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CDDIS 1999 Global Data Center Report

Carey E. Noll

Terrestrial Information Systems Branch
NASA Goddard Space Flight Center, Code 922
Greenbelt, MD 20771

Introduction

The Crustal Dynamics Data Information System (CDDIS) has supported the International GPS Service (IGS) as a global data center since 1992. The CDDIS activities within the IGS during 1999 are summarized below; this report also includes any changes or enhancements made to the CDDIS during the past year. General CDDIS background and system information can be found in the CDDIS data center summary included in the *IGS 1994 Annual Report* (Noll, 1995) as well as the subsequent updates (Noll, 1996, Noll, 1997, Noll, 1998, and Noll, 1999).

System Description

The CDDIS archive of IGS data and products are now accessible worldwide through anonymous ftp. New users can contact the CDDIS staff to obtain general instructions on the host computer, directory structure, and data availability. The CDDIS is located at NASA's Goddard Space Flight Center (GSFC) and is accessible to users 24 hours per day, seven days per week. The system is available to users globally through the Internet and the World Wide Web (WWW).

Computer Architecture

The CDDIS is operational on a dedicated Digital Equipment Corporation (DEC) AlphaServer 4000 running the UNIX operating system. All GPS data and product files are archived in a single filesystem, accessible through anonymous ftp, and are stored in UNIX compressed format, using lowercase filenames (with the exception of the *.Z* indicating a compressed file). At present, nearly 100 Gbytes of on-line magnetic disk space is devoted to the storage of daily GPS tracking data and products.

The CDDIS staff continues to archive older GPS data, not currently on-line, to CD-ROM for eventual access through a 600-platter CD-ROM jukebox. Thus far, most of the GPS data from 1995 through 1997 have been archived to CD, one week per CD. These data are migrated from magneto-optical disks (in VAX/VMS format) to the UNIX system where a CD-ROM image is created. After mounting the resulting CDs in the jukebox, users can access the data contained on these CDs in a transparent fashion, i.e., the jukebox software creates a filesystem similar to on-line magnetic disk filesystems. A dual-drive, rewriteable optical disk system connected to the VAX computer continues to be utilized for the off-line storage of older GPS data not yet recorded on CD.

The CDDIS computer facility experienced two major failures during 1999 that caused the system to be down to users for approximately three weeks each time. The first outage occurred in late August and was caused by a disk failure. The second outage in late December was due to a failed operating system upgrade. In both cases, backups of critical files, further compounded by problems with the backup facility in general, were lacking which extended the length of time the system was unavailable.

Archive Content

As a global data center for the IGS, the CDDIS is responsible for archiving and providing access to both GPS data from the global IGS network as well as the products derived from the analyses of these data.

GPS Tracking Data

The GPS user community has access to the on-line and near-line archive of GPS data available through the global archives of the IGS. Operational and regional data centers provide the interface to the network of GPS receivers for the IGS global data centers. The following operational or regional data centers make data available to the CDDIS from selected receivers on a daily (and sometimes hourly) basis:

- Australian Survey and Land Information Group (AUSLIG) in Belconnen, Australia
- Alfred Wegener Institute (AWI) for Polar and Marine Research in Bremerhaven, Germany
- Deutsches Geodätisches ForschungsInstitut (DGFI) in Munich, Germany
- European Space Agency (ESA) in Darmstadt, Germany
- GeoforschungsZentrum (GFZ) in Potsdam, Germany
- Geographical Survey Institute (GSI) in Tsukuba, Japan
- NOAA's Geosciences Laboratory (GL/NOAA) Operational Data Center (GODC) in Rockville, Maryland
- Korean Astronomy Observatory (KAO) in Taejeon, Korea
- Jet Propulsion Laboratory (JPL) in Pasadena, California
- National Geography Institute (NGI) in Suwon-shi, Korea
- National Imagery and Mapping Agency (NIMA) in St. Louis, Missouri
- Natural Resources of Canada (NRCan) in Ottawa, Canada
- Regional GPS Data Acquisition and Analysis Center on Northern Eurasia (RDAAC) in Moscow, Russia
- University NAVSTAR Consortium (UNAVCO) in Boulder, Colorado
- United States Geological Survey (USGS) in Reston, Virginia

In addition, the CDDIS accesses the other two IGS global data centers, Scripps Institution of Oceanography (SIO) in La Jolla California and the Institut Géographique National (IGN) in Paris France, to retrieve (or receive) data holdings not routinely transmitted to the CDDIS by an operational or regional data center. Table 1 lists the data sources and their respective sites that were transferred daily to the CDDIS in 1999. Over 55K station days from 199 distinct GPS receivers were archived at the CDDIS during the past year; a complete list of these sites can be found at URL *ftp://cddisa.gsfc.nasa.gov/pub/reports/gpsdata/cddis_summary.1999*.

Daily GPS Data Files

Once the daily RINEX data files arrive at the CDDIS, these data are quality-checked, summarized, and archived to public disk areas in daily subdirectories; the summary and inventory information are also loaded into an on-line data base. Typically, the archiving routines on the CDDIS are executed many times a day for each source in order to coincide with their automated delivery processes and pick up late-arriving data, thus ensuring timely availability in the CDDIS public disk areas. In general, the procedures for archiving the GPS tracking data are fully automated, requiring occasional monitoring only, for replacement data sets or re-execution because of system or network problems.

The CDDIS daily GPS tracking archive consists of observation, navigation, and meteorological data, all in compressed (UNIX compression) RINEX format. Furthermore, summaries of the observation files are generated by the UNAVCO quality-checking program TEQC (Estey 1999) and are used for data inventory and quality reporting purposes. During 1999, the CDDIS archived data on a daily basis from an average of 170 stations. Each site produces approximately 0.8 Mbytes of data per day (compressed RINEX, compressed compact RINEX, navigation, meteorological, and summary); thus, one day's worth of GPS tracking data totals nearly 130 Mbytes. Although the "compact RINEX" data format is the operational format for exchange of GPS data between the IGS and analysis centers, the CDDIS continues to archive and make data available in the compressed RINEX format for use by the general user community. In 1999, the CDDIS GPS data archive totaled over 50 Gbytes in volume; this figure represents data from nearly 55K observation days. Of the 170 or more sites archived each day at the CDDIS, not all are of "global" interest; some, such as those in Southern California, are regionally oriented. The CDDIS receives data from these sites as part of its NASA archiving responsibilities.

The ephemeris data files for a given day are decompressed and then merged into a single file that contains the orbit information for all GPS satellites for the day. This daily ephemeris data file, named *brdcddd0.yyn.Z* (where *ddd* is the day of year and *yy* is the year), is then copied to the ephemeris subdirectory as well as a general directory of all merged ephemeris files (*/gps/gpsdata/brdc*). Users can thus download this single daily file instead of all broadcast ephemeris files from the individual stations.

At this time, the CDDIS on-line archive of daily GPS data contains data from January 1998 through the present. Prior to mid-1998, these data are available in compact RINEX only; later data are archived in both compact RINEX and uncompacted RINEX formats. As the disks supporting this archive fill up, older uncompact RINEX observation data are deleted. The CD-ROM jukebox contains GPS data from 1995 through 1997; it is hoped the software interface to this device will be operational in mid-2000.

The majority of the data delivered to and archived in the CDDIS during 1999 was available to the user community within six hours after the observation day. As shown in Figure 1, nearly 50 percent of the data from the global sites delivered to the CDDIS were available within three hours of the end of the observation day; over twenty percent were available within one hour. These statistics were derived from the results of the daily archive report utilities developed by the IGS Central Bureau and executed several times each day on the CDDIS.

Hourly GPS Data Files

By mid-1999, four operational/regional data centers (BKG, ESA, JPL, and NRCan) were transmitting hourly data files to the global data centers. Each file of observation (in compact RINEX format only), navigation, and meteorological data contains a single hour's worth of thirty-second data. These individual hourly files are labeled by incrementing the sequence number digit in the RINEX file naming convention; e.g., the file *mmmmddd*a.*yy*o.Z contains the observation data for the first hour of day *ddd* (or the first file transmitted for day *ddd*) in year *yy* for site *mmmm*. Within minutes of receipt, the files are archived to separate subdirectories (*/gps/nrtdata*) by day on the CDDIS. These data are retained on-line for three days. After that time, the hourly data files are deleted; the daily file, transmitted through normal channels with a typical delay of one to two hours, will have been received and archived already and thus the hourly data are of little use. Furthermore, to ensure the most rapid delivery of these data to the user community, no validation or checks on data quality are performed. In 1999, these hourly data files were typically available to the user community within 25 minutes of the end of the hour; toward the end of 1999 this figure had been decreased to about 15 minutes. GPS sites supplying hourly data to the CDDIS in 1999 are denoted by an * in Table 1; nearly fifty sites transmitted hourly data files to the global data centers in 1999.

Meteorological Data

The CDDIS currently receives meteorological data from over thirty sites, as noted in Table 1 below. The meteorological data provided are dry temperature, relative humidity, and barometric pressure at thirty minute sampling intervals. These data are stored on CDDIS with the daily GPS observation and navigation data files in parallel subdirectories.

Other Data Sets

The solar eclipse visible in Europe on August 11, 1999 offered a unique opportunity for the scientific community to study the behavior of the ionosphere. Scientists wanted to collect observation data from many different sources, including GPS tracking data. A request from this community to the IGS Ionosphere Working Group to organize a high-rate tracking campaign on August 11 at those IGS sites that were in view of the solar eclipse. To aid in this activity, the CDDIS received and archived GPS and GLONASS data from 58 sites, many tracking at a one second sampling rate. The data are available through anonymous ftp from host *cddisa.gsfc.nasa.gov* in the filesystem */gps/99eclipse*. A full listing and map of the sites that participated in the activity are also available in this directory.

IGS Products

The seven IGS data analysis centers (ACs) retrieve the GPS tracking data on a daily basis from the global data centers to produce daily orbit and clock products and weekly Earth rotation parameters (ERPs) and station position solutions; the seven IGS associate analysis centers (AACs) also retrieve IGS data and products to produce station position solutions. The CDDIS archives the products generated by both types of IGS analysis centers. These files are delivered to the CDDIS by the IGS analysis centers to individual user accounts, copied to the central disk archive, and made available in compressed format on the CDDIS by automated routines that execute several times per day. The IGS Analysis Coordinator then accesses the CDDIS (or one of the other global analysis centers) on a regular basis to retrieve these products and derive the combined IGS orbits, clock corrections, and Earth rotation parameters as well as to generate reports on data quality and statistics on product comparisons. Users interested in obtaining precision orbits for use in general surveys and regional experiments can also download the IGS products. The CDDIS currently provides on-line access through anonymous ftp or the WWW to all IGS products generated since the start of the IGS Test Campaign in June 1992.

Regional Network Associate Analysis Centers (RNAACs) routinely generate station position solutions for regional networks in Software INdependent EXchange (SINEX) format. The three Global Network AACs (GNAACs) perform a comparison of these files and submit the resulting SINEX files to the CDDIS. The GNAACs also access the SINEX files from the IGS ACs and RNAACs and produced comparison and combined, polyhedron station position solutions. The CDDIS provides “short-SINEX” files, designated with an *.ssc* extension, for all AC and AAC SINEX files. These files contain the site information from the SINEX file but no matrices. These files are also stored in the weekly IGS product subdirectories.

In 1999, the IGS Reference Frame Coordinator, currently located at NRCan, began generating the official IGS combined weekly SINEX solutions, cumulative combined SINEX solutions, daily Earth rotation parameters, and residual files. These files are also available in the weekly IGS product subdirectories.

The derived products from the IGS ACs are typically delivered to the CDDIS within seven days of the end of the observation week; delivery times for AAC products vary, but average thirty days for regional solutions. Figure 2 presents the median delay during 1999, in days and by source, of AC and AAC products delivered to the CDDIS. The statistics were computed based upon the arrival date of the solution summary file for the week. The time delay of the IGS products and the combined SINEX solutions are dependent upon the timeliness of the individual IGS analysis centers; on average, the combined orbit is generated within one to two days of receipt of data from all analysis centers and is typically available to the user community within ten to twelve days.

The rapid orbit and ERP products generated by the IGS Analysis Coordinator, designated IGR, were made available to the IGS global data centers starting in June 1996. These products are produced daily, by 18:00 hours UTC. The predicted orbit, clock, and Earth rotation parameter combinations generated by the IGS Analysis Coordinator have been made available to the users since early 1997. These solutions, designated IGP, are available by 23:30 UTC. The IGS global data centers, including the CDDIS, download both the rapid and predicted products from the Analysis Coordinator and make them available in a timely fashion to ensure their usefulness to the user community.

Since January 1997, the IGS has conducted a pilot experiment on the combination of troposphere estimates. Using a sampling rate of two hours, the zenith path delay (ZPD) estimates generated by the IGS analysis centers were combined by GFZ to form weekly ZPD files for approximately 150 global GPS sites. As of early 1998, these troposphere products are available through the IGS global data centers; at the CDDIS the files are in a subdirectory of the weekly GPS products directories (i.e., */gps/products/wwww/trop,* where *wwww* is the GPS week number).

As of June 1, 1998, several IGS Analysis Centers began supplying daily, global ionosphere maps of total electron content (TEC) in the form of IONEX (an official format for the exchange of ionosphere maps) files. These products are also available from the IGS global data centers. At the CDDIS, the IONEX files are located in daily subdirectories of the main product area (e.g., */gps/products/ionex/yyyy* where *yyyy* is the four-digit year), rather than under the weekly subdirectory structure, since the files are produced daily.

Supporting Information

Daily status files of GPS data holdings, reflecting timeliness of the data delivered as well as statistics on number of data points, cycle slips, and multipath continue to be generated by the CDDIS. By accessing these files, the user community can receive a quick look at a day's data availability and quality by viewing a single file. Furthermore, monthly summaries of the data quality for the IGS sites are also generated. Both the daily and monthly status files are available through the WWW at URL *ftp://cddisa.gsfc.nasa.gov/pub/reports/gpsstatus/*. The daily status files are also archived in the daily GPS data directories.

Ancillary information to aid in the use of GPS data and products are also accessible through the CDDIS. Weekly and yearly summaries of IGS tracking data archived at the CDDIS are generated on a routine basis and distributed to the IGS user community through IGS Report mailings. These summaries are accessible through the WWW at URL *ftp://cddisa.gsfc.nasa.gov/pub/reports/gpsdata*. The CDDIS also maintains an archive of and indices to IGS Mail, Report, and Network messages.

System Usage

Figures 3 through 5 summarize the monthly usage of the CDDIS for the deposit and retrieval of GPS data during the first ten months of 1999. These figures were produced daily by automated routines that peruse the log files created by each network access of the CDDIS. Figure 3 illustrates the amount of data retrieved by the user community during 1999. Nearly two million files were transferred in 1999, totaling approximately 615 Gbytes in volume; the number of files transferred increased dramatically in 1999 due to the availability of hourly data files. Averaging these figures, users transferred nearly 500K files per month, totaling nearly 60 Gbytes in size. The chart in Figure 4 details the total number of host accesses per month with the number of distinct (i.e., unique) hosts per month shown as an overlay. Here, a host access is defined as an initiation of an ftp session; this session may transfer a single file, or many files. Figure 5 illustrates the profile of users accessing the CDDIS IGS archive during 1999; these figures represent the number of distinct hosts in a particular country, geographic area, or organization. This year, less that one half of the users of GPS data available from the CDDIS come from U.S. government agencies, universities, or corporations.

The figures referenced above present statistics for routine access of the on-line CDDIS GPS data archives. However, some amount of staff time is expended on fielding inquiries about the IGS and the CDDIS data archives as well as identifying and making data available from the off-line archives. Table 2 summarizes the type and amount of special requests directed to the CDDIS staff during 1999. To satisfy requests for off-line data, the CDDIS staff must copy data from the optical disk archive to an on-line magnetic disk area, or for larger requests, mount the optical disks in a scheduled fashion, coordinating with the user as data are downloaded. It is hoped that as CD-ROMs of older data become available through the on-line jukebox this figure can be reduced in the coming years.

Other Activities

In early 1998, a Call for Participation in the International GLONASS EXperiment (IGEX-98) was issued. IGEX-98, sponsored by several organizations, including the IGS, and requested participation by stations, data centers, and analysis centers. The CDDIS responded to this call and was selected to serve as a global data center for GLONASS data and products. The staff took advantage of the data archiving and processing procedures developed for the IGS in the support of IGEX. The campaign started in October of 1998 and continued through April 1999. Although the official campaign ended in April, many of the components continued to operate GLONASS stations, provide these data to the data centers, analyze the data, and provide the results to the data centers. In support of the IGEX-98 campaign, the CDDIS archived GLONASS data from over seventy sites totaling nearly 10K station days of data. GLONASS products from six analysis centers were also made available to the public. IGEX data and products are accessible via anonymous ftp to host *cddisa.gsfc.nasa.gov*, in the filesystem */igex*. At present, the CDDIS continues to archive both GLONASS data and products.

Publications

The CDDIS staff attended several conferences during 1999 and presented papers on or conducted demos of their activities within the IGS, including:

- "1998 IGS Data Center Reports" (Carey Noll) for 1998 IGS Annual Report
- "CDDIS 1998 Global Data Center Report" (Carey Noll) for 1998 IGS Technical Report
- "IGEX-98 Data Flow" (Carey Noll) was presented at the IGEX-98 Workshop in September 1999
- "The IGEX Data Center at the CDDIS" (Carey Noll and Maurice Dube) was presented at the IGEX-98 Workshop in September 1999
- "IGS Data Centers" (Carey Noll) was presented as part of the IGS Tutorial during the International Symposium on GPS (GPS-99) in October 1999

Electronic versions of these and other publications can be accessed through the CDDIS on-line documentation page on the WWW at URL *http://cddisa.gsfc.nasa.gov/documents.html*.

Future Plans

Computer System Enhancements

The AlphaServer 4000 computer supporting the CDDIS has been operational for over two years. Additional disk space may be procured in the near future, as well as a dedicated tape backup system. CDDIS staff will continue the migration of older, off-line GPS data from VAX/VMS formatted magneto-optical disks to CD-ROM.

The critical nature of the CDDIS computer facility to many international services will lead to the investigation of ways to ensure the system is not down for extended periods of time as was experienced in 1999 and early 2000. Procedures have already been instituted to ensure backups are executed in an appropriate manner on all operational disks. Alternate data flow paths within the IGS infrastructure will be further investigated for distribution and archive of IGS data and products.

Changes in the Data Archive

In early 2000, the IGS Governing Board approved the International GLONASS Pilot Project (IGLOS-PP) as a formal working group within the service. The IGLOS-PP committee will issue a Call for Participation in early 2000 and, in conjunction with representatives of various IGS components, will recommend how to incorporate the flow of data and the generation of official products into the existing IGS infrastructure.

The CDDIS plans to respond to IGS Call for Participation in Support of Low Earth Orbiting (LEO) Missions in early 2000. The GPS products required by these missions would need one second GPS data, probably on an hourly basis. The CDDIS, as well as other data centers responding to this call, will begin the archive and distribution of one second data files, probably utilizing a new, more efficient binary exchange format, during the mid-2000 timeframe. The CDDIS will also become involved in the archive of space-borne GPS receiver data. A pilot program for the use of this flight data will begin in 2000.

Changes in the Product Archive

The 1999 LEO Workshop also recommended that the IGS Analysis Centers should develop a new ultra-rapid analysis product (orbit, clock, EOP, and predictions) with a latency of less than three hours. These new products will most likely be developed and generated through a pilot program in 2000. The CDDIS and other IGS data centers will archive the official IGS ultra-rapid products.

Contact Information

To obtain more information about the CDDIS IGS archive of data and products, contact:

Ms. Carey E. Noll
Manager, CDDIS
Code 920.1
NASA GSFC
Greenbelt, MD 20771

Phone: (301) 614-6542
Fax: (301) 614-5970
E-mail: *noll@cddis.gsfc.nasa.gov*
WWW: *http://cddisa.gsfc.nasa.gov/cddis_welcome.html*

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Table 1: Sources of GPS Data Transferred to the CDDIS in 1999

Source	Sites								No. Sites
AUSLIG	ALIC	CAS1	*CEDU*	COCO	DARW	DAV1	HOB2	JAB1	**13**
	KARR	MAC1	MAW1	*STR1*	TOW2				
AWI	GOUG	VESL							**2**
BKG	*TUBI*	*WTZT*							**2**
CASM	*BJFS*^{m}								**1**
DGFI	BRAZ								**1**
ESA	KIRU*	KOUR*	MALI	MAS1	PERT*	VILL*			**6**
GFZ	KIT3^{m}	KSTU	LPGS	OBER^{m}	POTS^{m}	*RIOG*	URUM^{m}	ZWEN^{m}	**8**
GSI	*SYOG*	TSKB							**2**
IGN	ANKR	BOR1*	BRUS^{m}	EBRE	GLSV	GRAS	GRAZ^{m}	HARK	**34**
	HERS*^{m}	HOFN*	IRKT	JOZE	KERG	(KIRU)	(KIT3)	KOSG	**(41)**
	(KSTU)	LHAS^{m}	(LPGS)	(MAS1)	MATE*^{m}	MDVO	METS^{m}	NICO	
	NOUM	NTUS	NYA1	NYAL	OHIG	ONSA*	(POTS)	REYK*^{m}	
	THTI	TRO1	TROM	*UZHL*	WSRT	WTZR*^{m}	ZECK	ZIMM*^{m}	
	(ZWEN^{m})								
JPL	AOA1*	AREQ	ASC1	AUCK*^{m}	AZU1	BOGT*	CARR	CASA	**59**
	CAT1	CHAT^{m}	CICE/1*	CIT1	*CORD*	CRO1*	CSN1	DGAR	**(61)**
	EISL*	FAIR*^{m}	GALA*	GODE*^{m}	GOL2*	GOLD	GUAM*	HARV	
	HRAO*	IISC	JPLF	JPLM*	KOKB*^{m}	KRAK	(KUNM)	KWJ1*	
	LBCH	MAD2*	MADR*	MCM4*	MDO1*^{m}	MKEA*	NLIB*	OAT2	
	PIE1*	*PIMO**	QUIN*	*(RIOP)*	SANT*	SEY1	SHAO	SNI1	
	SPK1	SUTH*	THU1	TID2*	TIDB	UCLP	USC1	USUD*	
	WHC1	WLSN	XIAN	YAR1	*YKRO*				
KAO	D/TAEJ								**1**
NGI	SUWN								**1**
NIMA	BAHR^{m}								**1**
NOAA/GL	AMC2	AOML^{m}	BARB	BARH	BRMU	EPRT	FORT	HNPT	**15**
	JAMA	KELY	SOL1^{m}	USNA	USNO^{m}	WES2^{m}	WUHN		
NRCan	(ALBH)	*(ALBX)*	ALGO*	CHUR*	*(CHWK)*	(DRAO*)	(DUBO)	(FLIN)	**8**
	(HOLB)	(NANO)	NRC1*	*NRC2**	PRDS*	SCH2*	STJO*	(UCLU)	**(20)**
	(WHIT)	(WILL)	(WSLR)	YELL*					
PGC	ALBH	*ALBX*	*CHWK*	DRAO*	DUBO	FLIN	HOLB	NANO	**12**
	UCLU	WHIT	WILL	WSLR					
RDAAC	*ARTU*	*BILI*	MAG0^{m}	PETP^{m}	TIXI	YAKA	YAKZ	*YSSK*	**8**
SIO	BAKO	INEG^{m}	MONP^{m}	PIN1	PVEP	RAMO	SIO3^{m}	VNDP^{m}	**8**
UNAVCO	CHUM	KAYT	*KAZA*	KUMT	KUNM	NSSP	POL2	*RIOP*	**13**
	SELE	SHAS	SUMK	*TALA*	TVST				
USGS	AMUN	PALM							**2**
Totals:	**197 sites from 20 data centers during 1999**								

Notes: Sites in () indicate backup delivery route
Sites in *italics* indicate sites new to the CDDIS in 1999
* Indicates site also providing hourly data to the CDDIS in 1999
^{m} Indicates site providing meteorological data to the CDDIS in 1999

Table 2: Summary of Special Requests for GPS Data and Information in 1999

Type of Request	Totals
General IGS/CDDIS information	~200 requests (phone, fax, e-mail)
Off-line GPS data	~50 requests (phone, fax, e-mail)
Amount of off-line data requested	~17,000 station days†
Volume of off-line data requested	~13 Gbytes

Notes: †In this context, a station day is defined as one day's worth of GPS data (observation and navigation file in RINEX format)

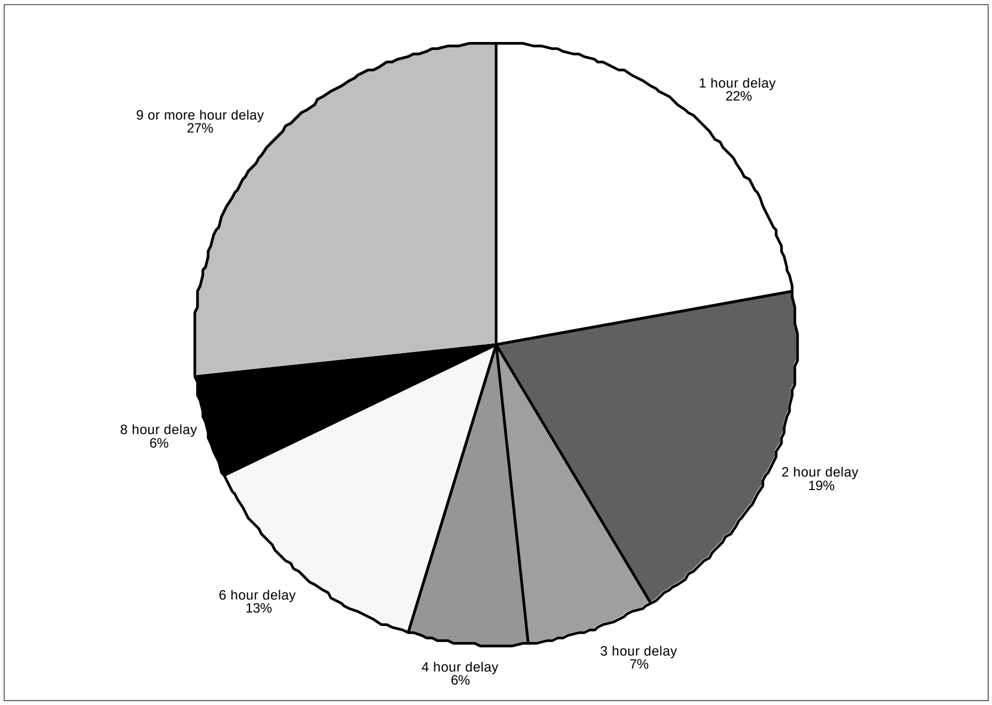

Figure 1: Average delay in GPS data delivery (global sites) to the CDDIS in 1999

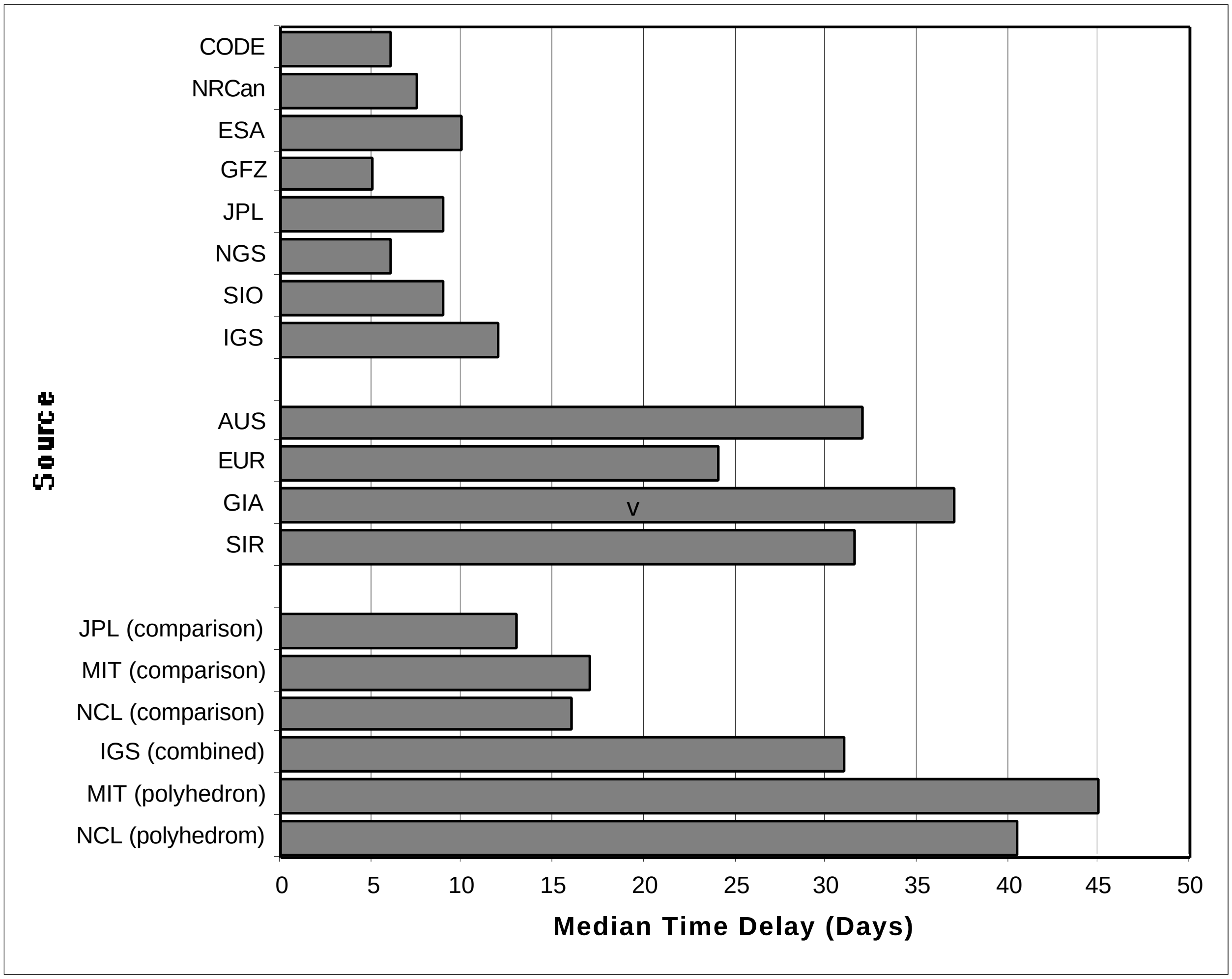

Figure 2: Median delay in GPS product delivery to the CDDIS (by source) in 1999

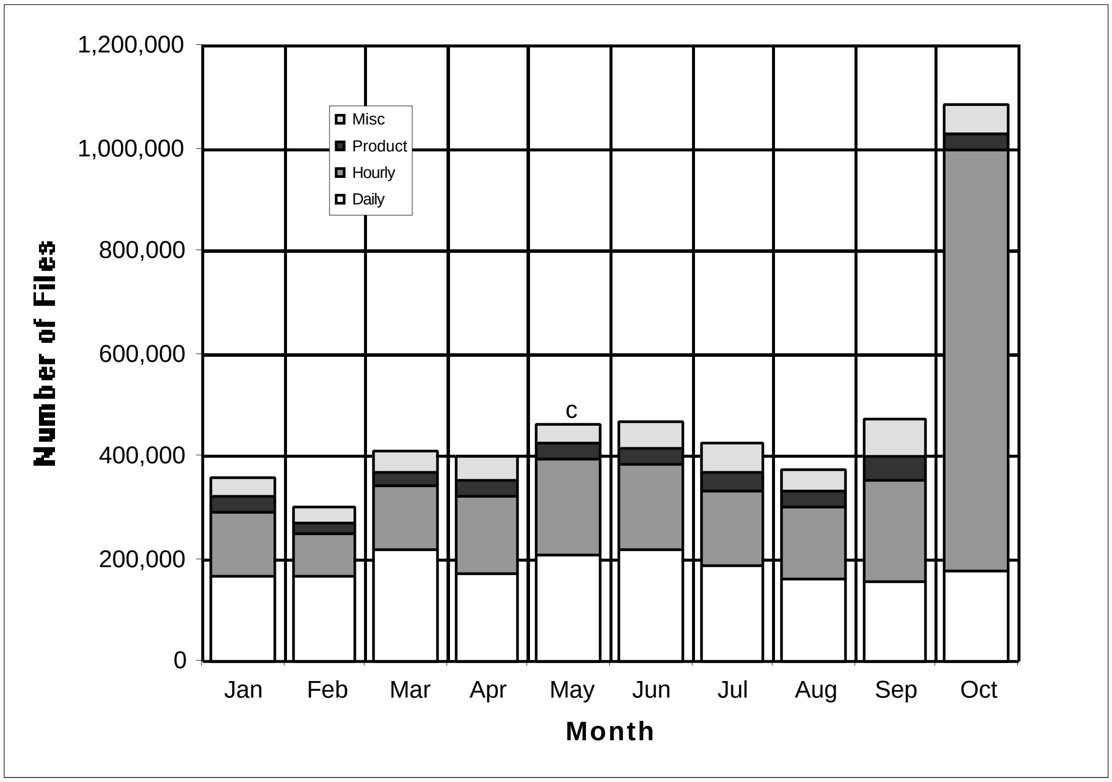

Figure 3: Number of GPS related files transferred from the CDDIS in 1999

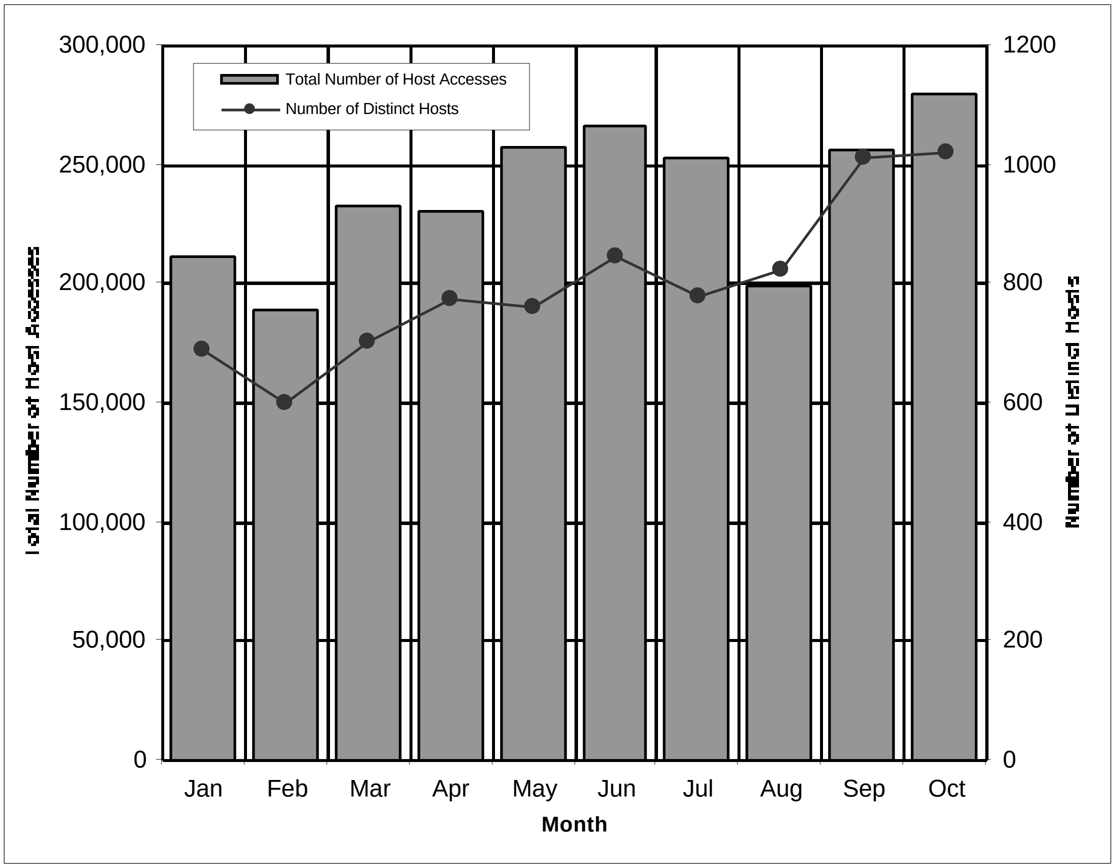

Figure 4: Number of hosts accessing GPS data and products on the CDDIS in 1999

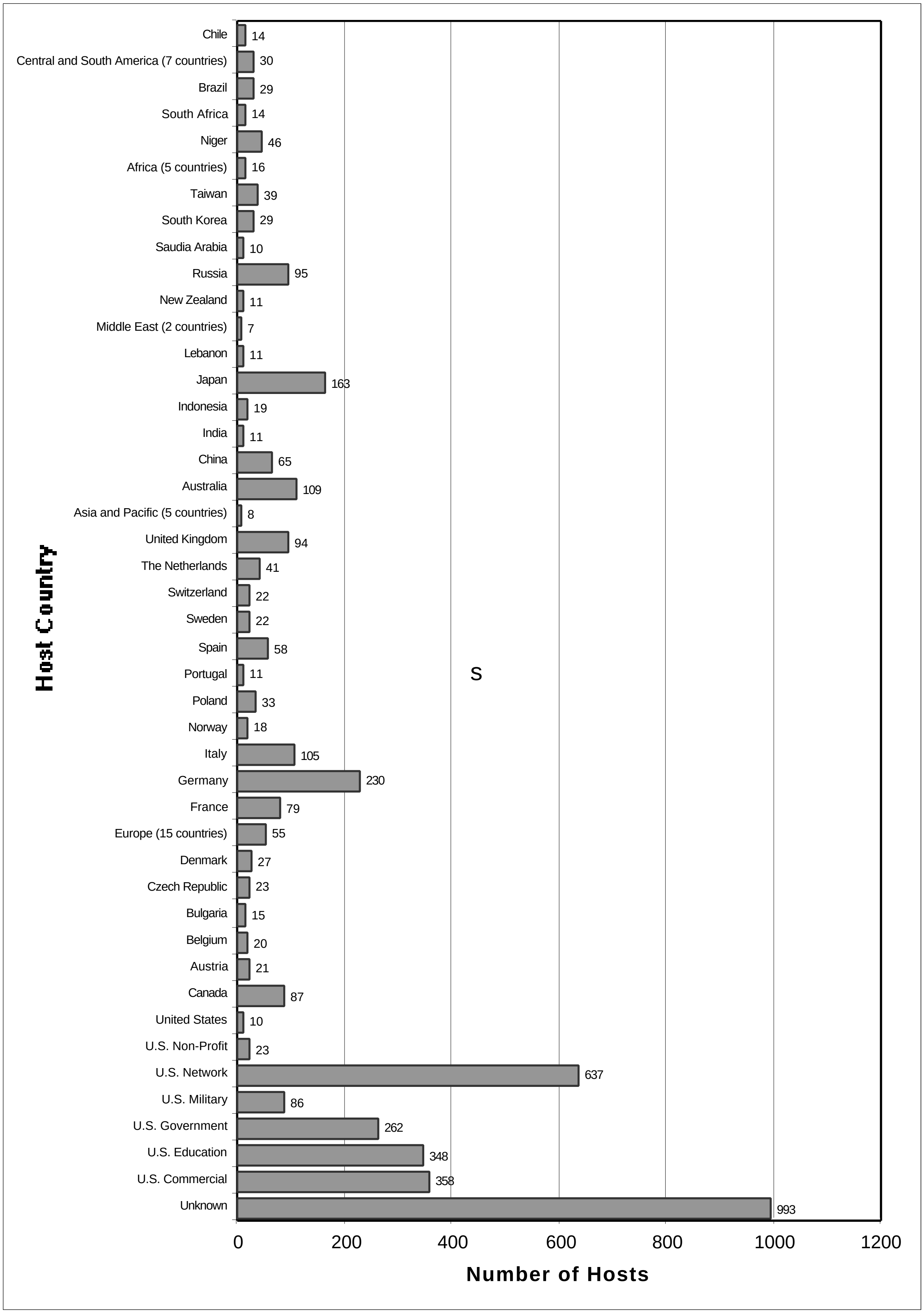

Figure 5: Distribution of IGS users of the CDDIS in 1999

Scripps Orbit and Permanent Array Center
1999 Global Data Center Report

Yehuda Bock, Brent Gilmore, Paul Jamason, Michael Scharber

Cecil H. and Ida M.
Green Institute of Geophysics and Planetary Physics
Scripps Institution of Oceanography
University of California San Diego
La Jolla, CA 92037
http://lox.ucsd.edu

Introduction

The Scripps Institution of Oceanography's Orbit and Permanent Array Center (SOPAC) at the Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics (IGPP), has served as an IGS Global Data Center and Global Analysis Center since 1994. It has also served as a Regional Data Center for the Southern California Integrated GPS Network (SCIGN) since 1997. SOPAC is responsible for the collection, archiving, processing and publishing of high-precision continuous GPS data to support the global GPS community. A description of SOPAC's data archive, user access, and computer architecture is provided here. Peng Fang and Matt van Domselaar at SOPAC perform analysis tasks for the IGS which are described in another report.

SOPAC also serves as a data archive for the University NAVSTAR Consortium (UNAVCO), NOAA's Forecast Systems Laboratory (FSL), and the California Spatial Reference Center (CSRC).

Data Archive

The SIO GPS archive has an online capacity of approximately 1.4 terabytes (TB) and is composed of a 750 gigabyte (GB) nStor RAID storage device, a 600 GB magneto-optical removable cartridge library, and other small capacity devices. The nStor RAID is used to store the most recent (and frequently accessed) RINEX data. A secondary magnetic disk array mirrors 330 GB of the primary storage. Older, lower-demand data are stored on the optical and other devices. Finally, data are backed up on DLT tape, which can be utilized by a large-capacity tape drive at the IGPP Digital Data Library.

GPS Data Description

The SIO archive contains over 700 GB of daily GPS data. The archive includes IGS tracking data in RINEX format, RINEX files from several regional GPS networks, and GPS raw and RINEX data for SCIGN (currently 164 sites). At this time, SIO archives about 750 permanent GPS sites, or approximately 1 GB of data per day (Table 1).

GPS Data Collection

SOPAC continuously probes and collects RINEX data from several remote archives. The current number of sites obtained per archive is listed in Table 1. This automated process was extensively re-written during the past year to increase efficiency, minimize data latency, and utilize an Oracle relational database. The process compares the database description of the SIO archive to the remote archives, ftp's any needed files, quality checks the data, and makes them immediately available for online access. Site log files are also compared and archived to provide current and historical listings of site equipment.

SOPAC is responsible for the maintenance and download of 37 SCIGN sites. Data collection is performed using the Extended GPS Array Downloading Software package (EGADS) (http://www.scign.org).

Table 1. Permanent GPS Arrays Archived at SOPAC

Array Code	Array Name	# Sites
IGS	International GPS Service	91
SCIGN	Southern California Integrated GPS Network	164
CORS	U.S. Continuous Operating Reference Stations	130
EUREF	European Reference Frame	102
BARGEN	Basin and Range GPS Network	48
FSL	NOAA's Forecast Systems Laboratory	40
BARD	Bay Area Regional Deformation Array, Northern California	34
PANGA	Pacific Northwest Geodetic Array	20
WCDA	Western Canada Deformation Array	19
ARGN	Australian Deformation Array	15
EBRY	Eastern Basin Range and Yellowstone	12
SOI-TAU	Survey of Israel / Tel Aviv University / Royal Jordanian Geographic Centre	10
PGF	Pacific GPS Facility, U. Hawaii	9
NEDA	Northeast Eurasia Deformation Array, Russia	7
JPL	Jet Propulsion Laboratory	6
AKDA	Alaska Deformation Array	2
RGNA	Red Geodesica Nacional Activa, Mexico	2
MISC	Miscellaneous	39
Total	All Sites	750

Analysis Products

GPS products from all IGS analysis centers, including SIO, are archived here. These include combined, rapid and predicted orbits, earth orientation parameters, tropospheric estimates, and SINEX solutions. Data required for the GAMIT/GLOBK processing software are also available online.

Weekly products have a latency of 4 days. SIO's predicted and rapid ephemerides are available within 18 hours from the end of the previous observation day. The IGS combined, rapid and predicted orbits are available within 22 hours from the end of the previous day.

Archive Access

The SIO GPS archive is available via anonymous ftp. SOPAC has established a Data Policy regarding the GPS archive. Statistics of all ftp transfers are collected in order to determine archive usage.

Connection Information

SOPAC's publicly available data archive is accessible via anonymous ftp at the following URL: ftp://lox.ucsd.edu.

Data Policy

SOPAC makes every attempt to provide data that it collects or produces in a timely manner. All data on SOPAC's public archive may be obtained without restriction. An open data policy is intended to provide public users with the easiest means of collecting data from SOPAC on both a regular and irregular basis. Although private commercial use of such data is permitted, additional services and/or requests by private entities are given lowest priority.

In addition to the regular nature of data collection and publication at SOPAC, older data and/or products are also added to the public archive, typically on an irregular basis. Various data formats are available from the SOPAC archive, such as ASCII and UNIX-compressed. In addition, formal requests for offline data are handled by SOPAC and dealt with in a timely and appropriate manner. These policies are encouraged by SIO for other data centers wherever possible.

Statistics

In 1999 SOPAC saw its total archive size (first-copy data, excluding backups) grow by 300 gigabytes (Figure 1) to roughly 1.5 terabytes . In addition, 724 different permanent GPS sites comprised the set of all RINEX data files collected by SOPAC for the year 1999 (Figure 2). This number, combined with the continuous nature of permanent GPS, has directly affected both the size and usage of SOPAC's public archive.

1999 was also a year where SOPAC saw continual growth in the number of file transfers by both public and private users, locally and from around the world. Topping more than 4 million transfers for the year SOPAC continues to provide GPS data to an ever-growing constituency of GPS users the world over. The most frequently downloaded GPS data at SOPAC were those affiliated with the IGS. See Figure 3 for ftp transfer statistics for IGS sites and IGS core sites.

SCIGN, the Southern California Integrated GPS Network (http://www.scign.org), also grew substantially in 1999. SOPAC is the primary data archive for the SCIGN network. The network will comprise a total of 250 sites by the end of 2000 (currently more than 180 sites have been constructed). SCIGN is the largest regional network at SOPAC, both in terms of the number of total sites archived (see Figure 2) and the total hard-disk space allocated for storage (Figure 4). Among file transfers from SOPAC, SCIGN was the fourth most popular network downloaded, behind EUREF, IGS-Core and IGS.

From the standpoint of a user constituency SOPAC continues to cater predominately to U.S. educational institutions, accounting for over 2,750,000 file transfers alone (see Figure 5). U.S. government and military organizations are the second and third largest user groups of SOPAC's archive.

RINEX observation format GPS data files continue to be far and above the most frequently accessed data at SOPAC, accounting for over 90% of the total file transfers in 1999 (see Figure 6). As such, there is a high correlation between the number of permanent GPS sites archived on a daily basis at SOPAC and both the total size of the SOPAC archive and the number of file transfers from SOPAC. We expect this trend to continue to rise in the future and are taking appropriate steps to ensure SOPAC can maintain its high level of service to the global GPS community.

Information Management

SOPAC is dedicated to providing the GPS community with useful and timely information describing GPS data. In this effort SOPAC utilizes a relational database to track information about data, creates web-based software to assist with user entry and retrieval of site information, and maintains ftp statistics about the data's access by the GPS community.

SOPAC Relational Database

Over the past year, SOPAC has integrated an Oracle Relational Database Management System into its archiving operations. This has enabled us to increase the efficiency of both local and remote GPS data downloading, and improve the accuracy of GPS site metadata stored at SIO.

Several front- and back-end applications have been rewritten to utilize the database. The "archive browsers" on the SIO web page now use this source, and the weekly reports describing the archive are created from the database (see http://lox.ucsd.edu/weeklyReports/).

Archive Information

The SIO database catalogs and organizes SIO data holdings, and the tools used to obtain these data. Revised remote collection software then utilizes this information to determine which remote archive files are needed.

Site Metadata

SIO has greatly improved its management of GPS site information. The Site Information Manager (SIM) is a web-based application that allows users access to site information contained in the SOPAC database. It provides secured users with a single mechanism of updating site information, which is then propagated to several applications. Alternatively, users may manually generate products such as site logs from the SIM. The SIM has extensive help sections with url links to helpful resources, and limits equipment types to those recognized by the IGS (see Figure 7).

Several SIO applications have been automated via the database and/or SIM. These include:

- submission of SCIGN site logs to the IGS Central Bureau
- GPS site log parsing into the database
- SCIGN site log creation and updating
- SCIGN mail generation
- updating of site equipment local download software to allow correct equipment types to be entered into RINEX headers
- automated updating of the GAMIT input file station.info

User Information

FTP access statistics for the SIO archive are updated semi-hourly in the database. The number of transfers from the archive may be queried based on GPS site name, array, several temporal parameters, and by remote host types. This allows for a timely, detailed description of the data archive's usage, and creates a usage profile which enables SIO to better deliver its products to the GPS community (see http://lox.ucsd.edu/cgi-bin/dbFtpStats.cgi).

Computer Facilities

The SIO GPS archiving facility is made up of two Sun Ultra 2 workstations, one Sun Ultra 30, and one SGI data server. One Sun Ultra 2 workstation is connected to an nStor RAID array (Figure 8). The second Sun Ultra 2 provides FTP and Web services. The Ultra 30 performs downloads of GPS data from remote sites. The SGI data server controls the magneto optical and DLT libraries.

During 1999 the focus of the GPS archive data management team at SIO was archive-related software development along with managing the ever growing archive. Time and energy was invested in switching from a flat file catalog to using a relational database (Oracle 8). Twenty- eight 36 GB drives were added to the archive for a 50% increase in available space from 1998 to 1.5 TB. The magneto-optical device was filled to capacity with 600 GB of data. The shared 8TB DLT library contains approximately 1 TB of GPS archive data.

Future Developments

SOPAC will replace sixteen 9 GB drives with 50 GB drives during 2000. This increase will provide SOPAC with a 12 month capacity at current usage rates. The use of Network Attached Storage (NAS) or a second disk array, and/or a writeable DVD library is being considered for possible implementation in early 2001. SOPAC will acquire two Dell Intel-based servers for GPS-related tasks. The first will host Oracle 8 and will utilize the 9 GB drives that were swapped-out of the primary disk array with 50 GB disks. The second server will run Linux along with the Apache Web server for web-related applications dedicated to the GPS archive. A new version of the SOPAC web site will be made available, using a contemporary, improved page design to facilitate easier navigation and access to data by users.

The major focus during the year 2000 is system redesign. This includes hardware upgrades, operating system upgrades, performance monitoring and tuning, network tuning, and implementation of security-related tools and services. Some services will be relocated to different equipment in order to increase performance and security. SOPAC will continue to rely on Sun Solaris as the primary server operating system along with Linux for certain tasks.

Work continues on the Seamless GPS Archive effort organized by the University NAVSTAR Consortium (UNAVCO). Prototype GSAC client development is currently utilizing the MySQL database and may access GPS data over HTTP rather than FTP. The HTTP protocol provides greater functionality, flexibility, and it is arguably safer to run a public HTTP server. The use of HTTP is still under investigation. A prototype client should be available in late 2000.

General Information

SOPAC Archive Team:

Brent Gilmore
Paul Jamason
Michael Scharber

Scripps Institution of Oceanography
IGPP Room 4212
8785 Biological Grade
La Jolla, CA 92037

Phone: (858) 534-7692
FAX: (858) 534-9873
E-Mail: archive@josh.ucsd.edu
Web: http://lox.ucsd.edu/

Acknowledgments

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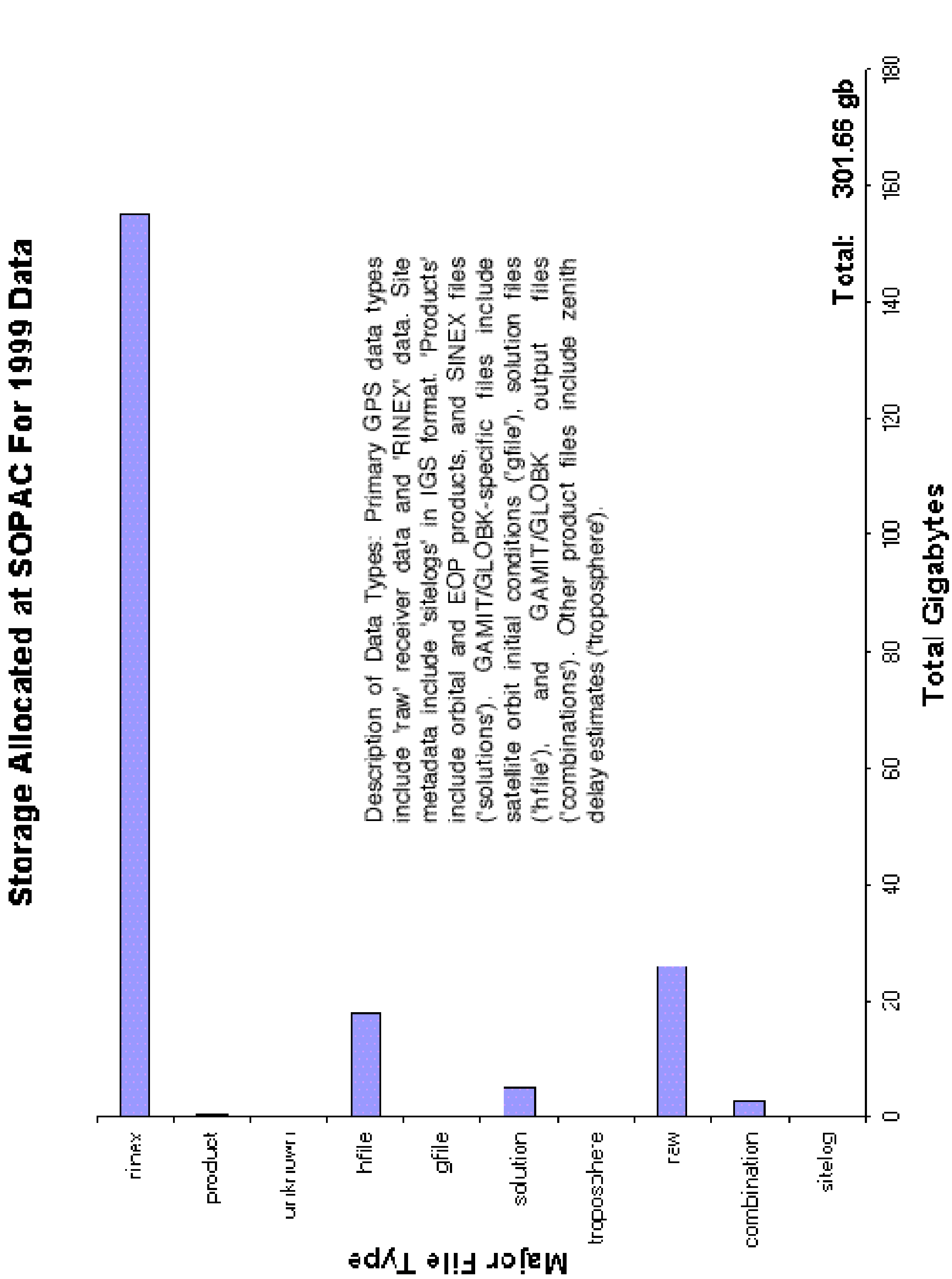
Figure 1.


Storage Allocated at SOPAC For 1999 Data
Description of Data Types: Primary GPS data types include 'raw' receiver data and 'RINEX' data. Site metadata include 'sitelogs' in IGS format. 'Products' include orbital and EOP products, and SINEX files ('solutions'). GAMIT/GLOBK-specific files include satellite orbit initial conditions ('gfile'), solution files ('hfile'), and GAMIT/GLOBK output files ('combinations'). Other product files include zenith delay estimates ('troposphere').
Total: 301.66 gb
rinex
product
unknown
hfile
gfile
solution
troposphere
raw
combination
sitelog
Major File Type
0
20
40
60
80
100
120
140
160
180
Total Gigabytes

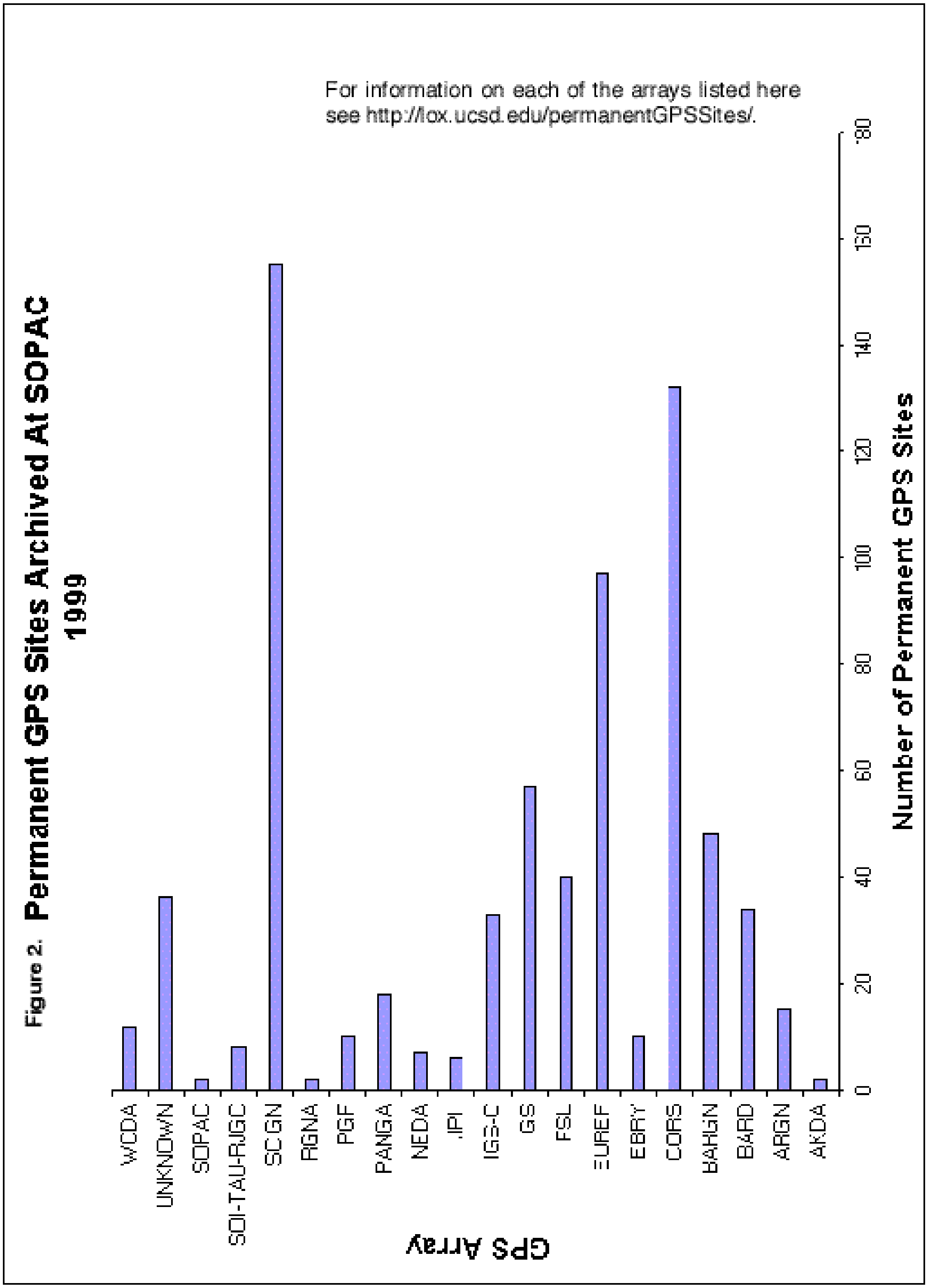


Figure 2. Permanent GPS Sites Archived At SOPAC
1999
For information on each of the arrays listed here see http://lox.ucsd.edu/permanentGPSSites/.
GPS Array
Number of Permanent GPS Sites
0
20
40
60
80
100
120
140
WCDA
UNKNOWN
SOPAC
PGF
PANGA
NEDA
GS
FSL
EBRY
CORS
BARD
ARGN
AKDA

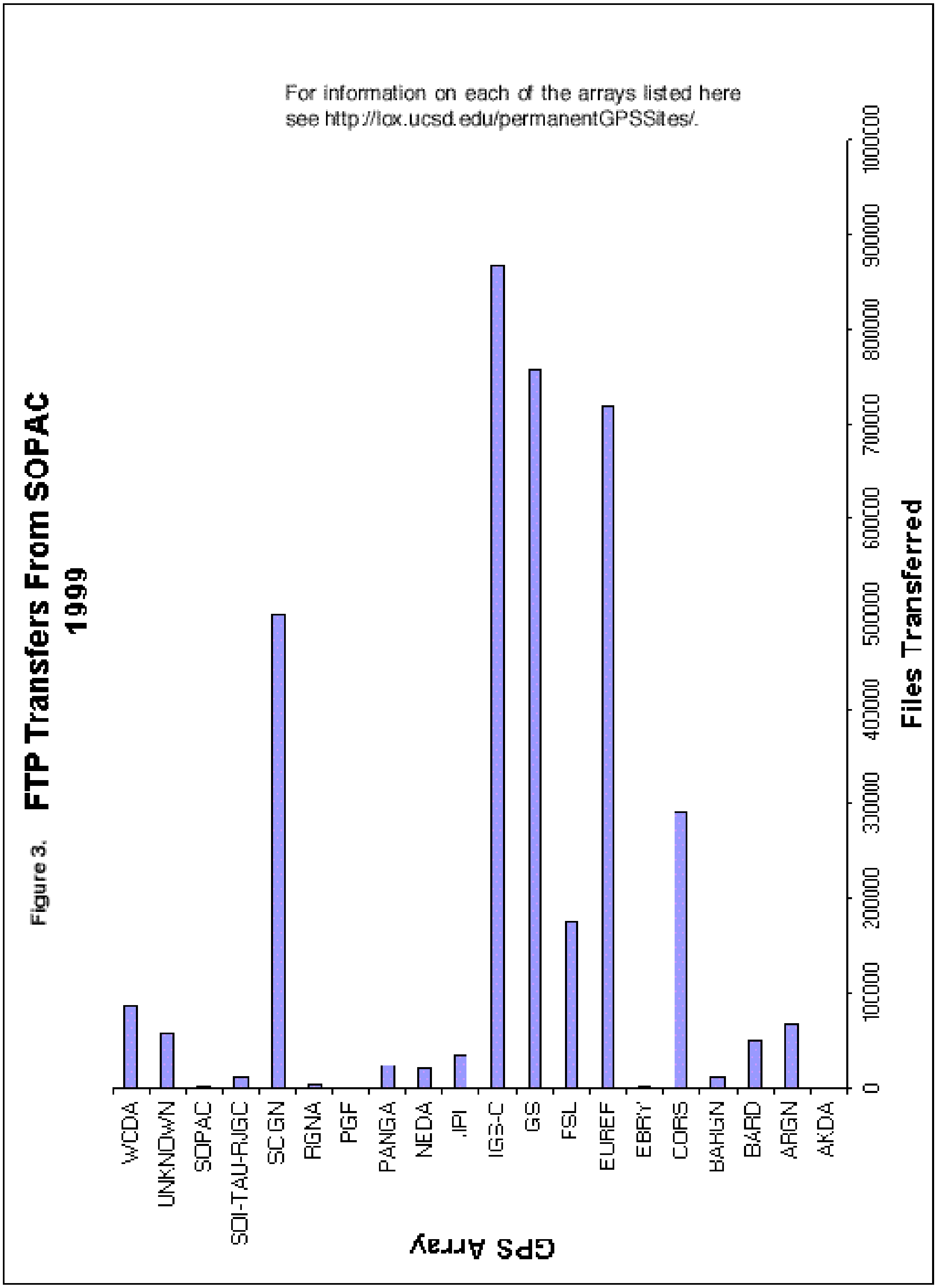
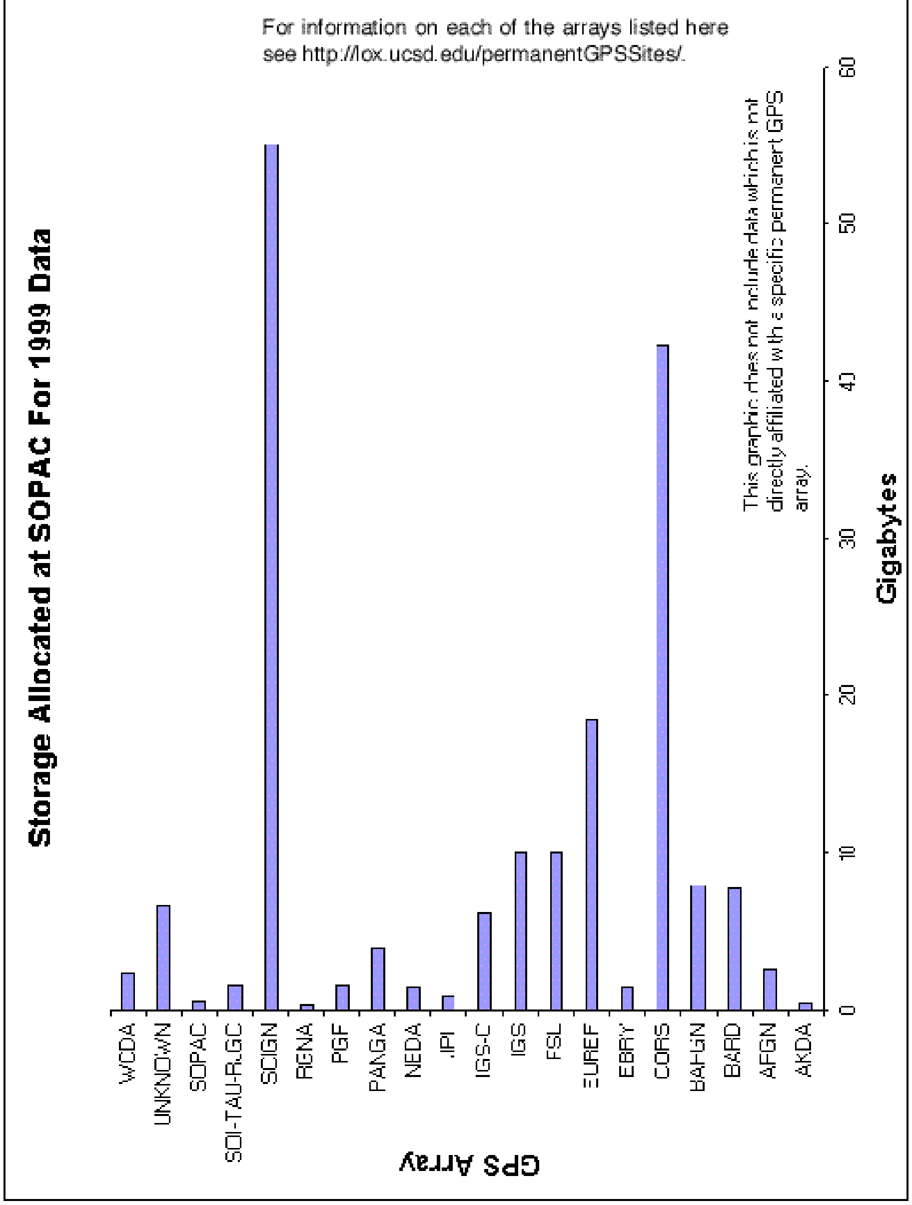


Figure 3.
FTP Transfers From SOPAC
1999
For information on each of the arrays listed here
see http://lox.ucsd.edu/permanentGPSSites/.
GPS Array
WCDA
UNKNOWN
SOPAC
SOI-TAU-RJGC
SCIGN
RGNA
PGF
PANGA
NEDA
JPL
IGS-C
GS
FSL
EUREF
EBRY
CORS
BARGN
BARD
ARGN
AKDA
0
100000
200000
300000
400000
500000
600000
700000
800000
900000
1000000
Files Transferred

Figure 4.


Storage Allocated at SOPAC For 1999 Data
For information on each of the arrays listed here
see http://lox.ucsd.edu/permanentGPSSites/.
This graphic does not include data which is not
directly affiliated with a specific permanent GPS
array.
Gigabytes
0
10
20
30
40
50
60
GPS Array
WCDA
UNKNOWN
SOPAC
SOI-TAU-RJGC
SCIGN
RENA
PGF
PANGA
NEDA
JPL
IGS-C
IGS
FSL
EUREF
EBRY
CORS
BAHGN
BARD
AFGN
AKDA

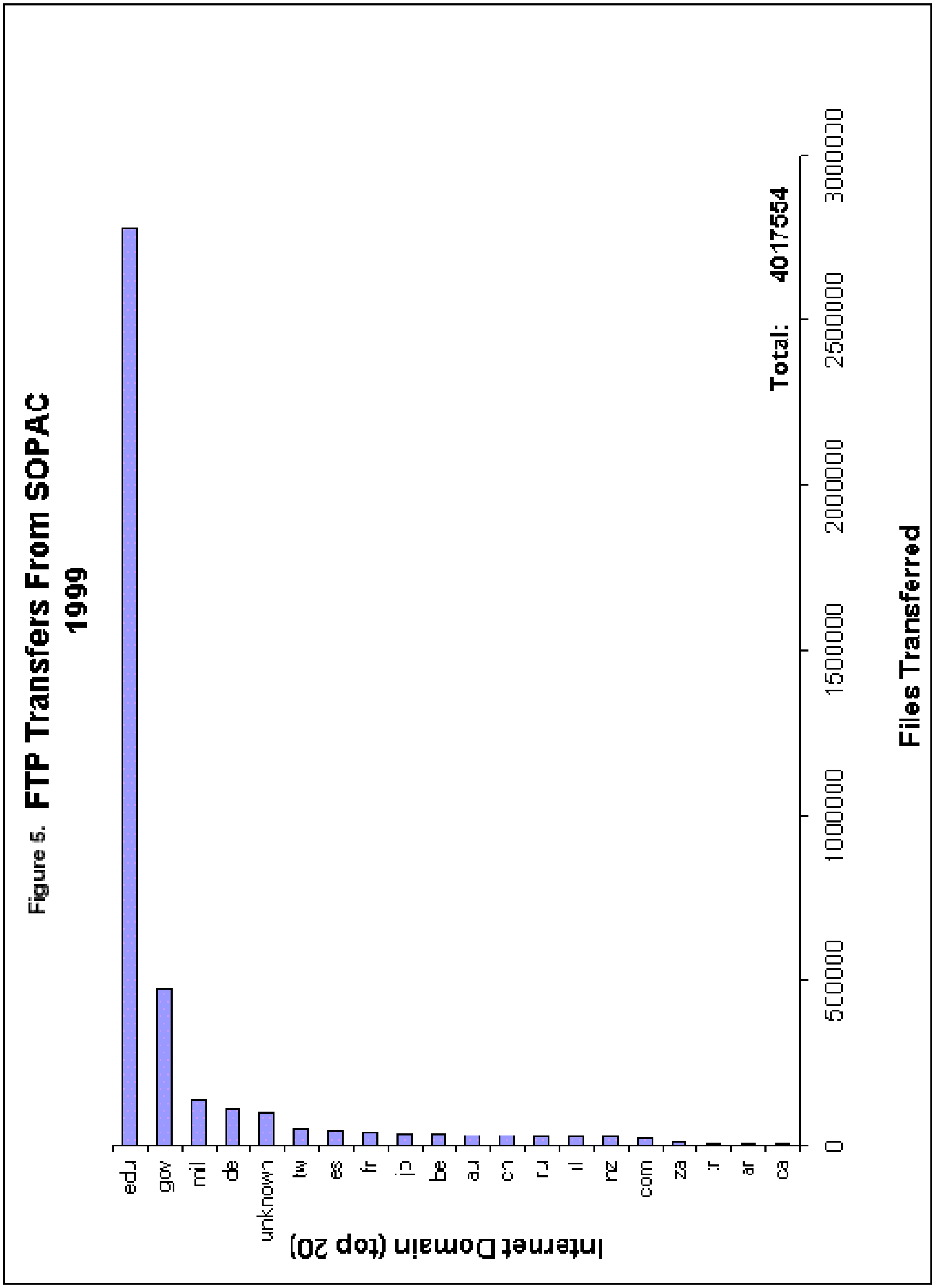


Figure 5. **FTP Transfers From SOPAC 1999**

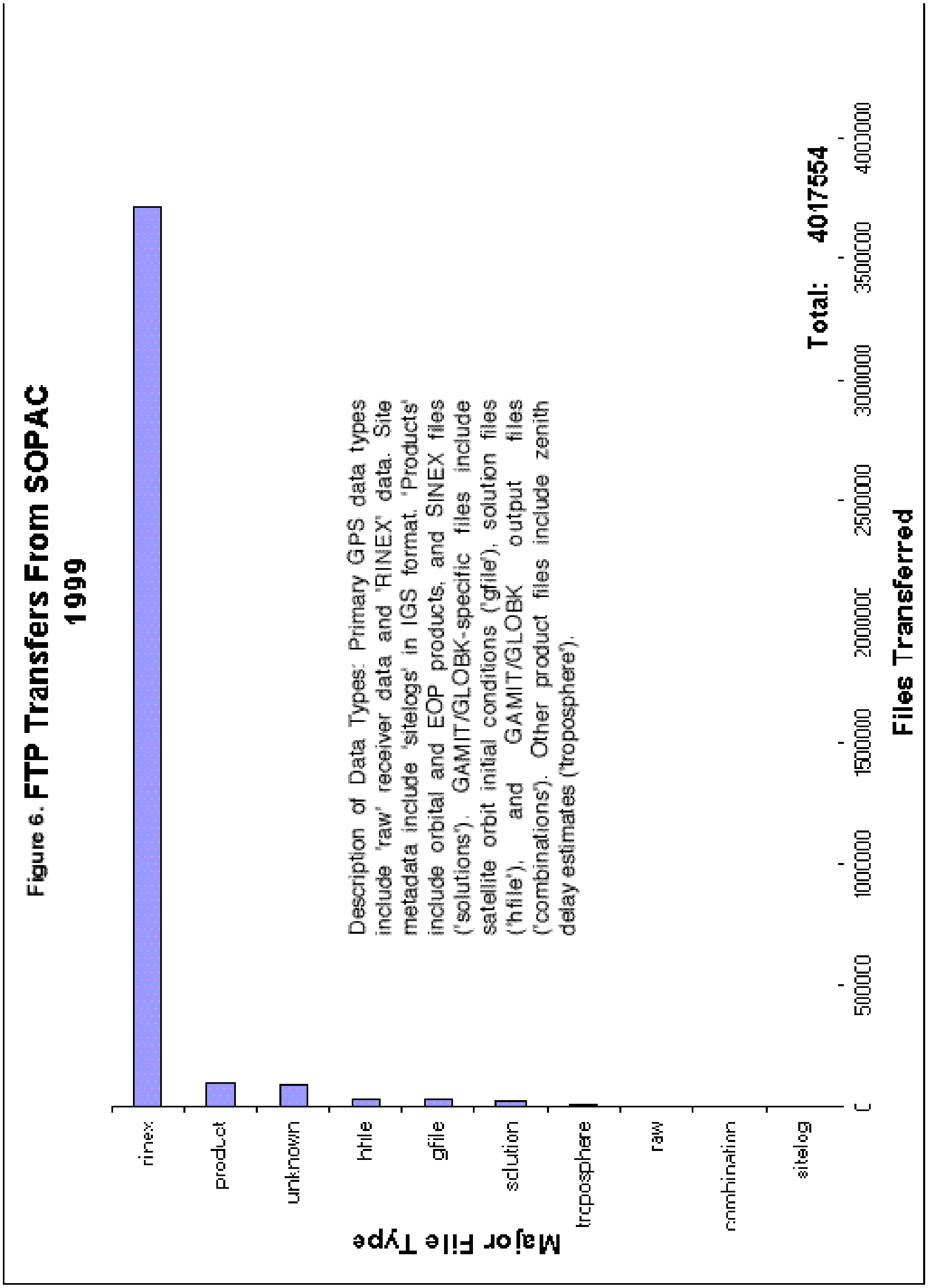
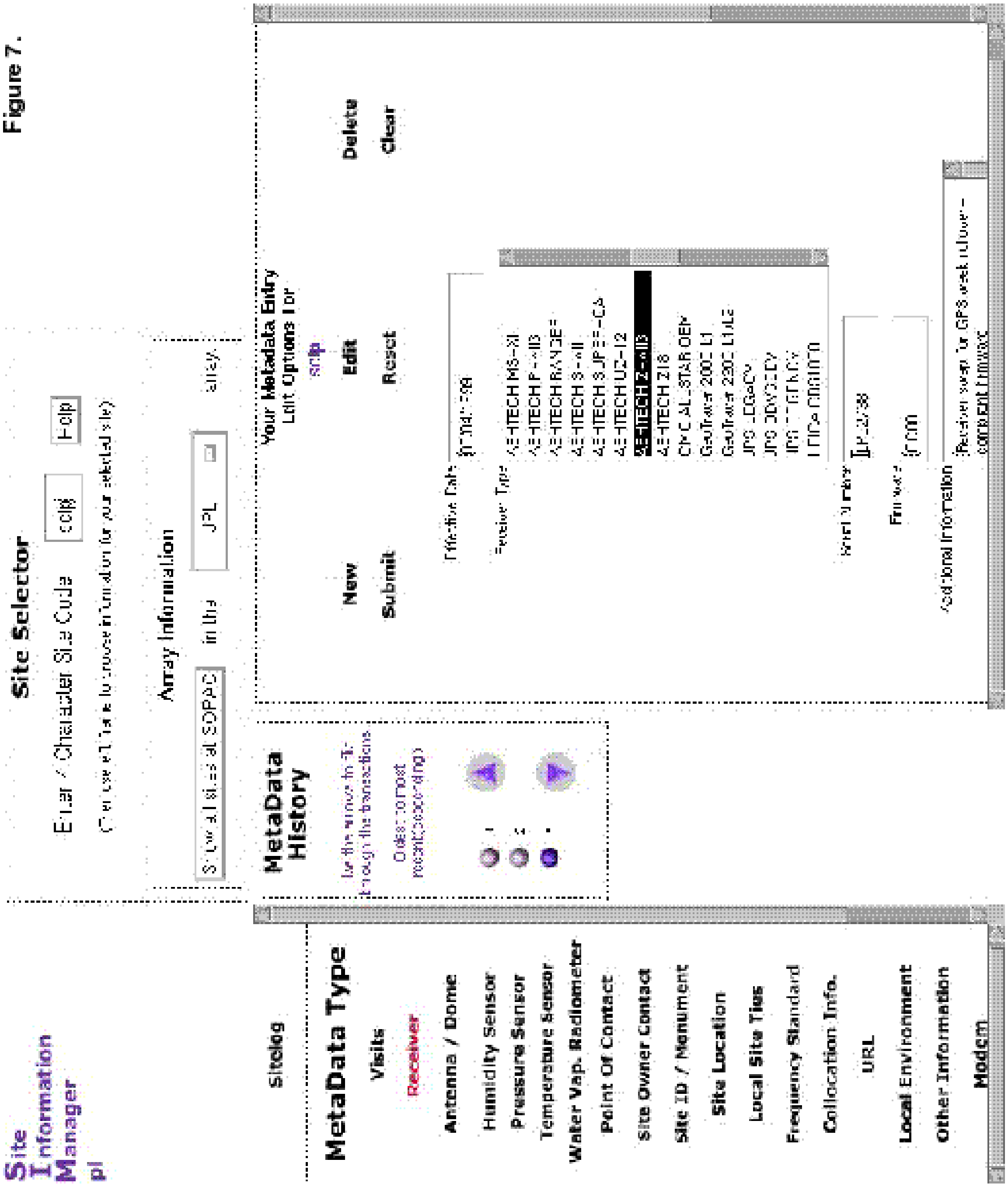


Figure 6. FTP Transfers From SOPAC 1999

Figure 7.



SOPAC's Site Information Manager

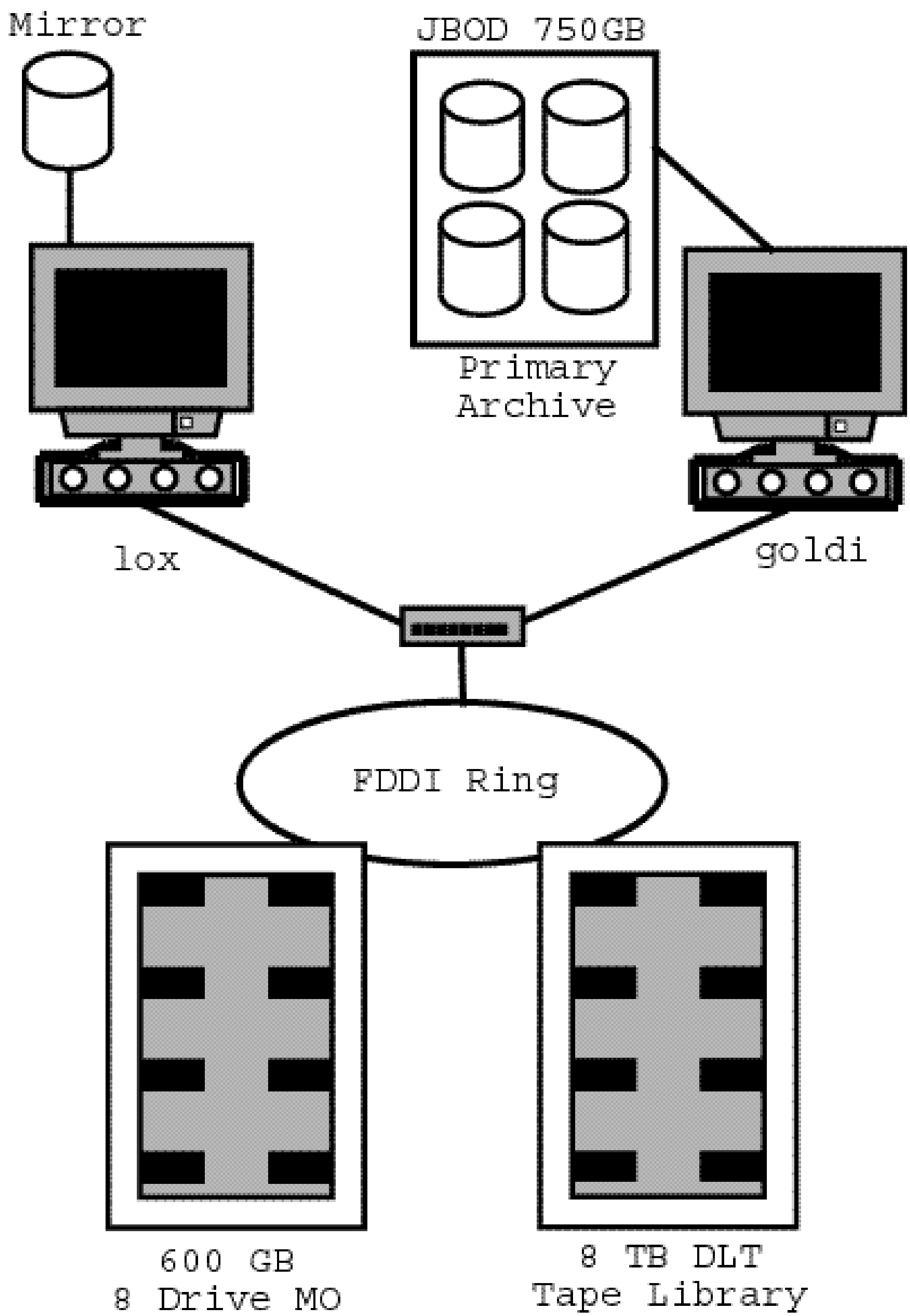


Figure 8. **Schematic of SOPAC's GPS Archive System**

IGS

REGIONAL/OPERATIONAL CENTERS

BKG Regional IGS Data Center Report 1999

Heinz Habrich, Kurt Herzberger

Federal Agency for Cartography and Geodesy
D-60598 Frankfurt at Main, Germany

Introduction

The Federal Agency for Cartography and Geodesy (BKG) operates the Regional IGS Data Center for Europe since the beginning of the IGS Test Campaign in June 21, 1992. GPS tracking data from permanent GPS sites in Europe are obtained from Operational Data Centers (ODC's), Local Data Centers (LDC's), or directly from the stations. Also tracking data from stations outside of Europe are transferred to BKG, if these stations are operated by an European institution. The received data are uploaded to the Global Data Center (GDC) at the Institut Géographique National (IGN) in Paris and to the Center for Orbit Determination in Europe (CODE) in Berne, and are also made available to other users. The IGS products as computed by the IGS Analysis Centers are downloaded from the GDC's to BKG in order to provide this information to European users.

GPS observation data from the permanent GPS network of the European Reference Frame (EUREF) and mixed GPS/GLONASS observation files from the International GLONASS Experiment 1998 (IGEX) are also available. A subset of the IGS and EUREF stations deliver hourly observation files to BKG additionally to the daily files.

Computer Architecture

The data center operates on an HP-workstation running the HP-UX operating system. This workstation is connected to the Internet with a maximum transfer rate of 128 kbit/s and three harddiscs (each of 16 Gbyte capacity) store the on-line data. The directory structure (see Figure 1) shows three project related directories (IGS, EUREF, and IGEX) which each of them includes a comparable subdirectory tree. Compared to the last report of the BKG data center some directories (e.g., "indata" and "outdata" on top level) do no longer occur. In fact these directories will be available for a limited period of time by reason of compatibility.

All information of the data center may be obtained by the anonymous ftp account. For those users which prefer a web browser we recommend to load the "ACCESS.htm" file (see Figure 1).

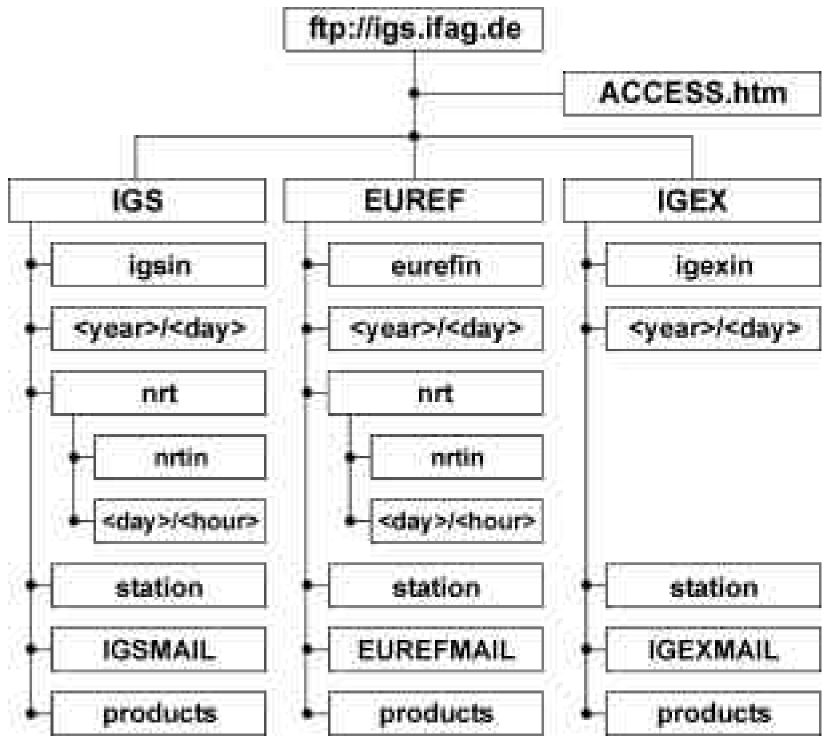


Figure 1: Access and Structure of the BKG Data Center.

GPS/GLONASS Tracking Data

The RINEX observation files of the IGS stations are now online available for 12 month. In May, 1996 the IGS has officially accepted the EUREF GPS network to become the European densification of the global IGS network. Because BKG acts as data center for this network the EUREF subdirectory tree was added to the file structure and holds the RINEX observation files of currently 40 EUREF stations. The IGEX subdirectory tree holds mixed GPS/GLONASS observation files and was created in October, 1998 when the IGEX campaign had started. BKG has the function of a regional data center for Europe within IGEX. The continuation of the IGEX campaign is now proposed to become an IGS pilot service for a period of four years (2000-2003) named International GLONASS Service – pilot project (IGLOS-PP). The size of the mixed GPS/GLONASS observation files is approximately 1.6 times higher compared to the IGS files because additional GLONASS satellites are observed. A separate RINEX navigation file with the filename extension "*.<year>G" if transferred for GLONASS satellites because of the different parameters of GPS and GLONASS broadcast ephemerides.

Hourly Observation Files

The hourly RINEX observation files may be used for near real time applications and could replace the daily files if all hourly files of one day are concatenated to one file successively. As soon as the daily observation files are available at the data center the hourly observation files are no longer of interest. Therefore, the hourly files are deleted after 7 days in the "nrt" subdirectory.

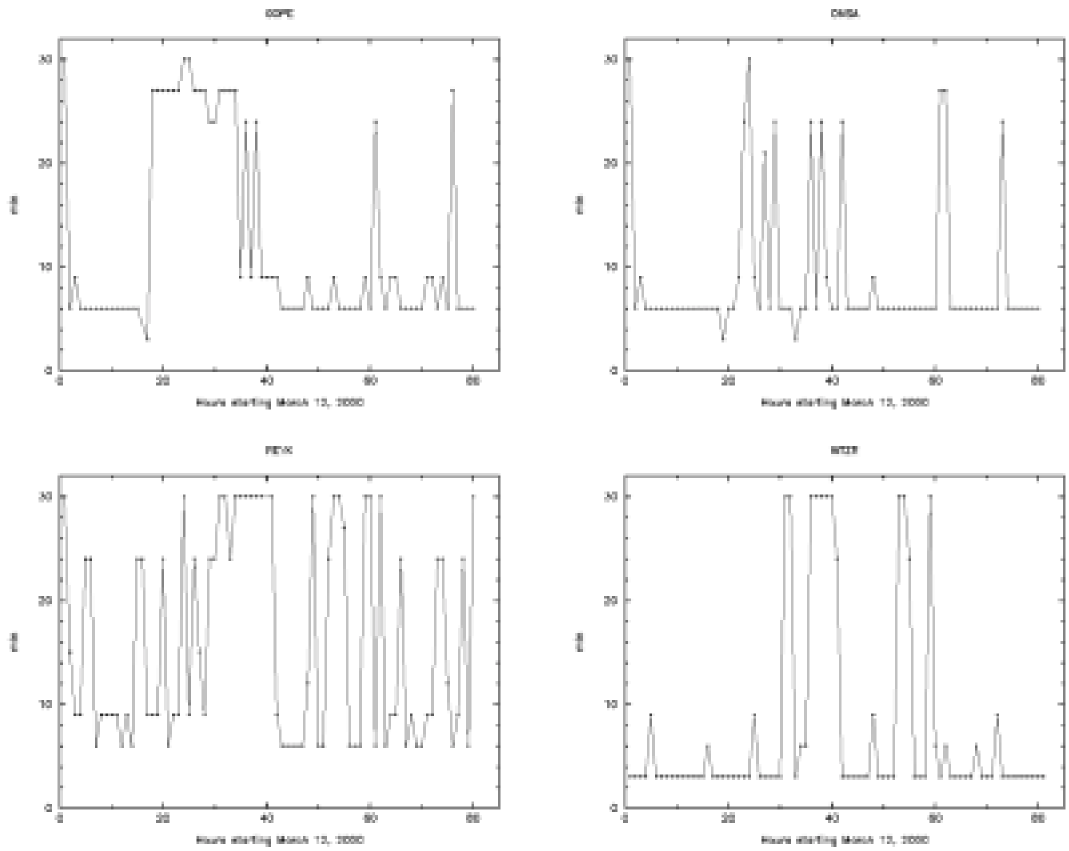


Figure 2: Latency of Hourly RINEX Files.

Figure 2 shows the latency of hourly RINEX observation files of 4 selected IGS stations. The latency is given in minutes for a period of 80 hours starting on March 12, 2000, where the 30 min latency has the meaning of greater or equal 30 min. There are quite small regular latencies of e.g. 3 min and 6 min for WTZR and ONSA, respectively. But for many file transfers these regular latencies couldn't be reached as may be seen for all stations. The period from hour 35 to hour 40 in Figure 2 show latencies of larger than 30 min for WTZR and REYK. Both stations are transferred from the same ODC and the connection to this ODC was lost during the period above. It demonstrates the capability of the hourly data transfer for monitoring and analyzing the internet connection.

User Activity and Future Plans

The total number of stations (i.e. of receivers) of BKG's data center has increased to 130. Approximately 100 distinct users contact the data center and perform more than 10,000 file transfers every day. During 2000 BKG's internet connection will be upgraded to 2 Mbit/s. In order to make the structure of the data center more transparent to the users the generation of new html-pages is in preparation.