	x	x	1	Larson	160			5	Preparation for field project to be completed in FY03. Three additional sites to be added to the network.
Guadalupe Island (NSF, SCIGN, USGS)	1	1	M(1)	x	x	x	x	x	x	x	1	Hudnut, Jackson	48	48	16	100	**Maintenance Trip** - Upgraded VSAT and power system.
Hawaii (NSF)	12			x	x	x	x	x	x	x	12	Segall				30	General support only.
IRIS/PASSCAL Seismic Integration (NSF)	1	7	R, I(1)	x	x	x	x	x		x	1	Fowler, Jackson	80	120	20	50	**New Installation** - PAS1, radio modem, VSAT, and digi link
Jalisco (NSF)	1			x	x	x			x	x	1	Stock, Demets				0	
Louisiana (NSF)	5			x	x	x	x	x	x	x	5	Dokka, Sella				160	Hardware testing (digi devices), repair, general in-office support.
Mediterranean (NSF, NASA)	9			x	x	x	x	x	x	x	9	Reilinger				150	**Computer Configuration:** TETN Training for Turkish Visitor, Shipping/Customs, General Troubleshooting/Support.
Montserrat (NSF)	2			x						x	2	Mattioli				5	
Nepal (NSF)	6			x		x	x	x		x	6	Bilham				10	Cables built, met pack training
Nisqually Earthquake Response (NSF)	8	1	M(8)	x	x	x	x	x	x	x	0	Miller	8	20	5	5	**Receiver Swap** - 8 sites
Oman	6					x	x	x	x		0	Herring	60		40		radios. Installed and configured software. Shipped equipment to Oman.
Oregon (NSF)	2										0	McCaffrey				0	
PANGA (NSF)	17	1	M(17)	x	x	x	x	x	x	x	0	Miller	25	130	40	10	**Maintenance** - Entire Panga Network
Popocatepetl (NASA)	2			x	x	x	x	x	x	x	2	Dixon, Cabral				10	
Puerto Rico	1										1	Matiolli				0	
SAGE New Zealand (NSF)	8			x	x	x	x	x	x	x	8	Molnar				60	Budgeting, purchasing, construction, repair, and shipping of equipment in support of network.
Saudi Arabia (NASA)	2	1	R,I(2)	x	x	x	x	x	x	x	0	Reilinger	100	180	40	5	**New Installations** - NAMA, HALY GSM cellular data transfer, short braced monuments
Taal Philippines (NSF)	3			x	x	x	x	x	x	x	3	Hamburger, Meertens				60	
Wasatch (NSF)	4			x	x	x	x			x	4	Smith, Meertens	20			25	Configured 1 pc for Wasatch.
Yellowstone Caldera (NSF, USGS)	5			x	x	x	x	x		x	5	Smith, Meertens	20			60	Configured 1 pc for Yellowstone network.
Yellowstone Hotspot (NSF, USGS)	8	2	M(1),I(2)	x	x	x	x	x		x	6	Smith, Meertens	40	90	5	40	**New Installations:** BBID, LTMN (monuments only). Removed HAMG. Configured one pc for Idaho.
Single Frequency Networks																	
Antarctica (NSF)	3			x	x	x	x	x	x	x	3	Kyle				10	
DIVE (NASA, NSF)	4			x	x	x	x	x	x	x	4	Miller, Meertens				15	
Hawaii (NASA, NSF)	13			x	x	x	x	x	x	x	13	Meertens, Lisowski				40	
Hayward Fault (NASA, NSF)	4	2	R,I(4)	x	x	x	x	x	x	x	4	Murray	100	100	100	30	**New Installations** - VOLM,WLDC,GRIZ,BDAM
Philippines Volcano (NSF, NASA)	11			x	x	x	x	x	x	x	11	Hamburger, Meertens				45	General Support Only. No FE trips in FY02.
Popocatepetl Volcano (NSF,NASA)	4			x	x	x	x	x	x	x	4	Dixon				10	
Sierra Negra Volcano (NSF,NASA)	4	2	R,I(4)	x	x	x	x	x	x	x	4	Geist, Meertens	220	190	50	25	**New Installations** - GV03,GV04,GV05,GV06
Other Networks																	
GGN (NASA)	56	6	R, M(2), I(2)	x	x	x	x	x	x	x	0	Stowers	200	250	100	1000	**New Installations** - GAL2, BREW **Maintenance Trips** - QUIN, GALA
Coast Guard CORS	2	4	I(2)					x	x	x	0	Otteni	20	80	10		**New Installations** - 2 concrete pillar monuments at Pueblo, CO and Myton, UT.
Souminet (NSF)	3	2	R, I(1)	x	x	x	x	x	x	x	3	Ware	20	35	10	20	**New Installations** - SC02 (Friday Harbor, WA)
Totals	**287**	**34**	**22 New Permanent Stations**										**1391**	**1693**	**509**	**2425**	

A representative permanent station network installation in FY2002 was on the Sierra Negra Volcano, Isabella Island, Galapagos (Figure 2-1). Jointly funded by the National Science Foundation/EAR and NASA/Solid Earth and Natural Hazards (SENH) Program, this project was a collaboration between the University of Idaho, Darwin Research Station, Galapagos National Park, and UNAVCO. The project was unique for several reasons. GPS data from two different receiver types were streamed via 900 MHz spread spectrum transceivers using the Time Domain Multiple Access (TDMA) protocol. This was the first time the UCAR/UNAVCO Facility incorporated multiple receiver types into a TDMA data stream. Secondly, the direct (no-repeater) 90 km RF link between the volcano rim on Isabella Island and the Darwin Research Station on Santa Cruz Island was the first permanent, direct, RF data link between these two islands. Lastly, the remoteness, difficult terrain, and harsh weather conditions of the Sierra Negra Caldera combined for an exceptionally challenging deployment.

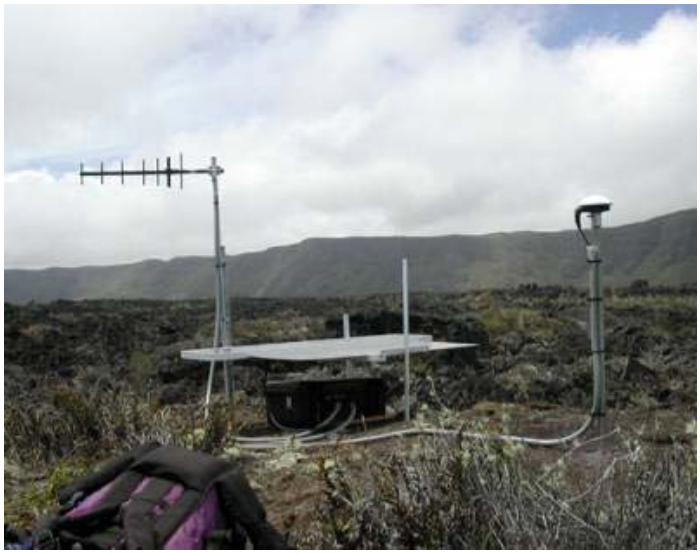

Figure 2-1. Single frequency GPS station (GV06) in the Sierra Negra Caldera, installed in June 2002 (Dennis Geist, PI).

2.2. Campaign Support and Equipment Loans

The UCAR/UNAVCO Facility provides support for campaign style geodetic GPS measurements including field engineering, equipment loan, training, data processing, and telephone and/or web-based consultation. A community-use equipment pool is maintained and deployed to projects worldwide, and currently consists of 26 NSF-EAR contributed receivers (primarily Trimble 4000 series) and 32 receivers contributed by other programs. Ancillary pool equipment includes antennas, tribrachs, tripods, solar panels, download PCs, and support cables.

Thirty-three campaign projects were supported in FY2002 (Table 2-2), and seven NSF projects received direct field support including Basin and Range Deformation (Figure 2-2), Mississippi Delta Vertical Control, Rio Grande Vertical Control, Antarctica (included 24 individual projects for the 2001/02 season), Barrow DGPS System Installation, and the Bench Glacier Velocity Survey. An additional 26 projects (21 NSF) received equipment, training, telephone, and/or web support.

Figure 2-2. Campaign survey of active tectonics of diffuse intracontinental deformation in the Nevada/Utah Basin and Range (B. Werniche PI).

In addition to providing direct project support, the Facility continues to evaluate new technology and capabilities to ensure continued leadership in geodetic GPS technology for campaign applications. For example, current generation GPS receivers provide better data quality, reduced power consumption, smaller size, and increased memory. Several new state-of-the-art Trimble 5700 receivers are part of the UNAVCO pool through NSF-OPP contribution, and the recently funded proposal *Acquisition of New GPS Receivers for the UNAVCO Community Pool in Support of Current and Emerging Solid-Earth Sciences Research Application* (on-line at www.unavco.org) will update the NSF-EAR receiver pool with 30 current generation receiver systems over the next three years. To better support community data processing needs, PC based GPS data processing software was also upgraded in 2002. The Trimble Geomatics Office software is available for community use on field projects, and UNAVCO provides complete training and support for in-field centimeter-level post-processing of data, network adjustments, and formal error generation.

Table 2-2: Campaign Project Support Provided in FY2002.

Project	Funding Source	Project PI	#Rx	Field Engineer
American Samoa 2002	NSF-EAR	Hart	3	
Aquifer Deformation 2002	NSF-EAR	Blewitt	0	Project planning
Basin/Range 2002	NSF-EAR	Wernicke	15	1, field support
Canyonlands 2002	NSF-EAR	Crider	0	ancillary equip. only
Caribbean 2002	NSF-EAR	DeMets	0	ancillary equip. only
Eastern Med 2002	NSF-EAR	Reilinger	3	
Galapagos 2002	NSF-EAR	Johnson	2	
Iceberg Lake 2002	NSF-EAR	Anderson	2	1, training
Irian Jaya 2002	NSF-EAR	McCaffrey	3	
Kenai 2002	NSF-EAR	Freymueller	3	
Lebanon 2002	NSF-EAR	Barazangi	0	ancillary equip. only
Mississippi Delta 2002	NSF-EAR	Tornqvist	3	1, field support
Morocco 2002	NSF-EAR	Reilinger	1	
New Zealand 2000	NSF-EAR	Molnar	3	
Rio Grande 2002	NSF-EAR	McDonnell	3	1, field support
Syria 2002	NSF-EAR	Reilinger	0	shipping support
Tibet 2002	NSF-EAR	Bendick	1	
Antarctica 2001	NSF-OPP	Johns	27	2, field support
Antarctica 2002	NSF-OPP	Johns	30	2, field support
Barrow DGPS 2002	NSF-OPP	Johns	2	2, field support
Bench Glacier 2002	NSF-OPP	Anderson	6	1, field support
Black Rapids 2002	NSF-OPP	Echelmeyer	1	
ITASE 2002	NSF-OPP	Hamilton	2	
Kuparuk 2002	NSF-OPP	Nelson	2	1, training
Matanuska 2002	NSF-OPP	Alley	1	1, training
Toolik Lake 2002	NSF-OPP	Balser	2	1, training
Yucatan 2002	NSF-BCS	Dahlen	2	1, training
Plum Island 2002	NSF-OCE	Hopkinson	2	
Bolivia Lakes 2002	NASA	Bills	2	
Ashtech Clock Offset 2002	NRL	Larson	0	antenna only
Iceland 2002	PI Internal	Dixon	3	
MIT Field Camp 2002	PI Internal	Herring	2	
Wabash 2002	USGS	Hamburger	3	
Totals: 126 receivers to 33 projects and 15 engineer trips/training.				

2.3. Data Management and Archiving

The UCAR/UNAVCO Facility continues to provide archiving support for campaign and permanent station GPS data collected by community investigators. In addition, the Facility maintains velocity and strain product archives for the UNAVCO Global GPS Velocity Field (GPSVEL) and International Lithosphere Program (ILP) Global Strain Rate Map (GSRM) projects.

Data in the UNAVCO Archive - Permanent station data are distributed via anonymous ftp, automatically via Local Data Manager-Internet Data Distribution (LDM-IDD) software, and upon request if nonstandard observables or raw data are desired by the user. Recently, the latest edition of the GPS Seamless Archive Centers (GSAC) Retailer has become a practical method for data discovery for both permanent stations and campaign data at UNAVCO.

All metadata for permanent stations and campaigns are managed in an Oracle relational database that is accessible to the user through a Web interface. GPS data are stored on RAID systems backed up with DLT tapes. The flow of data is managed using an extensive system of hardware and software tools that facilitate ftp push and pull, LDM-IDD, E-mail, and manual data transfers (Table 2-3 and Figures 2-3 and 2-4).

Table 2-3. Permanent Station Data Flow Method

Data Flow Method	**Network (number of stations)**	
LDM-IDD	Antarctica (1) Antarctica L1 (3) DiVE (1) DiVE L1 (1) Galapagos (2) Galapagos L1 (4) Mediterranean (1)	Philippines (3) Popocatapetl (2) Popocatapetl L1 (4) Suominet-C (3) Suominet-G (29) Wasatch (4) Yellowstone Hotspot (3)
scp	Cotopaxi L1 (2) GGN-UNAVCO (1)	GGN-Backup (3) Yellowstone Caldera (4)
ftp pull	Alaska (1) Central Asia (7) Costa Rica (1) DiVE (1) DiVE L1 (3) DSN/Other (6) GGN-UNAVCO (1) GGN-Backup (47) Hawaii (15)	Hawaii L1 (13) Hayward Fault L1 (4) Mediterranean (3) SCIGN/USGS (1) Taal L1 (11) UNAVCO (1) Yellowstone Caldera (1) Yellowstone Hotspot (4)
ftp push	Alaska (4) BARGEN (50) Central Asia (1) GGN-UNAVCO (2) Greenland (1)	Guerrero Coast (1) GULFNET (5) Jalisco (1) Mediterranean (4) SAGE New Zealand (9)
E-mail	Mediterranean (1)	
manual	Arenal (2) Ethiopia (2)	Nepal (5)

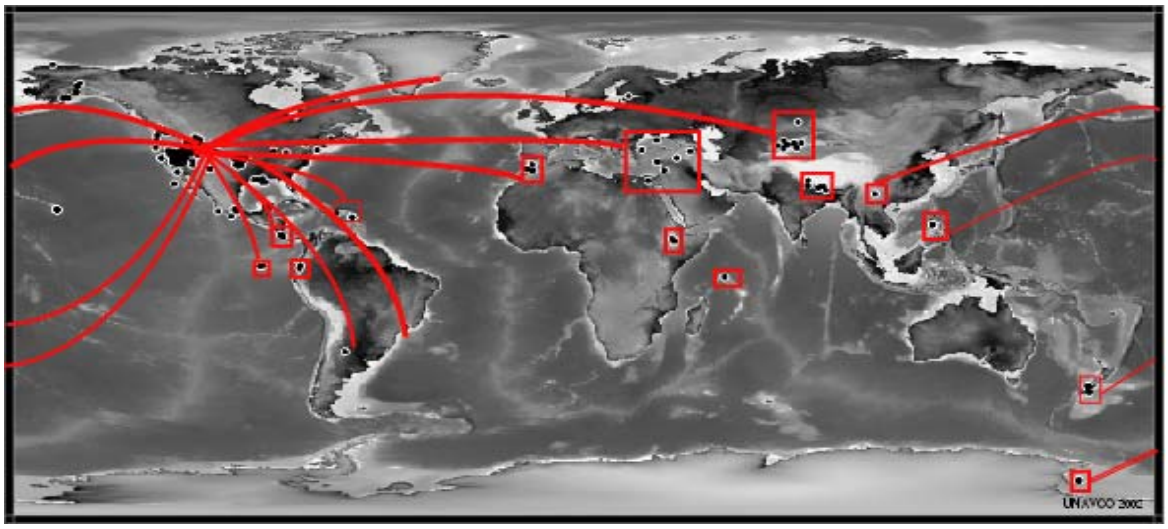

Figure 2-3. Generalized Data Flow for Global and Regional Networks.

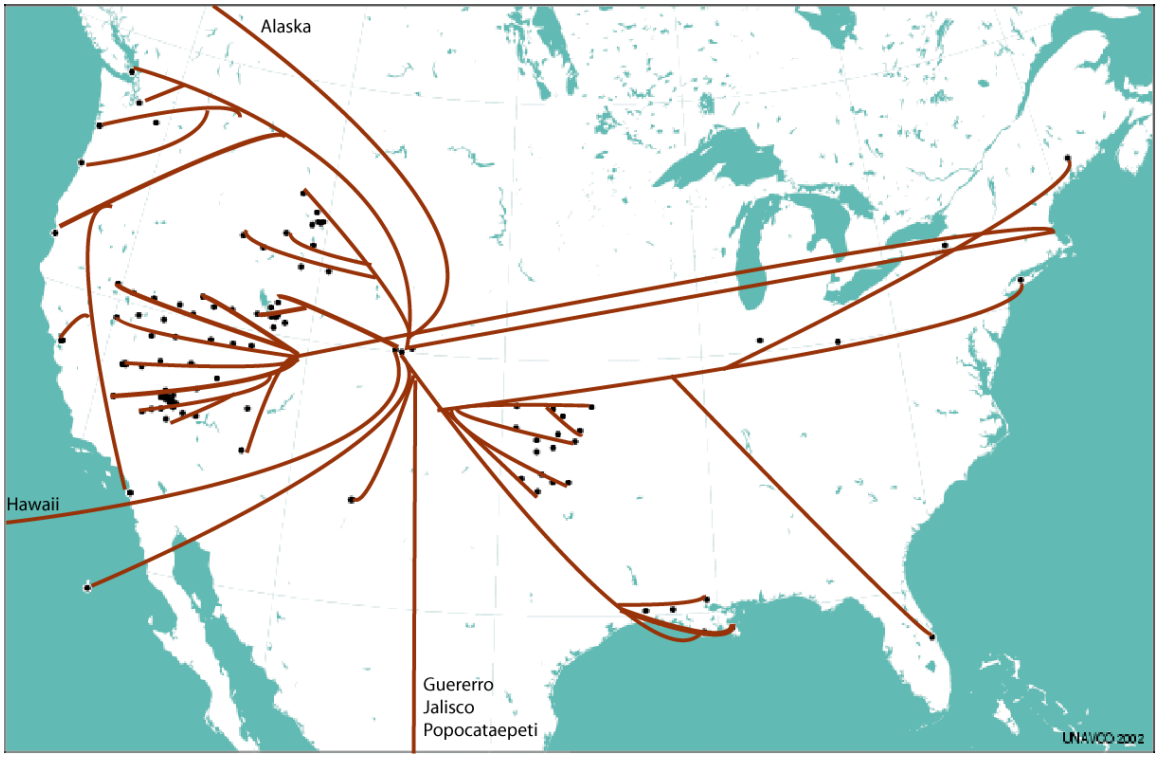

Figure 2.4. Generalized Data Flow for North American Regional Network.

Data from over 6000 monuments currently reside in the UNAVCO Facility Archive (Figure 2-5). Overall, the data volume handled in FY2002 was comparable to that of FY2001 (Figures 2-6 and 2-7 and Table 2-4). The Archive holds data from 419 campaigns and 265 permanent stations, 217 of which are currently active.

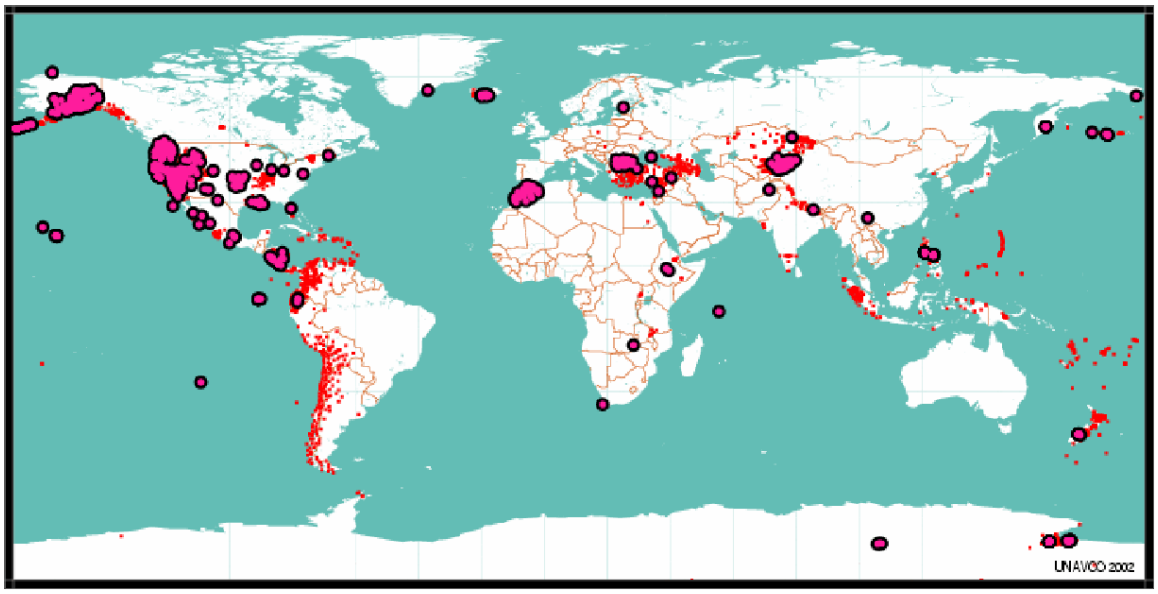

Figure 2-5. The small red dots show the monuments where we have archived data to date (6,089 monuments); the red circles outlined in black show where we have archived data during FY2002 (1,040 monuments).

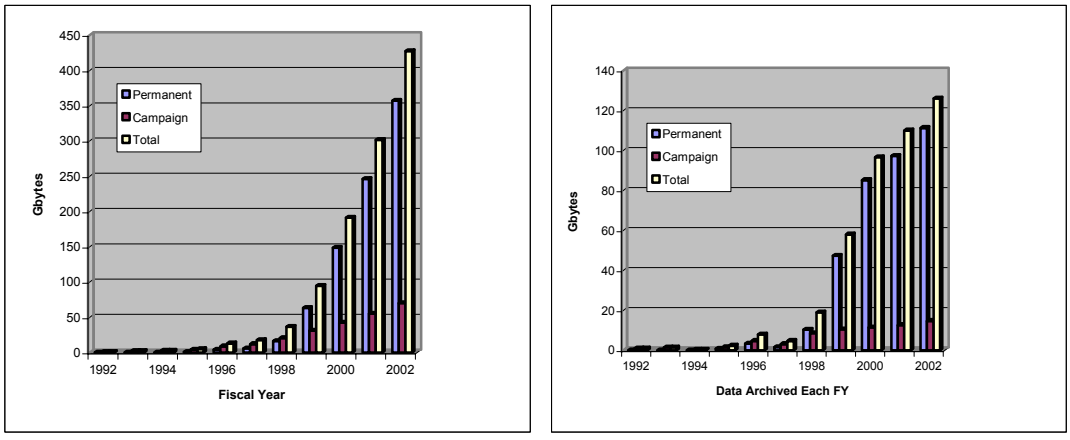

Figure 2-6. UNAVCO Archive cal
cumulative data volume by fiscal year.

Table 2-4. Boulder Archive Statistics for FY2002.

	Permanent Stations Handled (per year)			Campaigns Processed (per year)		
	# Archived	# Files	GBytes	#Archived	# Files	GBytes
FY1999	133	36,618	47.4	71	12,376	10.6
FY 2000	164	49,278	85.2	58	12,562	11.5
FY 2001	177	53,508	97.3	39	9,679	12.7
FY 2002	217	63,765	111.3	93	11,427	14.8
Total (includes pre-FY1999)	265 w/data	203,271	342.7	419	66,822	70.1

In the past, campaign data have been distributed only upon request. Beginning in FY2002, a number of campaigns have been packaged for access to metadata via the Web and data access via ftp (e.g., http://archive.unavco.ucar.edu/campaigns/1716/1/Index.html). Principal investigators for these publicly accessible campaigns are asked to provide release notes, links to html or pdf project reports, and any references that should be cited by users of the data. The references and release notes are incorporated as header comment lines of the RINEX files. There are currently nine campaigns that are accessible in this manner. Nineteen more campaigns have been prepared but await PI permission, release notes, and references before being made public. The goal is to continue to make available, via the Web, data and metadata from all campaigns that are publicly accessible under the UNAVCO data policy.

Data Management Software - UNAVCO continues to develop and support the GPS and Global Navigation Satellite System (GLONASS) Translation, Editing, and Quality Checking (TEQC) software package that remains the foundation of data input and output for the Facility data archive and is extensively used by the GPS community. In early 2002, TEQC entered its fifth year of availability, and is now used worldwide by investigators with GPS projects, for major networks like NASA's Global GPS Network (GGN), at many sites for the International GPS Service (IGS) global network, as well as at the Scripps Orbit and Permanent Array Center (SOPAC) facility, Southern California Integrated GPS Network (SCIGN), Basin and Range Geodetic Network (BARGEN), Bay Area Regional Deformation (BARD), Pacific Northwest Geodetic Array (PANGA), and new networks like SuomiNet. A major release of TEQC occurred in March 2002, the first comprehensive release replacing all previous versions since February 2000. Associated with TECQ is Binary Exchange (BINEX), the data format adopted for the Trimble 4700 receiver for SuomiNet and for the Ashtech micro-Z receiver currently deployed on UNAVCO projects. The BINEX format (see website: http://www.unavco.ucar.edu/data_support/software/binex/binex.html) was easily integrated into existing firmware by two GPS receiver manufacturers, Ashtech and Trimble. UNAVCO has developed BINEX in an effort to promote a robust binary standard. It can be implemented at the receiver level to facilitate data streaming, and to simplify data handling and integration of GPS with other systems such as seismic dataloggers. BINEX is being proposed as a requirement for EarthScope/PBO GPS receivers.

Project and Operational Database - UNAVCO operations and management of project information has been significantly enhanced over the last year due to significant developments of our Project and Operational Database. Built on a Microsoft IIs website, with MS SQL relational database, this Internet-accessible system has become a UNAVCO enterprise solution managing all user requests for UCAR/UNAVCO Facility project support, project planning, community contact information, permanent station information, equipment purchasing and tracking, and community meetings. Over the last year, an ArcIMS web-Geographical Information System interface was added to provide map reporting and queries. These developments have been designed to be scaleable to handle large projects like the proposed EarthScope PBO.

2.4. Permanent Station Systems Development

In FY2002, the Facility was involved in continued testing and implementation of new communication strategies related to PBO and EarthScope. For example, a Very Small Aperture Terminal (VSAT) was installed in Socorro, New Mexico, as part of the collaboration with IRIS/PASSCAL. Also, several serial-to-Ethernet devices were tested. These devices eliminate the need for a remote PC and can facilitate the downloading of GPS receivers via the Internet. These devices were installed in the BARGEN and Gulf of Mexico (GULFNET) networks. Various new cellular modems such as the Raven II Wireless Cellular Digital Packet Data (CDPD) were also tested in-house. This device, which provides an Internet presence for a remote GPS system, was installed at the COON site in the BARGEN network. Extensive computer system testing was done, including the testing of new download software for Ashtech receivers (EGADS/SHARC), Linux operating system upgrades, and the numerous required security patches. UNAVCO Facility engineers were involved in power system integration testing using a combination of solar arrays and wind generators. Development of UNAVCO's "JStream" GPS streaming data management software was completed with the final version handling dual-frequency BINEX data and single-frequency (L1) data via serial or TDMA radiomodem communications. In addition, an extensive evaluation of the potential use of the U.S. Geological Society (USGS) "Earthworm" seismic streaming software system for combined GPS/seismic data installations was completed. Lastly, a GAMIT GPS data processing computer was set up at the UCAR/UNAVCO Facility, giving the Facility the resources and capability to provide short-term station analysis after a site installation.

2.5. Polar Programs

UNAVCO provides year-round support to the NSF Office of Polar Programs (OPP) under direct OPP funding. Thirty-one individual research projects (25 Antarctic and six Arctic) were supported in FY2002. Detailed polar support information, including the 2001-2002 Season Report, is available at http://www.unavco.ucar.edu/project_support/polar/polar.html.

3.0 Community Initiativess

3.1. Seamless Archive

There are a number of independent GPS data archiving and distribution centers in the U.S. and worldwide. To simplify access to GPS data from any center, UNAVCO initiated the GPS Seamless Archive Centers (GSAC) concept for exchanging GPS data and metadata http://www.unavco.ucar.edu/data_support/data/gsac/gsac.html. During the past year, software has been developed at SOPAC, and installed there and at the Boulder Facility, allowing efficient exchange of holdings records among participating archives. This software includes both a web-based and command-line client for scientists to search for and acquire data. The GSAC Working Group, including representatives from the major U.S. archives, met in Boulder for two days in July to review the current software and update formats and procedures (http://www.unavco.ucar.edu/data_support/data/gsac/gsac_meeting_boulder-jul02.html). By the end of calendar year 2002, investigators will be able to retrieve data through the GSAC from all of the U.S. archives except possibly the National Geodetic Survey (NGS). In parallel with the U.S. developments, participation and software contributions are being solicited from GPS archives in Canada, Europe, Japan, and Australia. The goal is to bring into the GSAC the rich body of GPS data acquired by scientists and government agencies outside of the U.S. Figures 3-1a and 3-1b show an actual GSAC query and response.

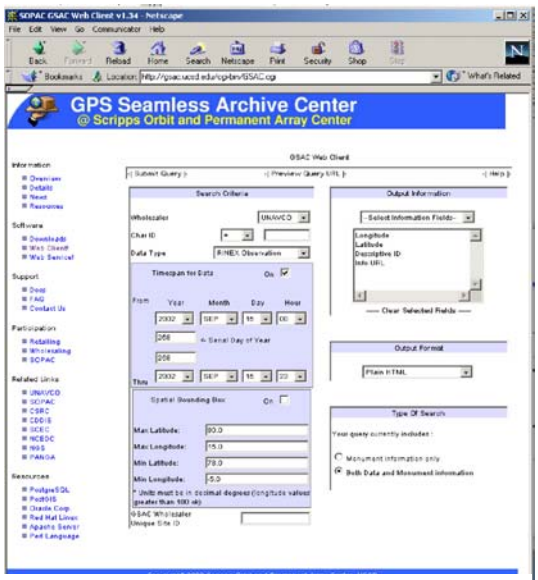

Figure 3-1a. GSAC query using SOPAC's Retailer Web Client, requesting information on RINEX Obs file holdings at UNAVCO for Sept. 15, 2002.

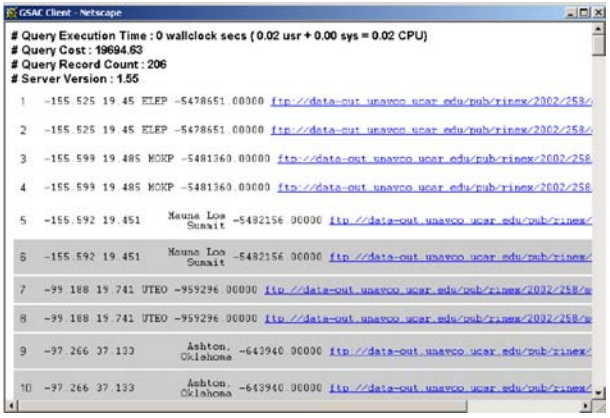

Figure 3-1b. Result of query to SOPAC's Retailer database showing RINEX Obs file holds at UNAVCO for September 15, 2002.

Over the past year, SOPAC's involvement in the GSAC project has both broadened and intensified in a number of different aspects. Most notably, SOPAC has successfully constructed a "production" GSAC Retailer system (Figure 3-2). A GSAC Retailer is a point of entry into the GSAC for the user community to find and obtain data held by GSAC Wholesalers. A GSAC Wholesaler operates a data archive and provides information about their archived data to the GSAC. Development and maintenance of the GSAC software has taken a large portion of SOPAC's GSAC resources over the past year. There are four software components under development at SOPAC, including the GSAC Retailer Distribution Kit, the web-based GUI client utility (GSAC.cgi), the command-line GSAC client utility (gsac-client), and the GSAC Wholesaler Kit. Clients communicate with the Retailer service through http using a specialized GSAC Retailer-Client protocol. Retailers communicate with Wholesalers using files available over ftp.

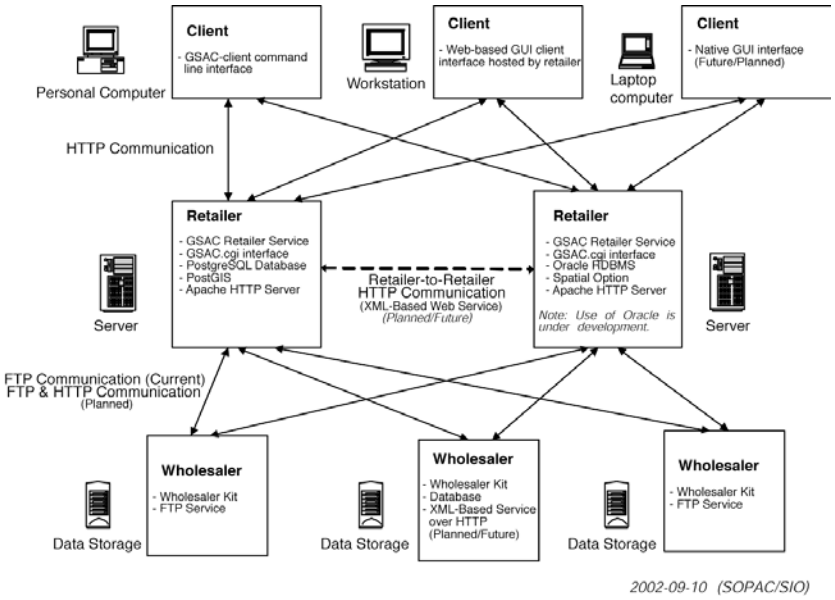

Figure 3-2. GPS Seamless Archive Centers - Data Discovery.

The GSAC Retailer Distribution Kit is responsible for storing metadata about GPS data holdings and communicating with clients and wholesalers. The Retailer Kit is written in the Perl programming language using shared libraries and includes a relational database schema with supporting database triggers. The GPS community currently has two GSAC Retailers in semi-production, SOPAC and UCAR/UNAVCO Facility. The initial version (1.1) of the GSAC Retailer Kit was provided to the Facility and implemented at both locations in February 2002, providing the first on-line facilities for development and testing of Retailer functionality at two different locations. The initial version was followed by subsequent releases of version 1.2 and 1.3 in the summer of 2002.

The client utility, GSAC.cgi, is a web-based interface to a GSAC Retailer, facilitating nominal data discovery, functional testing of the GSAC, and providing basic familiarity with some of the capabilities provided by the GSAC. This interface includes text-based, temporal and spatial querying capabilities, providing a peek into the wide array of

applicable venues where GSAC functionality will be used in the future. GSAC.cgi has no dependence on any given GSAC Wholesaler or Retailer and can be installed on almost any webserver and can be configured/modified to suit different tastes and/or Retailer preferences.

The product, gsac-client, is a command-line utility written in Perl which communicates with GSAC Retailers over http using the GSAC Retailer-Client protocol. The utility is made available in both source and binary (pre-compiled) forms to the public at http://gsac.ucsd.edu. GSAC-client has some of the "discovery" characteristics of GSAC.cgi and includes useful data downloading and compression-handling features. With the same query functionality of GSAC.cgi, the gsac-client can optionally take information returned from queries and download and decompress data. Data can be downloaded from both ftp and http servers. The GSAC Wholesaler Kit assists Wholesalers with publishing data holdings to the GSAC.

As the number of participants in the GSAC has risen over the past year, SOPAC also has broadened the data wholesaling (publication) involvement to include fully-integrated and automated publication of IGS-style site information logs (site_log_igs data type) and non-automated publication of merged ephemeris RINEX navigation files. Furthermore, SOPAC is also the first GPS data archive to take advantage of GSAC Retailer services to facilitate data collection from another GSAC Wholesaler, in this case the UCAR/UNAVCO Facility.

During the coming year SOPAC will be integrating Oracle RDBMS and Oracle Spatial with the GSAC Retailer Kit. SOPAC will also continue to develop and improve the gsac-client, GSAC.cgi client, and investigate the use of XML/http communication between Retailers and Wholesalers. Rather than rely entirely on ftp for Retailer-to-Wholesaler communication, and to provide support for Retailer-to-Retailer synchronization, SOPAC will be investigating Web service support.

3.2. GPS Data Analysis Support

The MIT analysis group (R. King and T. Herring) has separate funding for supporting investigators using the GAMIT and GLOBK GPS processing and analysis software. Activities include improving the utility of the software for a broad spectrum of users; improving the documentation; and providing training and on-going support for investigators and their overseas collaborators.

As a result of this support and the availability of the software at no cost for educational and research applications, the number of users has grown to over 300, with 60 added during the past year. In January, with support from Roger Bilham at the University of Colorado and the Council on Scientific and Industrial Research (CSIR) of India, Herring conducted a one-week course in Bangalore, India, attended by 25 analysts from all parts of the country. The notes from this course are now available on the Web for other GAMIT/GLOBK users (http://bowie.mit.edu/~tah/IndianGPSCourse). At the UNAVCO Annual Meeting in February, Herring and King conducted a half-day, intermediate-level

GAMIT workshop to acquaint analysts with the automatic processing scripts recently developed for the software.

3.3. GPSVEL (Global GPS Velocity Field) Project

The goal of the GPS velocity project (GPSVEL) is to synthesize velocity vectors worldwide from GPS campaigns and permanent networks into a consistent global frame. The project is designed to allow consistent interpretation of results between analysis groups, preserve well-documented electronic solutions in the UNAVCO archive, and provide high-quality velocity products for geophysical interpretation. The project is producing benchmark GPS solutions which provide key reference frame input to the GSRM.

The core of the GPSVEL solution consist of a precise and reliable global velocity solution estimated using IGS weekly Solution Independent Exchange (SINEX) solutions from the Newcastle Global Network Associate Analysis Center (GNAAC). Velocities are estimated by a free-network approach, solving for seasonal signals to mitigate the velocity error [Blewitt and Lavallée, 2002], for example due to seasonal mass loading [Blewitt et al., 2001], enforcing a minimum 2.5-year observation period and estimating offsets due to earthquakes and equipment changes. Differences in the approach to offset estimation have caused major discrepancies in published velocities and hence an important part of this project has been to develop a format for recording estimated offsets and possible causes so others can use a consistent approach. All the GPSVEL solutions, which consist of SINEX files, offset and exclusion files as well as supporting information are available on-line at: http://archive.unavco.ucar.edu/science_support/crustal_motion/dxdt/gpsvel.

Regional permanent network and campaign solutions have been attached to the global solutions. The preliminary GPSVEL 0.0 solution [Lavallée and Blewitt, 2000] incorporates only global sites. GPSVEL 0.1 [Lavallée et al., 2001] contains 119 global sites and 38 regional velocities estimated from weekly solutions from the IGS Regional Network Associate Analysis Centers (RNAAC) EUR, SIR and AUS. This year updated RNAAC velocity solutions have been estimated and additional regional solutions added. The current solution, GPSVEL 0.2, contains 122 global velocities, 57 RNAAC velocities, 65 velocities from the Central Greece campaign network [Clarke et al., 1998] and 264 velocities from the Western U.S. Cordillera solution [Bennett et al., 2001]. All 443 GPSVEL 0.2 site locations are shown in Figure 3-3.

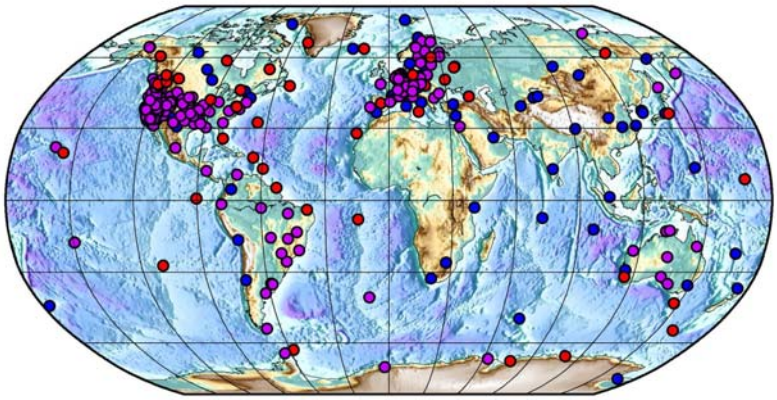

Figure 3-3. All 443 GPSVEL 0.2 site velocity locations. Points in blue are locations of global velocities estimated from weekly IGS GNAAC solutions, sites in purple are locations of velocities taken from regional (campaign and permanent) velocity SINEX solutions and estimated from weekly IGS RNAAC results. Red points are locations of

3.4. Global Strain Rate Map

Significant improvements in the ILP Global Strain Rate Map (http://archive.unavco.ucar.edu/ilp_gsrm) have been made in 2001 and 2002. These advances began with a visit by Wayne Shiver, Chuck Meertens, and Lou Estey to the Department of Geosciences, Stony Brook University, in September 2001. Plans were made with Bill Holt and Corne Kreemer for the development of an interactive website. The basic tasks that the site would handle were outlined during this meeting, and arrangements were made for the transfer and implementation of data from the global digital kinematic model. This model consists of over 230,000 deforming grid elements that encompass plate boundary zones and about 25 spherical rigid caps. In this model, the full velocity gradient tensor is defined through the interpolation of over 3000 GPS vectors. Strain rates inferred from Quaternary fault information are also interpolated in parts of the model. The website, developed at the UCAR/UNAVCO Facility by Lou Estey and Chuck Meertens, was fully functional by December 2001. At the fall AGU meeting in San Francisco, the site was presented at the ILP GSRM Steering Committee meeting. The response to the interactive website was quite favorable. Within the interactive website one can view existing GPS vectors, along with model relative motion vectors, within any frame of reference, strain rates, and predicted faulting mechanisms. These features can be displayed together with topography and fault information. (see also: http://www.unavco.org/community/workinggroups_projects/crustal_motion/dedt/gsrmp/gsrmp.html).

A new revision to the global model has recently been developed at Stony Brook, and plans have been made to include this new data, along with implementation of new features, within the interactive website. The new model includes more updated GPS vectors, better defined reference frames, and generally more accurate results within the plate boundary zones. Plans are being made to again present the updated models and tools at the 2002 AGU meeting during the ILP GSRM Steering Committee meeting. Plans are also being made to incorporate more fault slip data into the model. Even within areas where fault slip rates are not known, active fault data can still provide useful information, since active faults represent directions of zero-length-change in the

instantaneous velocity field. Thus, we hope to obtain more accurate estimates of strain rates within areas with poor GPS coverage by inclusion of new fault data.

3.5. Education and Outreach (E&O)

Education and Outreach activities are a vital part of the scientific research endeavor. They provide a mechanism for disseminating research results beyond the confines of the small research community; they provide an opportunity to enhance the visibility and, in turn, support for the scientific research itself; they provide a resource for educating Americans, at all levels, about the value of scientific research in general, and the importance of geophysical research in particular; they provide a focal point for interest and involvement in scientific activities by the next generation of geophysics students and, thus, are essential for maintaining the human infrastructure on which our science depends.

For the last several years, UNAVCO has expanded its outreach activities to make GPS-related science accessible to a broader community of citizens. These include:

- development of an attractive brochure describing GPS contributions to a broad array of scientific problems (http://www.unavco.org/research_science/brochure/brochure.html)
- creation of a poster depicting state-of-the-art research in plate boundary zone dynamics
- development of inquiry-based curricular materials for environmental studies as part of the Global Learning and Observations to Benefit the Environment (GLOBE) program
- development of web-based materials describing highlights of GPS technology and latest GPS-based scientific results
- creation of computational tools for understanding global plate motions

Through a subcontract to Indiana University, UNAVCO provided support for a sabbatical visit to the UCAR/UNAVCO Facility by Michael Hamburger, August 2001 – January 2002. The research leave included a range of collaborative research activities, as well as expansion of Education and Outreach activities for UNAVCO. The work was conducted in collaboration with UNAVCO colleagues Chuck Meertens, Lou Estey, and Digital Library for Earth Science Education (DLESE) colleagues Marianne Weingroff and Mary Marlino. The principal target of efforts was development of new resources for web-based access to UNAVCO's scientific results. The collaboration resulted in the development of three new tools: (1) the Jules Verne Voyager, Jr., a web-based map tool for accessing geophysical and geological data; (2) Exploring our Dynamic Planet, a web-based curricular resource built around the JVV, Jr. map tool; and, (3) EarthScope Explorer, Jr., a new map tool for visualizing EarthScope related scientific results on deployment plans.

The two new map tools provide a user-friendly interface that allows users to access a variety of maps, satellite images, and geophysical data at a range of spatial scales. The web-based resources allow users to interactively create maps of the Earth, allowing students access for study of global-scale geodynamic processes. Users can choose from a

variety of base maps, including "Face of the Earth" and "Earth at Night" satellite imagery, global topography, geoid, sea-floor age, strain rate and seismic hazard maps, and others. A number of geographic and geophysical overlays can be used, including coastlines, political boundaries, rivers and lakes, earthquake and volcano locations, and stress axes. These can be superimposed with both observed and model velocity vectors representing a compilation of 2933 geodetic measurements from around the world. A remarkable characteristic of the geodetic compilation is that users can select from some 21 frames of reference, allowing a visual representation of both 'absolute' plate motion (in a no-net rotation reference frame) and relative motion along all of the world's plate boundaries. The tool allows users to zoom among at least three map scales. A beta version of this map tool can be viewed at http://jules.unavco.ucar.edu/VoyagerJr/Earth. Because the system uses pre-constructed gif maps and overlays, it can rapidly create and display maps to a large number of users simultaneously.

For the EarthScope Voyager, a number of EarthScope-specific features have been added, including: (1) maps of proposed USArray and PBO instruments; (2) detailed maps of EarthScope focus areas; and, (3) examples of EarthScope-related scientific results with specific links to geographical locations.

The *Exploring our Dynamic Planet* website javascript-based interface can incorporate the JVV, Jr. map tool, curriculum materials, and other supporting materials to enable students and teachers to better understand the relationship between geophysical and geological processes, structures and measurements with high-precision GPS data. In support of the EarthScope map tool, we are developing a similar ancillary website that includes explanatory material on the *EarthScope Explorer*, background material on EarthScope, and curricular activities that encourage users to explore Earth processes using the new map tool.

In addition to these new resources, UNAVCO played a key role in developing an integrated Education and Outreach program for the EarthScope initiative. Hamburger and Meertens took a lead in organizing a national workshop on EarthScope Education and Outreach. The workshop, hosted by UNAVCO, was held at the NCAR Conference Center in Boulder, January 30-February 1, 2002. The meeting was attended by some 60 representatives of the academic research community, science educators, government agencies, professional societies, and public school teachers. The outgrowth of the conference was the development of a comprehensive E&O plan that will become an integral part of the EarthScope initiative.

3.6. SuomiNet

SuomiNet is a university-based, real-time, national GPS network for atmospheric research and education funded through the NSF Major Research Infrastructure Program. The UCAR/UNAVCO Facility is responsible for system development and operational deployment for the 73 GPS station network. The first 31 GPS stations were deployed in FY2001, and an additional 31 stations were deployed in FY2002 (Table 3-1). Half of the stations provide data from geodetic quality monuments of interest to the solid Earth sciences GPS community. All geodetic quality SuomiNet data are publicly available from

the UNAVCO archive. Detailed SuomiNet information is available at http://www.unavco.ucar.edu/project_support/suominet/suominet.html.

Table 3-1: Thirty-one (31) SuomiNet GPS Stations Delivered in FY2002.

Participating Institution	Number of Sites	Data Type
Cayuga	1	Geodetic/Atmospheric
Central Washington/Friday Harbor	1	Geodetic/Atmospheric
Grand Valley State University	1	Geodetic/Atmospheric
Kean University	1	Atmospheric
Monash University	1	Atmospheric
NASA GSFC	1	Atmospheric
National Center for Atmospheric Research	1	Atmospheric
Pennsylvania State University	1	Atmospheric
Purdue	1	Geodetic/Atmospheric
Seoul National University, Korea	1	Geodetic/Atmospheric
SUNY – Stony Brook	1	Geodetic/Atmospheric
Universidad Nacional Autonoma de Mexico	1	Geodetic/Atmospheric
University of Alaska	1	Geodetic/Atmospheric
University of Arizona	3	Atmospheric
University of Calgary	1	Atmospheric
University of Colorado/Niwot Ridge	1	Geodetic/Atmospheric
University of Connecticut	1	Atmospheric
University of Illinois, Urbana-Champaign	1	Atmospheric
University of Maryland, Baltimore County	1	Atmospheric
University of Miami	1	Atmospheric
University of Missouri	1	Atmospheric
University of New Brunswick, Canada	1	Atmospheric
University of North Dakota	1	Geodetic/Atmospheric
University of Oklahoma, Norman	1	Geodetic/Atmospheric
University of Texas, Austin	3	Atmospheric
University of Wyoming	1	Atmospheric
Utah State	1	Atmospheric

4.0 References

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