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# CDDIS 2002 Global Data Center Report

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## 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 2002 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, Noll, 1999, and Noll, 2001).

## System Description

The CDDIS archive of IGS data and products are accessible worldwide through anonymous ftp. 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.

*Computer Architecture*

The CDDIS is operational on a dedicated UNIX server. All GPS data and product files are archived in a single filesystem, accessible through anonymous ftp, and are stored in UNIX compressed format. At present, nearly 400 Gbytes of on-line disk space is devoted to the storage of daily GPS tracking data and products. GPS data since 1995 and IGS products since 1992 are available on-line.

## 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. Nearly forty of these IGS data centers make data available to the CDDIS from selected receivers on a daily (and in some cases hourly and/or sub-hourly) basis. The CDDIS also accesses the archives of 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. Over 87K station days from 313 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.2002*. Table 1 below summarizes the types of GPS data archived at the CDDIS.

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. These metadata are utilized to generate various reports on data holdings and data latency.

The CDDIS daily GPS tracking archive consists of observation (in both RINEX and "compact" RINEX format), 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 2002, the CDDIS archived data on a daily basis from an average of 280 stations. One reason for the large increase in stations is that as of June 11, 2002, GPS+GLONASS receiver data were archived in what was previously a GPS-only directory structure in the CDDIS archive. This new archive structure for the IGS regional and global data centers was mandated by the Central Bureau under recommendation from the IGLOS-PP. In 2002, the CDDIS GPS archive of daily GPS data files totaled over 31 Gbytes in volume (compact RINEX format only); this figure represents data from over 87K observation days. Of the 280 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.

At this time, the CDDIS on-line archive of daily GPS data contains data from January 1995 through the present. Prior to mid-2002, 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. However, in recent weeks, the GPS data are typically only available in compact RINEX format due to severe disk space constraints on host *cddisa.gsfc.nasa.gov*.

The majority of the data delivered to and archived in the CDDIS during 2002 was available to the user community within six hours after the observation day. Nearly sixty percent of the data from the global sites delivered to the CDDIS were available within three hours of the end of the observation day.

Hourly GPS Data Files

Since 2000, many IGS operational/regional data centers transmit hourly data files to the global data centers. Within minutes of receipt, the files are archived to separate subdirectories (*/gps/nrtdata*) by day and hour 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 2002, approximately sixty percent of these hourly data files were available to the user community within twenty minutes of the end of the hour. Over 160 sites (both GPS and GLONASS+GPS) transmitted hourly data files to the global data centers in 2002.

The site-specific ephemeris data files for each hour are decompressed and then appended to a single file that contains the orbit information for all GPS satellites for the day up through that hour. This merged ephemeris data file, named *hourddd0.yyn.Z* (where *ddd* is the day of year and *yy* is the year), is then copied to the daily subdirectory in the hourly filesystem (*/gps/nrtdata/yyddd*). At the end of the day, this file is copied to the corresponding subdirectory under the daily filesystem (*/gps/gpsdata/yyddd/yyn*) and renamed to *brdcdd0yyn.Z*. Users can thus download this single daily file instead of all broadcast ephemeris files from the individual stations.

<u>High-Rate GPS Data Files</u>

In May of 2001, the CDDIS began the archive of high-rate (typically one-second) GPS data in support of the IGS Pilot Project for Low Earth Orbiting (LEO) Missions. The data are made available to the CDDIS from four principal sources, JPL, GFZ, NRCan, and ESA as well as other operations centers (e.g., ASI, GOPE, UNB, etc.). The RINEX data are archived in files containing fifteen minutes of data using the filenaming convention *ssssdddhmi.yyt.Z* where *ssss* is the monument name, *ddd* is the day of year, *h* is the hour (a-z), *mi* is the minute (00, 15, 30, 45), *yy* is the year, and *t* is the file type (d, m, n). On average during 2002, the CDDIS archived high-rate data from 52 sites totaling approximately 250 Mbytes per day, and a total of 90 Gbytes for the year.

*Meteorological Data*

The CDDIS currently receives meteorological data from over fifty sites. 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.

*LEO GPS Data*

The CDDIS proposed to serve as a data center supporting the IGS Pilot Project for Low Earth Orbiting (LEO) Missions in 2000. In 2002, the CDDIS established an archive of space-borne GPS receiver data from selected missions (e.g., SAC-C and CHAMP); future missions supported will include Jason-1, GRACE, and ICESat.

*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 as well as 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. The CDDIS currently provides on-line access through anonymous ftp or the web 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. All RNAAC solution files are also stored in the weekly IGS product subdirectories. The official IGS combined weekly SINEX solutions and cumulative combined SINEX solutions generated by the IGS Reference Frame Coordinator are also available in the weekly IGS product subdirectories.

Both the rapid (designated IGR) and the predicted orbit, clock and ERP (designated IGP) combined products generated by the IGS Analysis Coordinator continued to be available through 2002. Furthermore, a new product, the IGS ultra-rapid combination (designated IGU) were made available twice daily. The IGS global data centers, including the CDDIS, download the rapid, predicted, and ultra-rapid products from the Analysis Coordinator and made them available in a timely fashion to ensure their usefulness to the user community.

The CDDIS also continued to archive combined troposphere estimates in directories by GPS week (i.e., */gps/products/wwww/trop,* where *wwww* is the GPS week number). Global ionosphere maps of total electron content (TEC) from the IONEX AACs were also archived in subdirectories by day of year (i.e., */gps/products/ionex/yyyy* where *yyyy* is the four-digit year). The CDDIS archived products generated by the individual analysis centers contributing to the IGS LEO Pilot Project (LEO-PP). Thirteen AACs have thus far submitted products for review by the LEO-PP analysis coordinator; these files are archived in subdirectories by AAC within filesystem */gps/products/leopp*.

*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. The daily status files are available through the web 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 (both daily and high-rate) 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 web at URL *ftp://cddisa.gsfc.nasa.gov/pub/reports/gpsdata* and *ftp://cddisa.gsfc.nasa.gov/pub/reports/igshrdata*. The CDDIS also maintains an archive of and indices to IGS Mail, Report, Network, and other IGS-related messages.

**GLONASS Data and Products**

During 2002, the CDDIS continued as a global data center for GLONASS data and products in support of the IGLOS-PP Call for Participation issued in 2000. The CDDIS archived GLONASS data from over fifty sites. As of June 2002, data from GPS+GLONASS receivers are archived within the GPS directory structure to improve data retrieval for the user community; data from GLONASS-only receivers continue to be archived in the */igex/data* filesystem. GLONASS products from three analysis centers (BKG, ESA, and MCC) as well as the Analysis Coordinator (at the Technical University of Vienna) were also made available to the public. GLONASS products are accessible via anonymous ftp in the filesystem */igex/products*.

**System Usage**

Figures 1 through 3 summarize the monthly usage of the CDDIS for the retrieval of GPS and GLONASS data and products for 2002. Figure 1 illustrates the amount of GPS and GLONASS data retrieved by the user community during 2002, categorized by satellite (GPS or GLONASS) and type (daily, hourly, high-rate). Nearly forty million files were transferred in 2002, with an average of over three million files per month. Furthermore, nearly 170K GPS product files were retrieved each month from the CDDIS; less than 1,000 GLONASS product files were retrieved each month. Figures 2 and 3 illustrate the profile of users accessing the CDDIS IGS archive during 2002. Most accesses were through network gateways, which did not yield sufficient information about the user. Figure 3 displays the usage information by geographic region; the majority of CDDIS users are from hosts in North America.

**Publications**

The CDDIS staff attended several conferences during 2002 and presented papers on or conducted demos of their activities within the IGS, including:

- Noll, Carey E. "2001 IGS Data Center Reports", 2001 IGS Annual Report (submitted in 2002)
- Noll, Carey E. "CDDIS 2001 Global Data Center Report", 2001 IGS Technical Report (submitted in 2002)
- Noll, Carey E., "The CDDIS Data Center – NASA's Space Geodesy Data Archive", EOS Transactions American Geophysical Union, May 2002.

- Noll, Carey E. "Current Status of IGS Data Centers" IGS Network, Data, and Analysis Center Workshop, Ottawa, Canada, April 2002, in press.
- Noll, Carey E. and Maurice Dube. "The IGS Global Data Center at the CDDIS – an Update" IGS Network, Data, and Analysis Center Workshop, Ottawa, Canada, April 2002, in press.

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

### Future Plans

The AlphaServer 4000 computer supporting the CDDIS has been operational for over five years. In 2003, a Linux-based system (and backup server) will be procured. Over four terabytes of RAID storage and a dedicated tape backup system will also be purchased for this new computer facility. Migration to the Linux operating system will begin in late 2003.

### Contact Information

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


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|---|---|---|
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### Acknowledgments

The author would once again like to thank the Raytheon Information Technology and Scientific Services (RITSS) contractor staff, Dr. Maurice Dube, Ms. Ruth Kennard, and Ms. Laurie Batchelor. The recognition and success of the CDDIS in many international programs is significantly helped by their continued dedicated, consistent, professional, and timely support of its daily operations.

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**Table 1: GPS Data Summary**

| Data Type | Sample Rate | Avg. No. Sites/Day | Avg. Volume/Day | Total Volume/Year | Data Format | Available On-line |
|---|---|---|---|---|---|---|
| Daily GPS | 30 sec. | 260 (1) | 90 Mb | 31 Gb | RINEX and compact RINEX (2) | Since 1995 (3) |
| Hourly GPS | 30 sec. | 160 (1) | 70 Mb | 350 Mb | Compact RINEX | Last 5 days |
| High-rate GPS | 1 sec. | 50 | 250 Mb | 90 Gb | Compact RINEX | Since May 2001 |
| LEO GPS | 10 sec. | 2 (4) | 2 Mb | 750 Gb | Compact RINEX | Since 2002 |

Notes: (1) Includes data from GPS+GLONASS sites
(2) Amount of non-compact RINEX data available on-line dependent upon available disk space
(3) Some older data migrated to temporary disk areas until more disk space available; data since 1992 archived in CDDIS
(4) Indicates number of LEO satellites

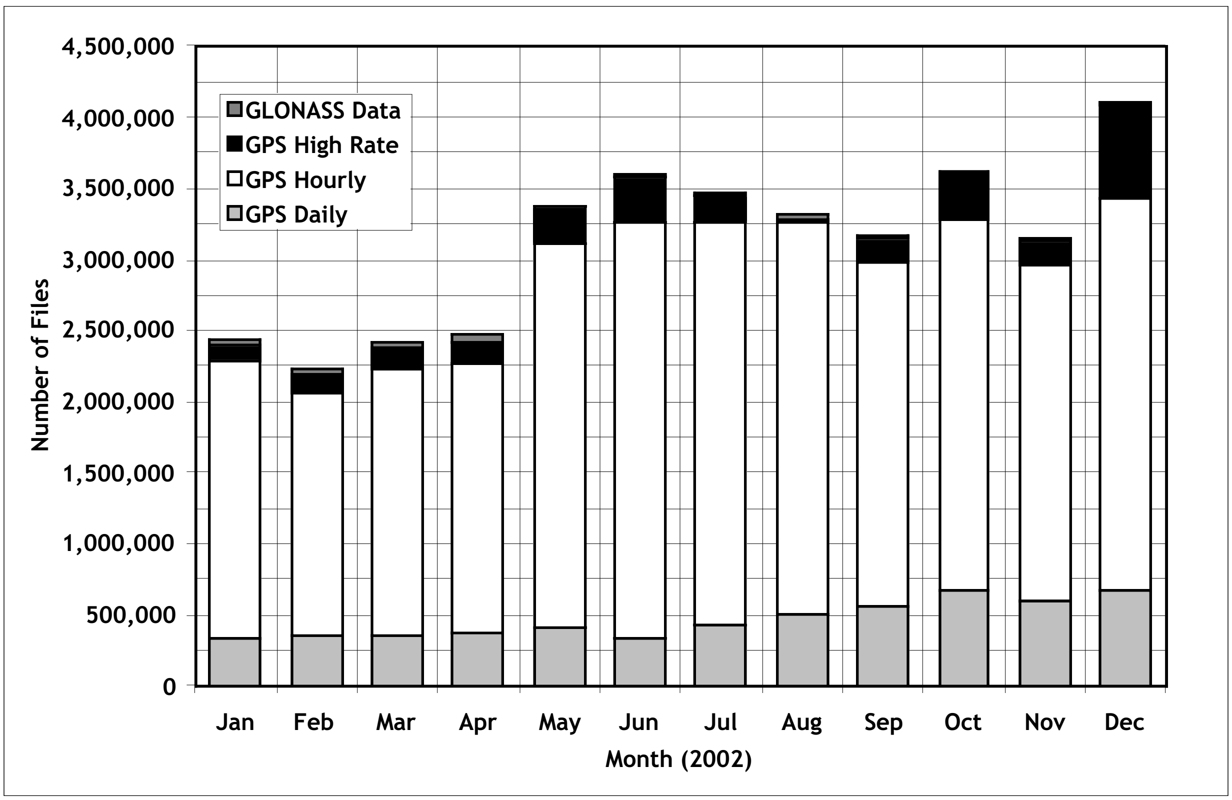


**Figure 1: Number of GPS data files transferred from the CDDIS in 2002**

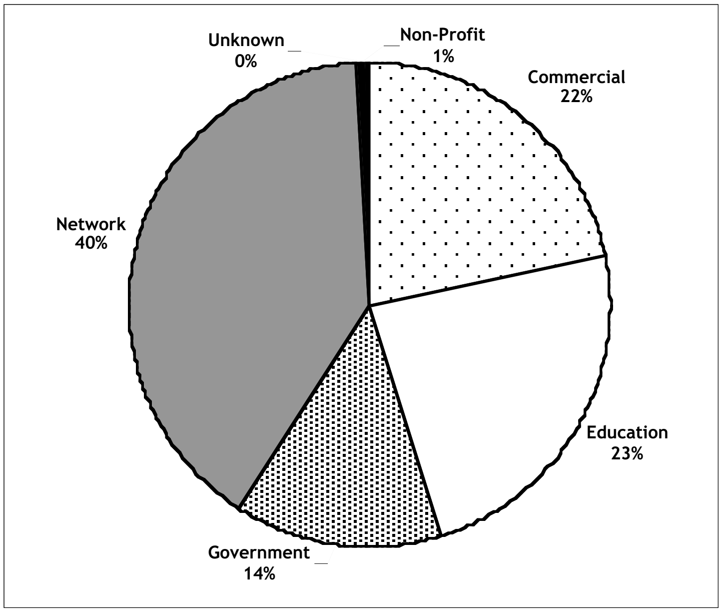


**Figure 2: Distribution of IGS users of the CDDIS in 2002**

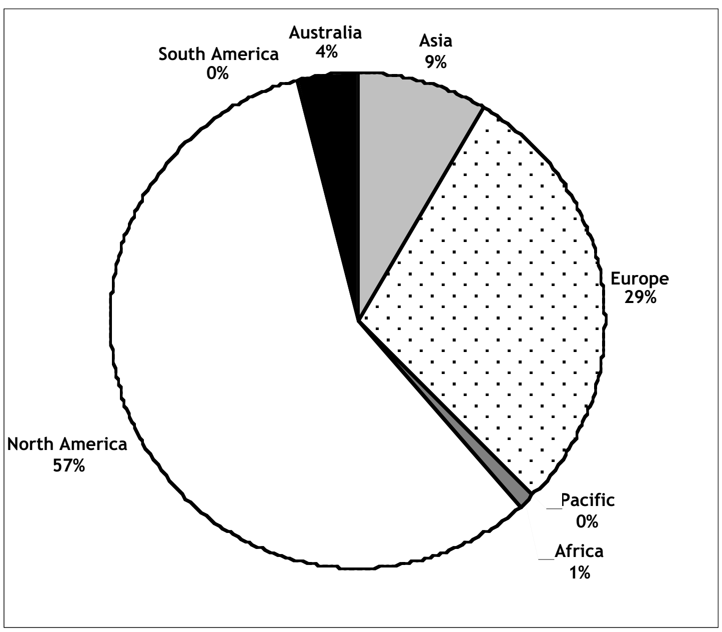


**Figure 3: Geographic distribution of IGS users of the CDDIS in 2002**

# IGN 2002 Global Data Center Report

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## Introduction

The *Institut Géographique National* (IGN) has been involved in IGS since its beginning through the *Laboratoire de Recherche en Géodésie* (LAREG). For a long time, a single person has administrated IGN Global Data Center (GDC): Loïc DANIEL. Since May 1st 2001, Edouard GAULUE has been appointed to assist him in his mission as IGS services around data kept growing (new stations, products and data transfer strategies, web developments). Here is a summary of IGN GDC activities from September 2001 to December 2002.

## Service Overview

As a global data center, the IGN server gets observation files from regional and operational data centers and product files from analysis centers. All collected files (since 1997) are accessible to the user community through anonymous FTP. Moreover IGN also mirrors the central bureau directory for administrative reasons.

## History

### *Hardware*

IGN GDC has been working on a VAX/VMS machine until 1997. Many of the files obtained during this period had been archived on magneto-optical disks (75 Gb) that we expect to restore soon. In 1997, this server has been changed to an HP D230 machine running HP-UX. At the same time, the service moved to the *Ecole Nationale des Sciences Géographiques* (ENSG) equipped with a 2 Mb/s bandwidth Internet link. Five years later, due to the addition of external disks, a CD jukebox and a saving-robot, this machine has grown from half a cubic meter to 3. It has also become a little obsolete. Two machines have been ordered at the end of 2001 and should be delivered in 2003. In February 2002, the bandwidth of the ENSG has raised to 10 Mb/s.

### *Online service*

In the middle of 2001, the FTP server has been refurbished taking into account a new stations (and name changes) and new products. In 2002, a new web site has been developed but it had to remain on a test server because of the delay in the delivery of the new servers.

Due to everyday service, our first 150 CDs jukebox accessible online is today more than half-full (about 90 Gb). In addition to the jukebox, 25 Gb are reserved for data storage on the server hard disks. Files online on hard disks represent about 200 days. After this time a CD is burned and stored in the jukebox from which data are still accessible online.

*Service availability in 2002*

In 2002, the IGN GDC FTP service has not experienced an interruption exceeding 3 days. Most of the interruptions were due to (i) our Internet provider during the bandwidth change, or (ii) the lack of space on the server. In fact, the principal difficulty we had to deal with in 2002 came from the continuous increasing delay concerning our new machines arrival.

**How Does IGN GDC Work?**

A diagram presenting the operating mechanism of the IGN IGS global data center server is given in Figure 1.

IGN GDC stores information about partner FTP sites in a MySQL database. In the meantime, using an automatic procedure on sitelog it also gets information concerning station sites. A third table links stations and centers according to the different information sources IGS provide and IGN GDC policy. This table gathers the station observations files (as well as navigation, meteorological and quality checks) for each center. For products, filenames are directly store with partner FTP sites information. Every night, based on these information, a "mirror configuration file" is generated for each partner data center.

This file is then processed by the so-called "mirror" program. This program questions the distant site and compares it to the local one before starting transfers. Files arrive directly in the public area. This procedure is the same for data centers which "put" data to IGN GDC: the distant site in this case is their local deposal directory at IGN. More information concerning the mirror program is displayed on Figure 2.

All mirroring tasks are scheduled using the CRON system. Moreover tasks are placed in specified queues depending of their aim to avoid download conflicts and control server overload.

Once in public area, automatic files scanning is done either for IGS community through check import or to feed our database. The "file" table is then used for statistical analysis, building data and products holding reports and web requests.

**IGN Policy**

*Near Real Time (NRT) data*

As NRT data doesn't need to be archived, IGN GDC tries to get data from a maximum number of stations (about 100 in 2002).

*Observation files*

Due to the server limitation, we prefer not to deal with more than 150 stations. A new policy will be defined when new machines will be in place. In 2002, priority is first given to regional stations (coming mainly from IFAG, CNES and ORSTOM) and then to global station. A few other stations have been dealt on request.

From May 2001 to the end of 2002, the number of processed stations rose from 70 to 150.

*Product files*

In 2002, IGN GDC tried to deal with more product files, taking into account new ultra rapid products. Moreover ionospheric and tropospheric data are always accessible in special tropo and iono directory.

*GLONASS*

No GLONASS data has been processed since the end of 2001. It has been decided at the Ottawa workshop to improve IGEX services by gathering observations and products in the same directories than IGS. All the IGN GLONASS services will be refurbished and implemented in 2003.

*DORIS*

Since December 2002, IGN has become a global DORIS data center. This event implied a transfer of the service to another server. Concerning observation, IGN DORIS GDC is just a mirror of the CDDIS archive. Concerning products, everything as been done to propose IGS-like services.

**IGN GDC Usage in 2002**

*Incoming files*

Figure 3 displays the average delay for incoming daily observation files in 2002. We can point out that 2/3 of the files arrive in less than 3 hours and 3/4 in less than half a day.

Figure 4 displays the same information for NRT data. One can notice that data arrival at IGN is in fact largely driven by the scheduled time in the CRON. The first scan of remote data centers begins approximately 10 minutes after the beginning of each hour and lasts 10 minutes. The next scan (for "*retardataires*") starts 45 min past the hour. The last files of the day (x files) follow a particular schedule for administrative reason. That explains why download begins 30 minutes after the end of the day.

Figure 5 and 6 show mean delays for data or products download at IGN GDC according to their origin. The delays for incoming observation are rather short. The mean delay for IGS final products arrival at IGN was about 17 to 18 days in 2002.

*Outgoing files*

Figure 7 and 8 show general statistics on observation and data downloads from IGN server. On the observation graph, the three first months show an unusual download: someone was downloading identical observation files 64 times a day. Nevertheless we can remark a systematic trend during spring and summer months certainly due to the global activity.

Figure 9 shows downloads and associated average transfer rates grouped by Internet domain. We can notice a particularly good connection to Luxembourg an Switzerland certainly due to our provider connection.

**Future Development**

In 2003, the IGN GDC activity will critically need its new computers to function properly. This would be the opportunity to completely rethink its procedures and use newer and better tools. Servers should be running under debian Linux distribution and should provide a MySQL 4.x database and a PHP-apache web server. Those machines will be shared with the permanent French geodetic GPS array. They should in term work in a mirroring scheme, one in Paris and the other one in Marne-La-Vallée with a heart-bit connection. Load balancing will have to be considered.

IGN GDC would also like to participate in real time transfer experiments. Contacts have been taken in Ottawa and at AGU to move towards this objective.

Last, IGN GDC will have its new web site online. Figure 10 displays a screenshot of what it could look like. Some modules are already operational but lots of work still has to be done until official opening. In relation to this topic, the IGN GDC team is interested to exchange on topics related to XML and particularly by the way to introduce this technology in IGS documentation.

**Contacts**

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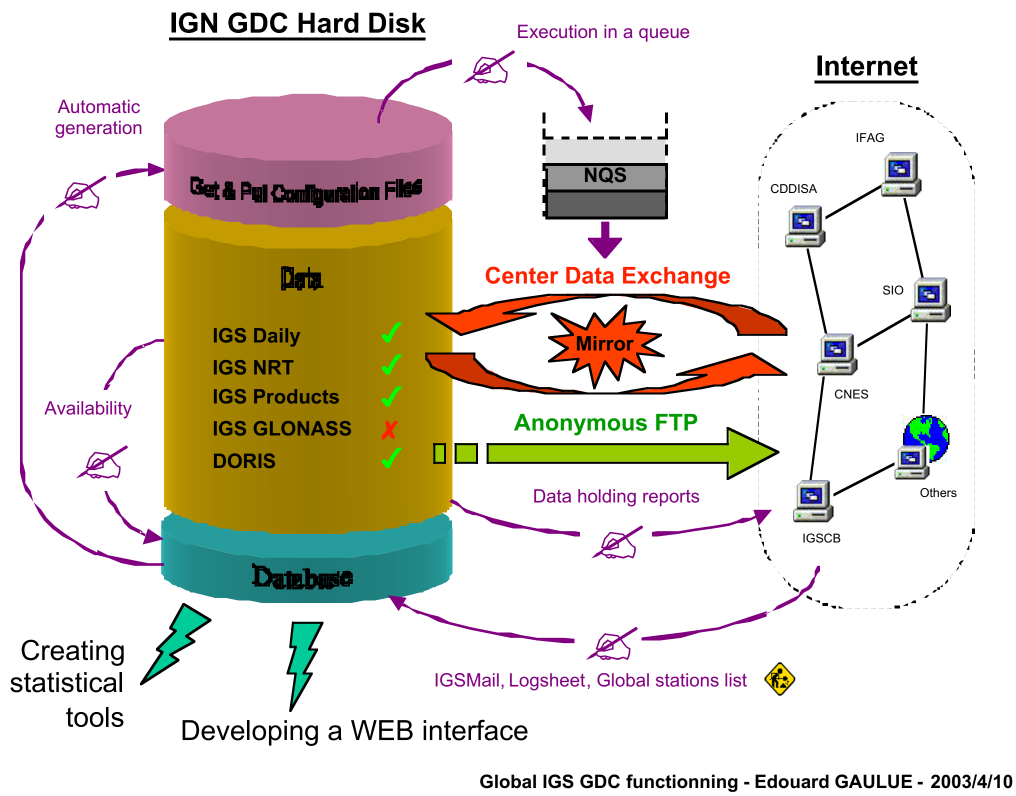



**Figure 1. Global IGS GDC Functioning**

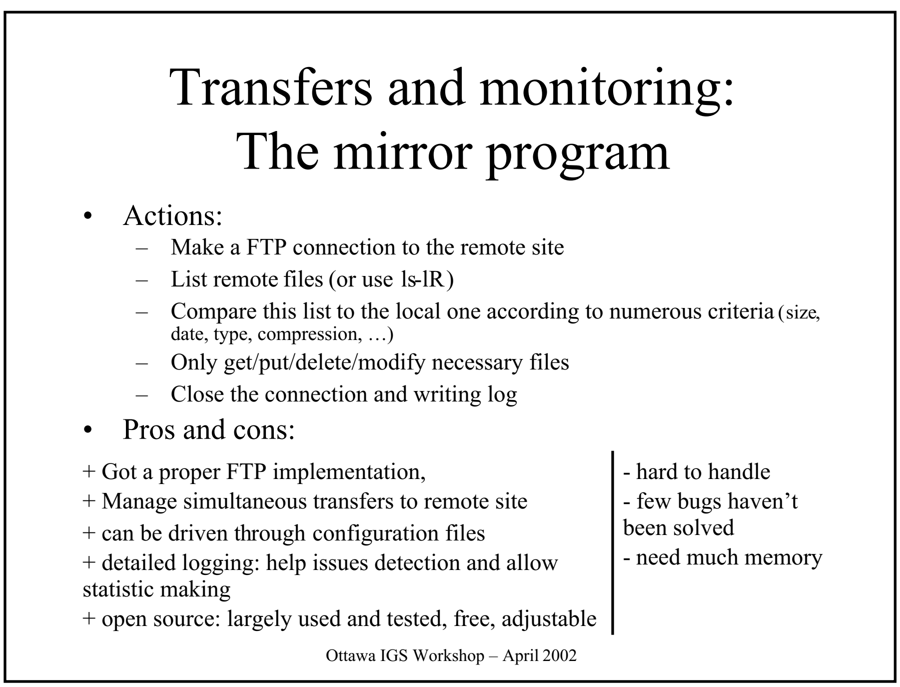



**Figure 2. Mirror Program**

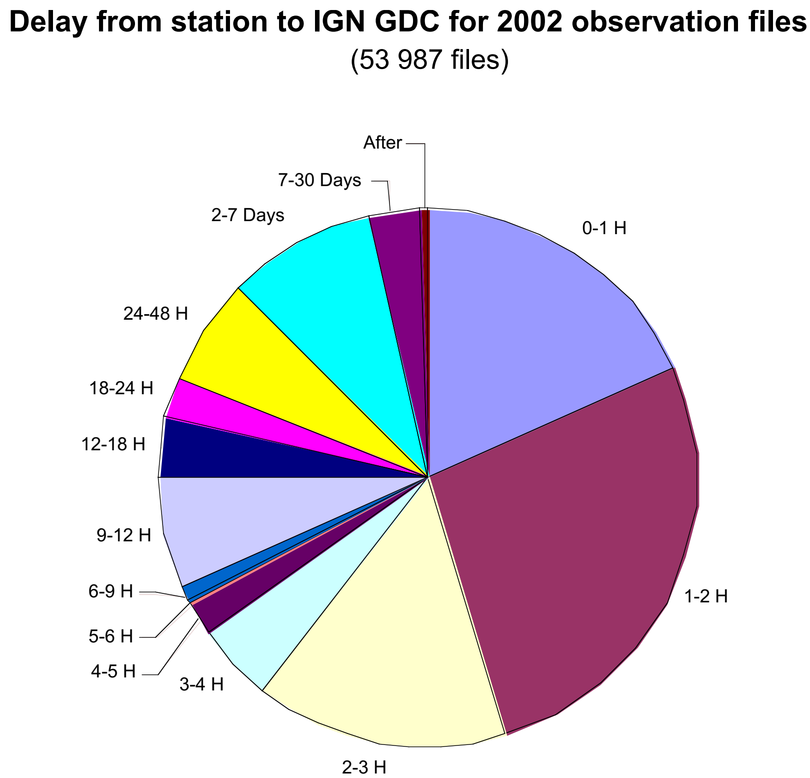



**Figure 3.**

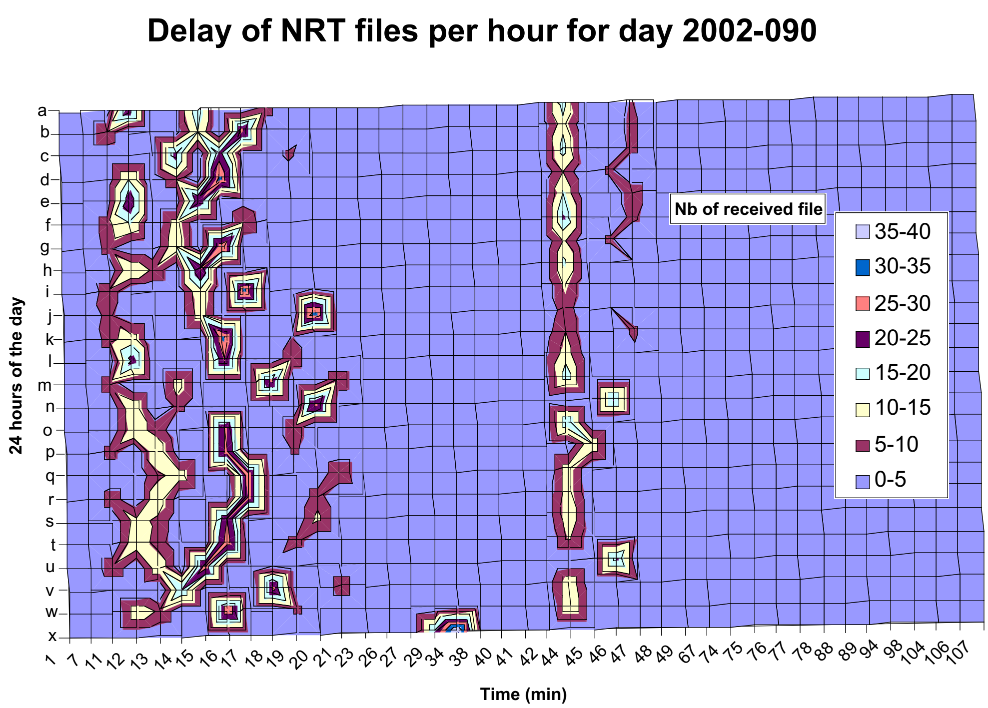
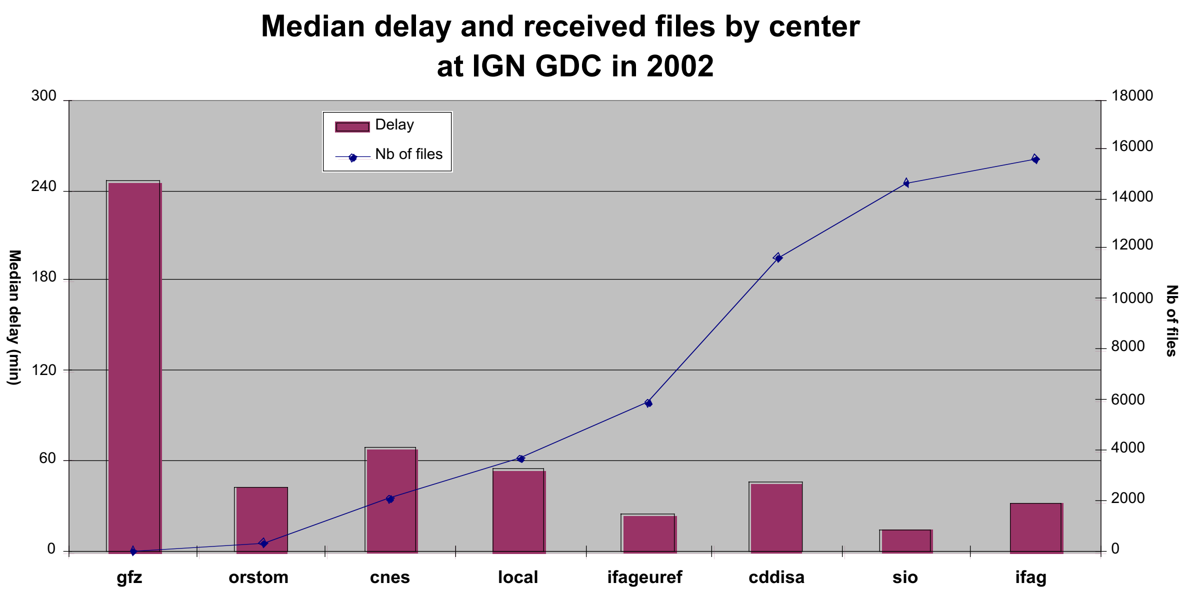



**Figure 4.**

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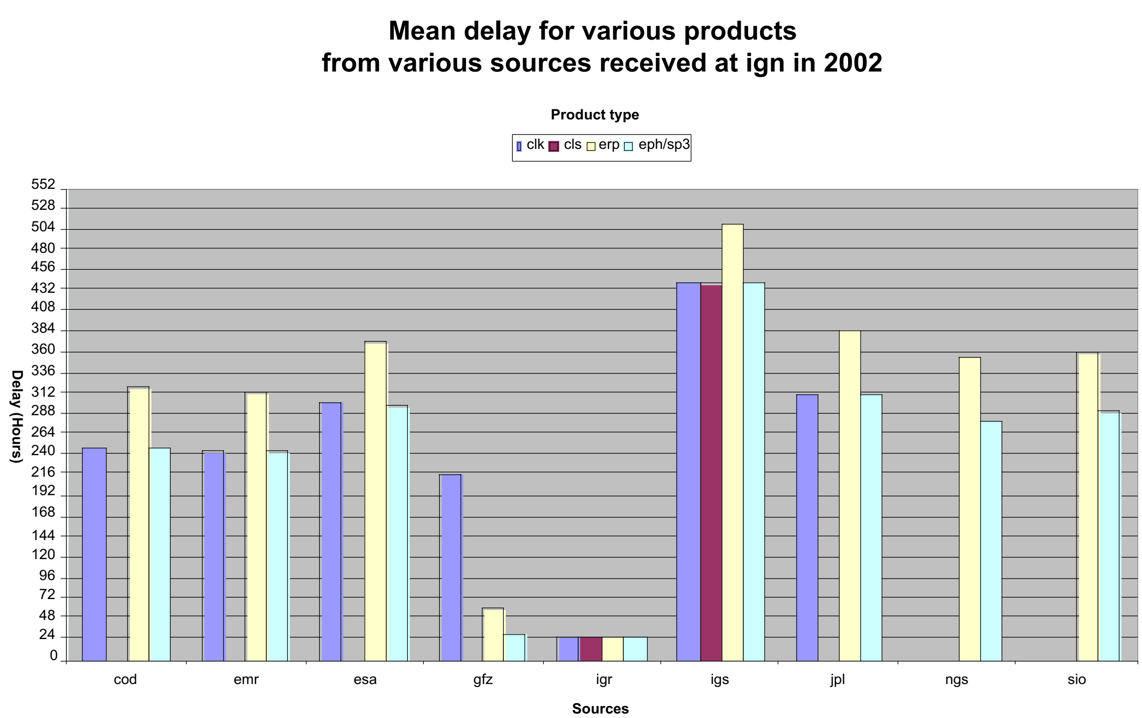


**Figure 6.**

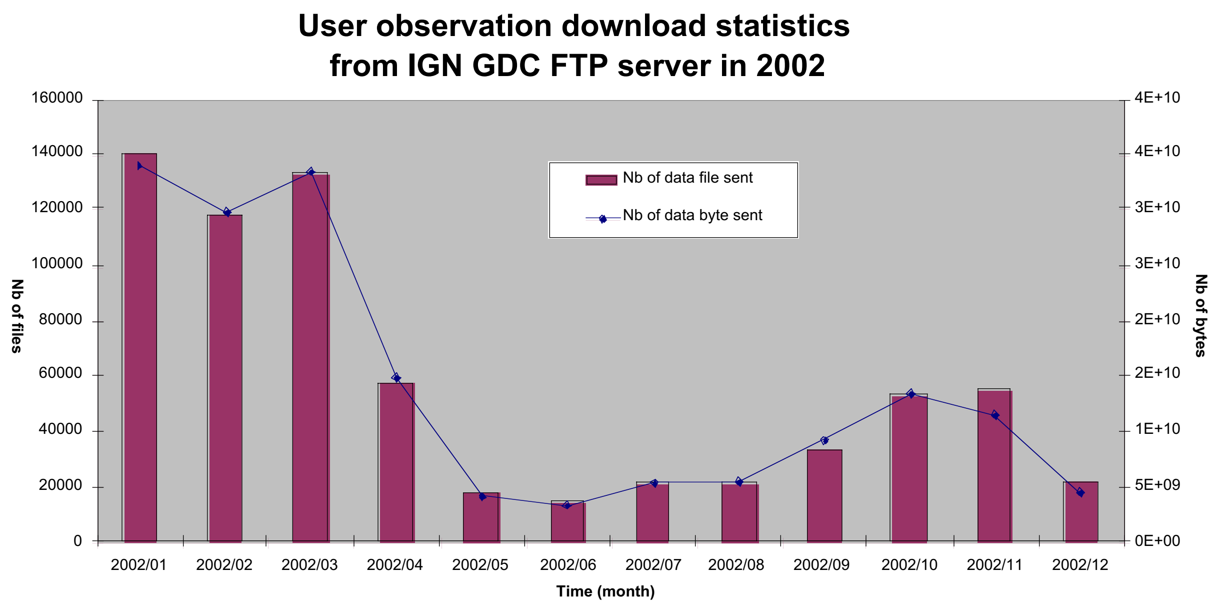


**Figure 7.**

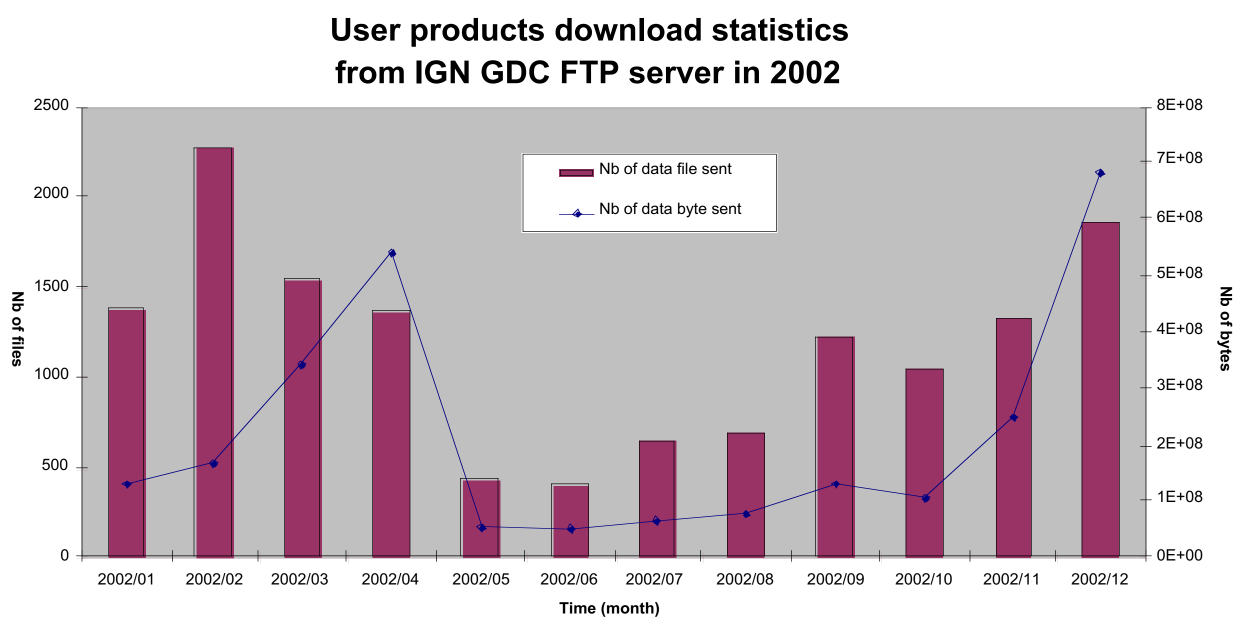


**Figure 8.**

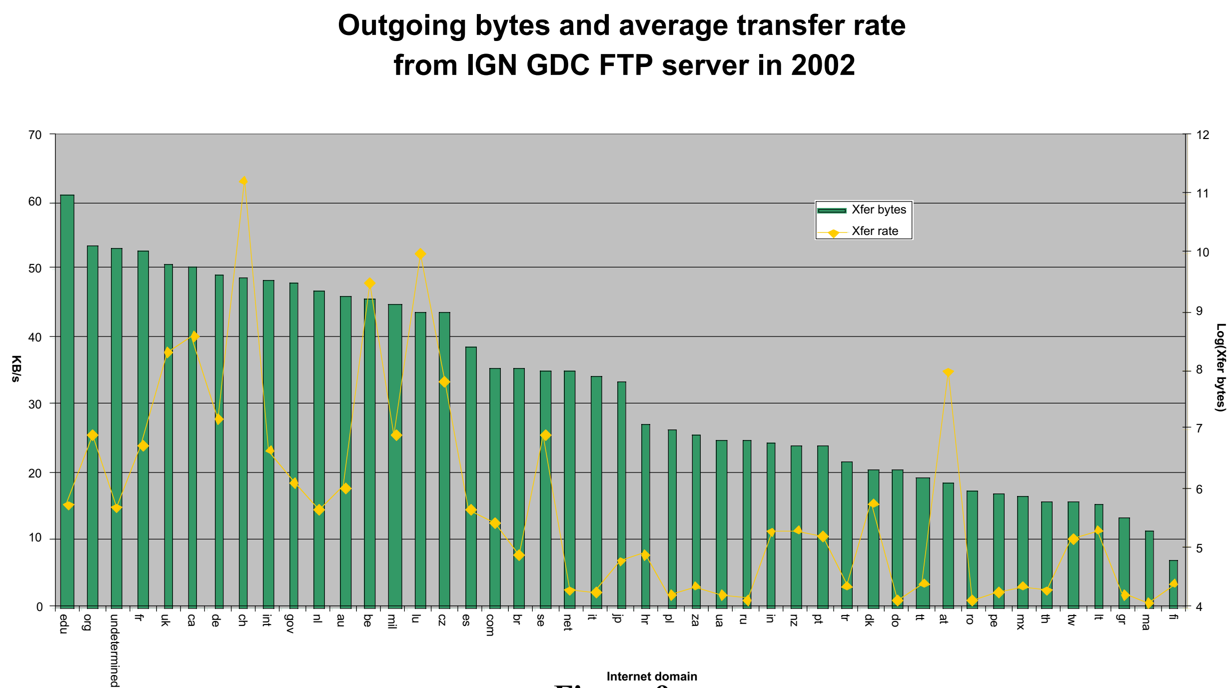


Figure 9.

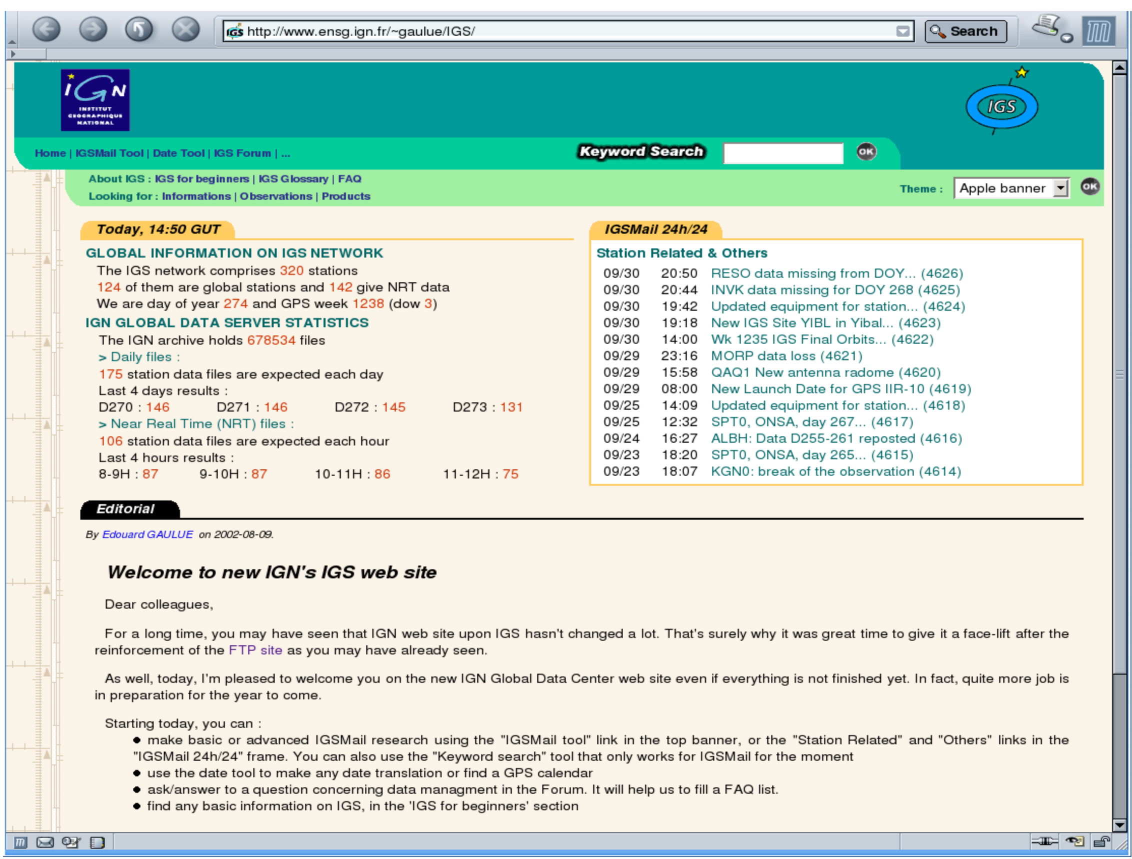


Figure 10.

# SOPAC 2002 IGS Global Data Center Report

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email: bgilmore@gpsmail.ucsd.edu; mscharber@gpsmail.ucsd.edu

## Summary

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 a Global Data Center and Global Analysis Center for the IGS since its inception in 1994. SOPAC is responsible for the collection, archival, analysis and publication of high-precision continuous GPS data to support the global GPS community. SOPAC's two primary functions, archival and analysis of GPS-related data and data products, serve the interests of the IGS in addition to a number of other complementary SOPAC activities, including: the Southern California Integrated GPS Network (SCIGN), the National Geodetic Survey, the California Spatial Reference Center (http://csrc.ucsd.edu), NOAA's Forecast Systems Laboratory (FSL), and UNAVCO, Inc.

Some of the most noteworthy SOPAC activities in 2002, of interest to the IGS, included:

- Increase in the number of continuous GPS stations archived on a daily basis to over 1100.
- Increase in the number, scope, and function of interactive user applications, with a strong emphasis on analytical utilities such as GPS timeseries modeling and "any epoch" station positions using precise models.
- Development of GPS Seamless Archive (GSAC) for UNAVCO.
- Increase in physical archive storage to over 4 TB, spread across a dozen hosts and several different types of filesystems.
- Addition of primary/secondary dual online copies of most historical data on SOPAC archive (logical mirrors).
- Addition of several new hosts for GPS data archival and analysis.
- Centralized management of parallel archiving routines by SOPAC's Archive Data Manager (ADM) as well as numerous efficiency and participatory ADM improvements including RINEX file quality-checking, GSAC support and fault tolerance

*Archive Content and Access*

The SOPAC public GPS archive currently contains nearly 5 TB of on-line data, of which over 3 TB are primary copies. Included in this collection are real-time, 1 Hz GPS data files (24 hour maximum latency), near real-time GPS data files (from minute-level latency), daily GPS RINEX files, related GPS analysis products, GPS site information logs, software, and an assortment of other data files related to the use of GPS data.

The comprehensive age range of files in this collection stretches from 1990 (and sometimes earlier) to one hour ago, all of which are immediately available to the public through anonymous ftp (ftp://garner.ucsd.edu), as well as http (http://garner.ucsd.edu/).

Though the bulk of SOPAC's data collection and archiving activities involves recent data, occasionally older data and/or products are collected or generated. In these instances the files are added to the SOPAC archive as soon as possible, and are subject to the same open data policy as all other data files at SOPAC. This policy includes all data served via ftp or http from the above-mentioned servers, includes no restrictions on data acquisition and is intended to provide public users with the easiest means of collecting data on both a regular and irregular basis. Other than making appropriate acknowledgements[1] for data acquired from SOPAC there are no access restrictions on any data from the SOPAC archive.

*GPS Observation Data Files*

On a daily basis SOPAC is now archiving RINEX data files for over 1100 continuous GPS stations from around the world (see Figure 1), including the global IGS network (part of SOPAC's role as Global Data Center for the IGS). This number has steadily increased over the past several years, and most likely will continue to increase in the near future. A significant portion of SOPAC's public archive is dedicated to the storage and provision of data files associated with the Southern California Integrated GPS Network (http://www.scign.org); SOPAC is the primary data archive for the SCIGN network, a network comprised of over 250 continuous GPS stations spread throughout Southern California and Baja California, Mexico.

RINEX data files are divided into three primary directories on ftp://garner.ucsd.edu, /pub/rinex (observation), /pub/nav (navigation) and /pub/met (meteorological). Raw GPS data files are located under /pub/raw (daily and sub-daily sessions), as well as /pub/highrate/cache/raw (realtime raw data). For a complete list of data and data products available from the SOPAC public archive see http://garner.ucsd.edu/.

[1]Wherever applicable SOPAC strongly suggests acknowledging the source of data or products acquired from SOPAC. In particular data associated with the Southern California Integrated GPS Network (SCIGN), with UNAVCO, or the IGS, shall require acknowledgement of the variety listed at http://sopac.ucsd.edu/dataArchive/dataPolicies.html.

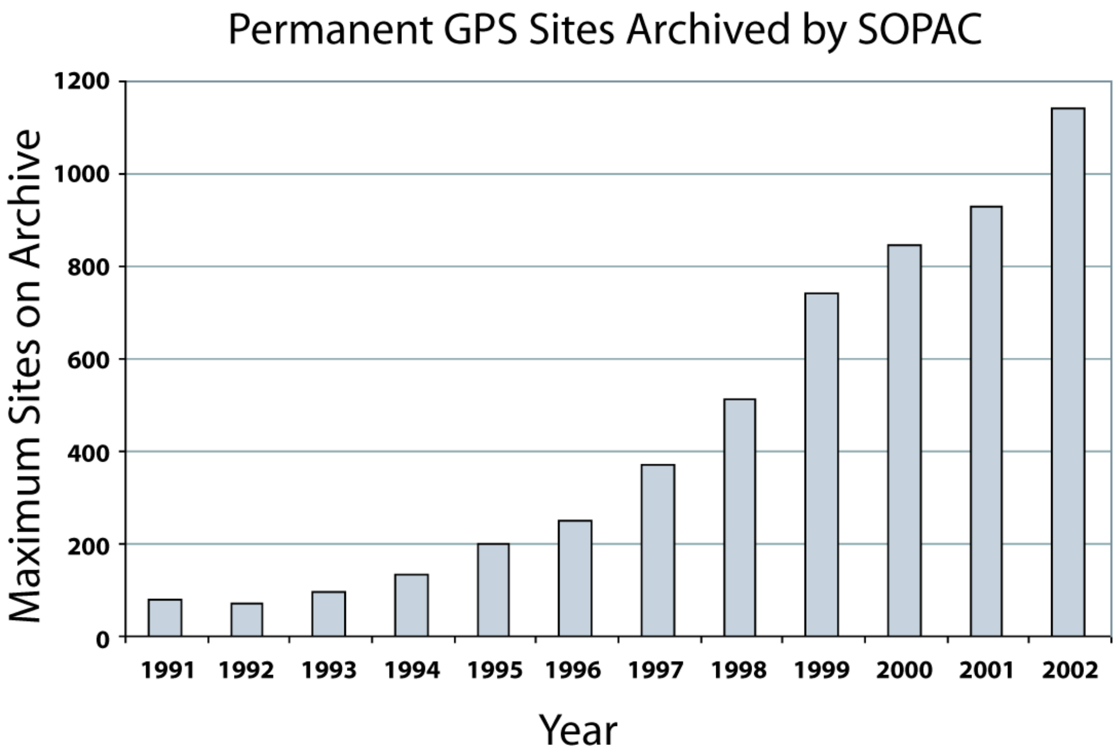



**Figure 1.** In 2002 the number of continuous GPS sites for which SOPAC archived data increased to nearly 1200.

*GPS Analysis Products*

In addition to RINEX and raw GPS data files, GPS products from all IGS analysis centers, including SOPAC (SIO), are available from SOPAC's public archive. 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 orbits 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.

Raw site time series generated from SOPAC's daily and weekly GAMIT/GLOBK processing are archived. Modeled time series from SOPAC's refined model are also available. Outliers and model site parameters, such as site offsets, are included. All time series products are available for download as tar files.

Please refer to our analysis center report in this volume for more information.

## Archive Usage

In 2002 the total number of FTP transfers (from the SOPAC public archive) by both public and private users, locally and from around the world (Figure 2) more than doubled from 2001, approaching nearly 16 million in all (~ 7 million in 2001). Increasing slightly from 2001, the total number of unique hostnames/clients accessing the SOPAC archive via ftp topped 8000 (Figure 3). Overall, the vast majority of files transferred to these 8000 client machines were RINEX Observation, Navigation and Meteorological files - 14 million in all (Figure 4).

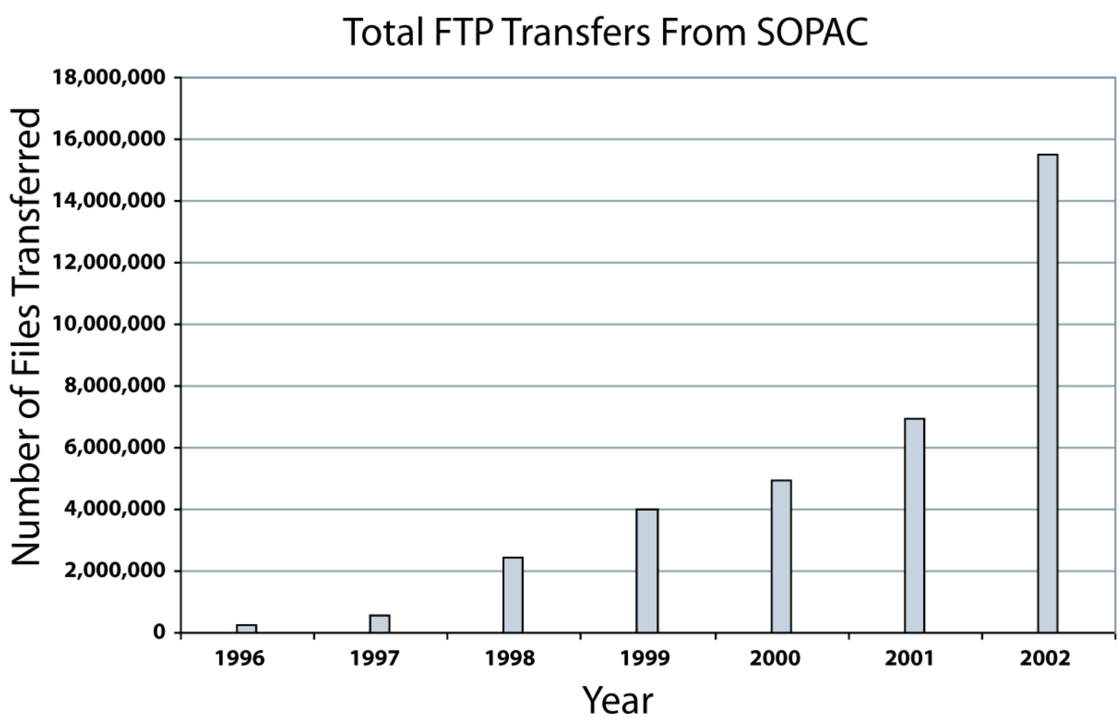



**Figure 2.** Number of files transferred from SOPAC via ftp://garner.ucsd.edu between 1996 and 2002.

SOPAC's user constituency in 2002 was comprised in large part of U.S. educational institutions (.edu domains) and U.S. government institutions (.gov domains). The .gov domains accounted for the highest number of transfers (Figure 5), followed closely by machines without identifiable hostnames (e.g. only IP addresses), the Swiss domain (.cz), U.S. education domain (.edu) and the German domain (.de). As far as total number of gigabytes transferred (Figure 6), U.S. education domains topped the list, followed by .gov, unidentifiable hosts, the French domain (.fr) and machines in Italy (.it).

As the number of continuous GPS sites archived by SOPAC continues to increase each year, so does the amount of space needed to serve this data and the need for more efficient archiving procedures. Maintaining its public archive has become one of the most important functions for

SOPAC over the years, as the demand for data continues to increase rapidly - in an ever-decreasing timeframe (latency). As such SOPAC has been dedicated to improving all aspects of its archive for the GPS community.

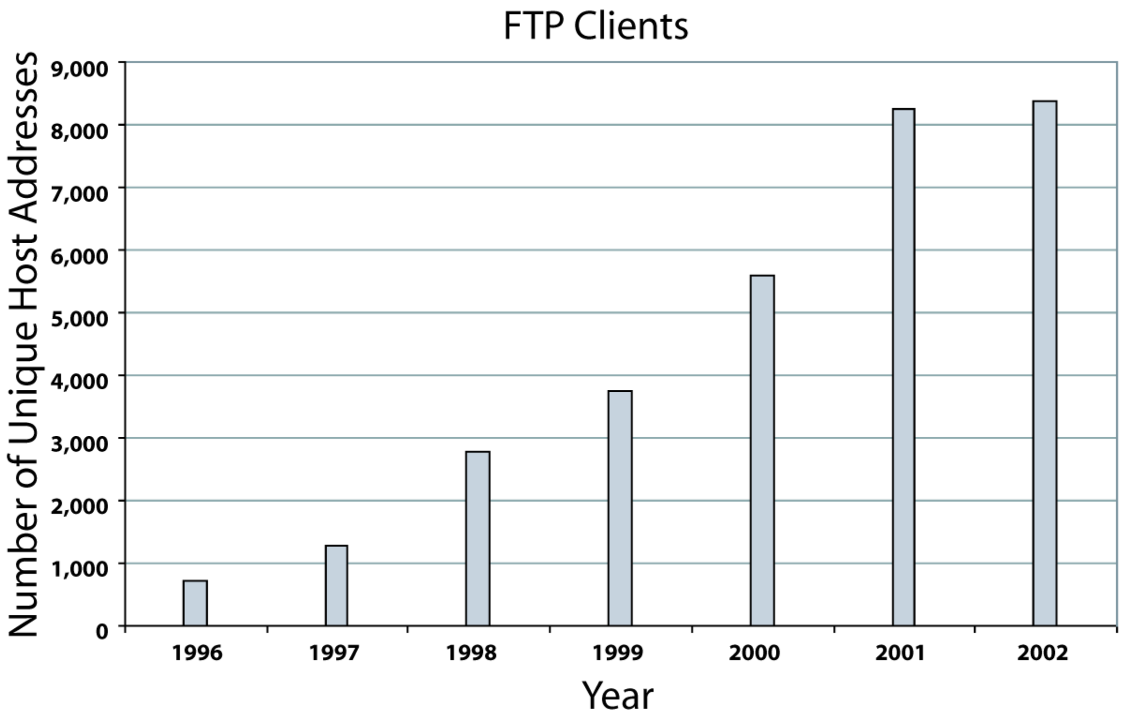



**Figure 3.** Number of unique clients using ftp to transfer data from SOPAC in the years 1996 through 2002. In the absence of user registration, unique hostnames are used as an indicator of the number of individuals acquiring data from SOPAC.

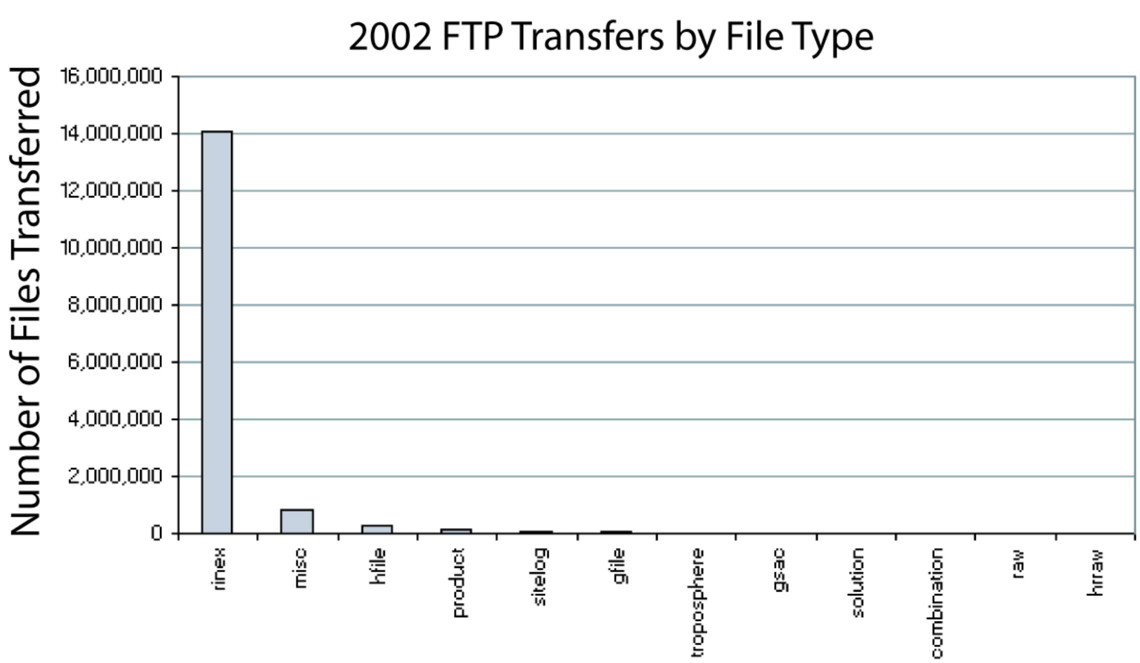



**Figure 4.** In 2002, as in previous years, RINEX files comprise the vast majority of files transferred by users from SOPAC's public archive.

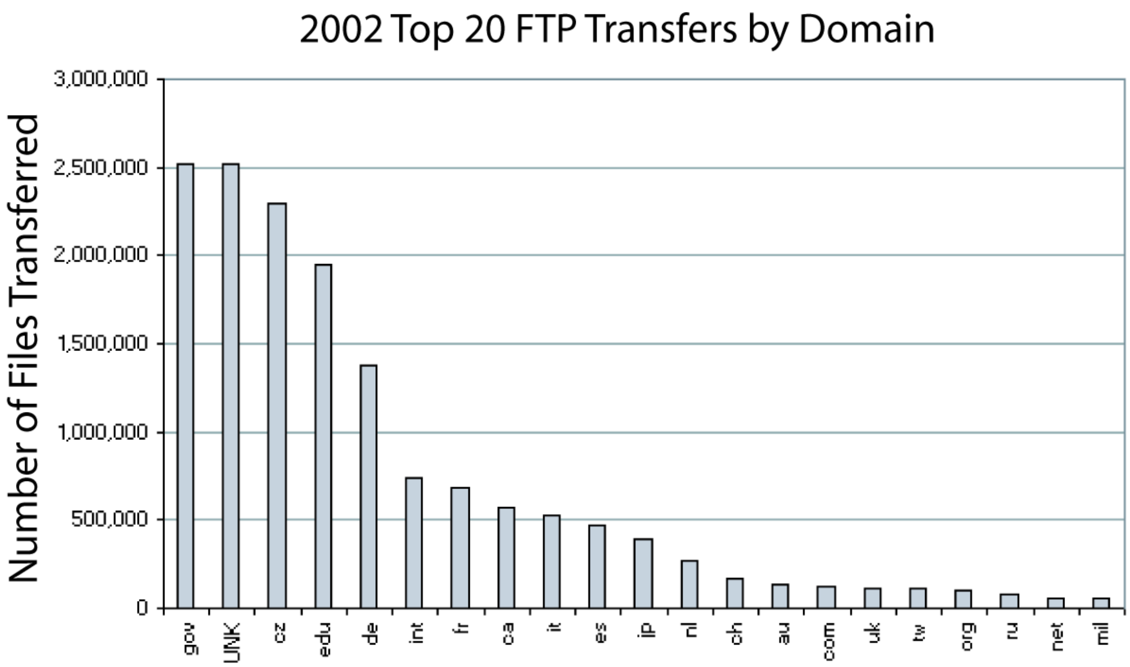



**Figure 5.** In 2002 .gov machines (acknowledging through DNS lookup) comprised the domain with the largest number of ftp transfers from SOPAC.

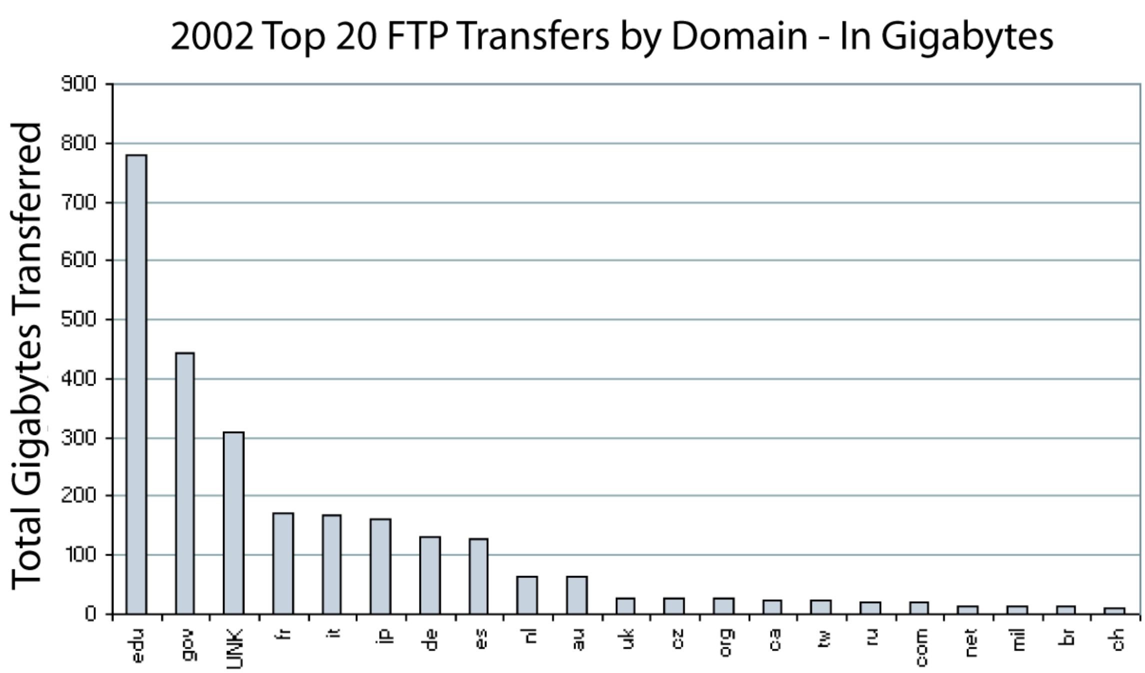



**Figure 6.** .U.S. educational domains (.edu) comprised, cumulatively, the most significant amount of gigabytes transferred from SOPAC via ftp.

## Systems Architecture

SOPAC owns and maintains over 50 different hosts spread across three different buildings on the campus of the Scripps Institution of Oceanography. This collection of systems perform a variety of functions, ranging from basic mail servers, to a Beowolf cluster, user workstations, centralized development library servers, primary public access machines hosting ftp and/or http services, database servers and two dozen GPS data archiving and analysis machines.

SOPAC's public access systems consist of a three Dell PowerEdge servers and a Sun E220R. The Sun server (garner.ucsd.edu) hosts the primary ftp and http interface for the SOPAC public archive. The public hosts, http://sopac.ucsd.edu and http://gsac.ucsd.edu, (as of January 2003) were hosted by two different Dell PowerEdge servers. A third Dell, geopub.ucsd.edu, hosts SOPAC's primary ftp upload service. Together these four hosts play a critical role in providing public access to SOPAC.

From garner.ucsd.edu (via ftp or http) more than 3 TB of data are immediately available to the public 24 hours a day, 7 days a week. By late 2003 the amount will approach 4 TB, with another 2 TB of online copies for redundancy/backup purposes; these “secondary” copies are not linked to garner, but are immediately available in the event of host-specific outages. The data served through garner.ucsd.edu is supported through the use of the Network File Systems (NFS) protocol. Filesystems are spread across nearly a dozen hosts, and include SCSI-based RAID5, SCSI-based IDE, SCSI-based RAID1, IDE RAID0, Firewire and an AIT tape library.

For a graphical representation of SOPAC's systems architecture see the Appendix.

## Archive Management

Over the years, as SOPAC's participation in various projects, particularly, but not limited to, the IGS, has expanded so has the size and complexity of its computational infrastructure and the processes required to construct it, maintain it, populate it and provide access to it. In response, SOPAC has taken steps to automate as many of these tasks as possible, while simultaneously improving other areas of major concern to SOPAC, such as information management and GPS-related scientific research. The most important aspect of this integration and automation has taken the form of a single, robust, Perl-based database application called Archive Data Manager (ADM).

### *Archive Data Manager (ADM)*

Nearly all aspects of managing the SOPAC public archive are fully-automated – driven by a single SOPAC application called Archive Data Manager[2], which derives its configuration, job lists, archive structure (local and remote archives) and other functioning needs from a relational

[2]ADM, and its supporting collection of libraries, is a custom, system-level Perl application written and maintained at SOPAC. Over the past 3 years ADM has evolved significantly, absorbing numerous tasks once associated with one or more manual functions at SOPAC. The flexible nature of ADM, combined with its close relationship with SOPAC's production database, has allowed SOPAC staff members to direct a greater amount of their time to the analysis of GPS-related information and data files, and the modeling of GPS-related information for wider, community-based initiatives – especially those involving XML.

database schema in an Oracle 9i database server. ADM handles nearly all facets of SOPAC's public archive management and incorporates a number of automated features including 1-second latency GSAC publication of RINEX files and mirroring of RINEX content from the CDDIS and IGN global data centers.

ADM continuously probes and collects data files from more than 40 different local, regional, sub-regional and global GPS archives from around the world. Utmost attention is paid to the efficiency, intelligence and notification capabilities of ADM by SOPAC staff members, especially in relation to the topics of file collection latency, archive availability (up-time), file recollection, IGS data center mirroring, RINEX file quality-checking, GSAC integration, IGS site information log parsing, raw GPS file translation (using teqc) and near real-time RINEX archival.

As the installation of continuous GPS sites around the world continues to increase, and the frequency with which those sites record GPS observations, so does SOPAC's attention to issues related to managing the collection, archival and provision of these datasets in a professional and highly available manner. In response, SOPAC is preparing for the rapid increase in both the number of data files collected as well as the total amount of physical space required to store (and serve) these datasets.

***Collection.*** Collection of data files by ADM occurs in parallel, across numerous SOPAC hosts. Individual processes are launched by Unix cron table entries and communicate through a common relational database server. Since 2001 (when ADM was originally written) a number of improvements have been made with regard to making SOPAC's overall archiving operations more stable, less prone to problems with a particular host, network filesystem, or remote archive and intelligent enough to recognize patterns related to particular files (e.g., quality), local hosts, or remote servers. These enhancements include load balancing, NFS traffic reduction, mirrored data files in two locations and centralized configuration maintained through database-driven user interfaces.

***Storage.*** Storage components used by ADM are distributed across multiple servers with varying amounts of space, RAM, network bandwidth, up-time expectations, redundancy and file retrieval response times. Typically ADM stores a copy of each file it collects, in a “staging” pool (usually an inexpensive Firewire drive to be shelved when full, and cleaned to tape at a later time), in the primary archive location, and in a secondary archive location (to have two copies online at all times). Depending on the type of data file, and its association with a given project, different assignments are made to different physical storage components. Typically, older, infrequently accessed data, are stored in two separate locations (both online) on inexpensive Firewire drives. More recently, frequently accessed data files are temporarily housed on more expensive RAID disk arrays covered by on-site maintenance contracts. Yet another important storage component utilized by SOPAC, but managed by IGPP (our host department), is an 18TB AIT tape library; this system is used to store large, infrequently accessed data files such as high-rate sampling GPS raw data from realtime networks.

***Administration.*** As far as actual staff resources are concerned, administration/oversight of ADM occurs primarily through two different means: a) via 'indicator' emails sent to SOPAC staff by

ADM, and b) configuration management by SOPAC staff through web-based applications and direct database queries.

The indicator emails highlight actual, as well as potential, problems encountered or anticipated by ADM and allow multiple staff members to remain informed of the general health of the archive. Important topics addressed by ADM in this manner include: filesystem problems (out of space, hung mount points, etc), server-related problems (archive hosts, upload ftp server, etc), file-related problems (quality-checking, small file size, availability issues, etc) and 'discoveries' (previously unknown GPS site possibly found at another archive).

Email notification by ADM works well in a reactive setting, for irregular events and otherwise unanticipated occurrences. However, the configuration of ADM (e.g., what to do, when, how) is managed primarily through SOPAC's Site Information Manager (SIM) and direct SQL interfaces with SOPAC's production database.

Overall, SOPAC's archive management functions remain a top priority and will continue to be a top priority into the foreseeable future. Nearly every week an improvement or addition of some kind is made to the ADM system.

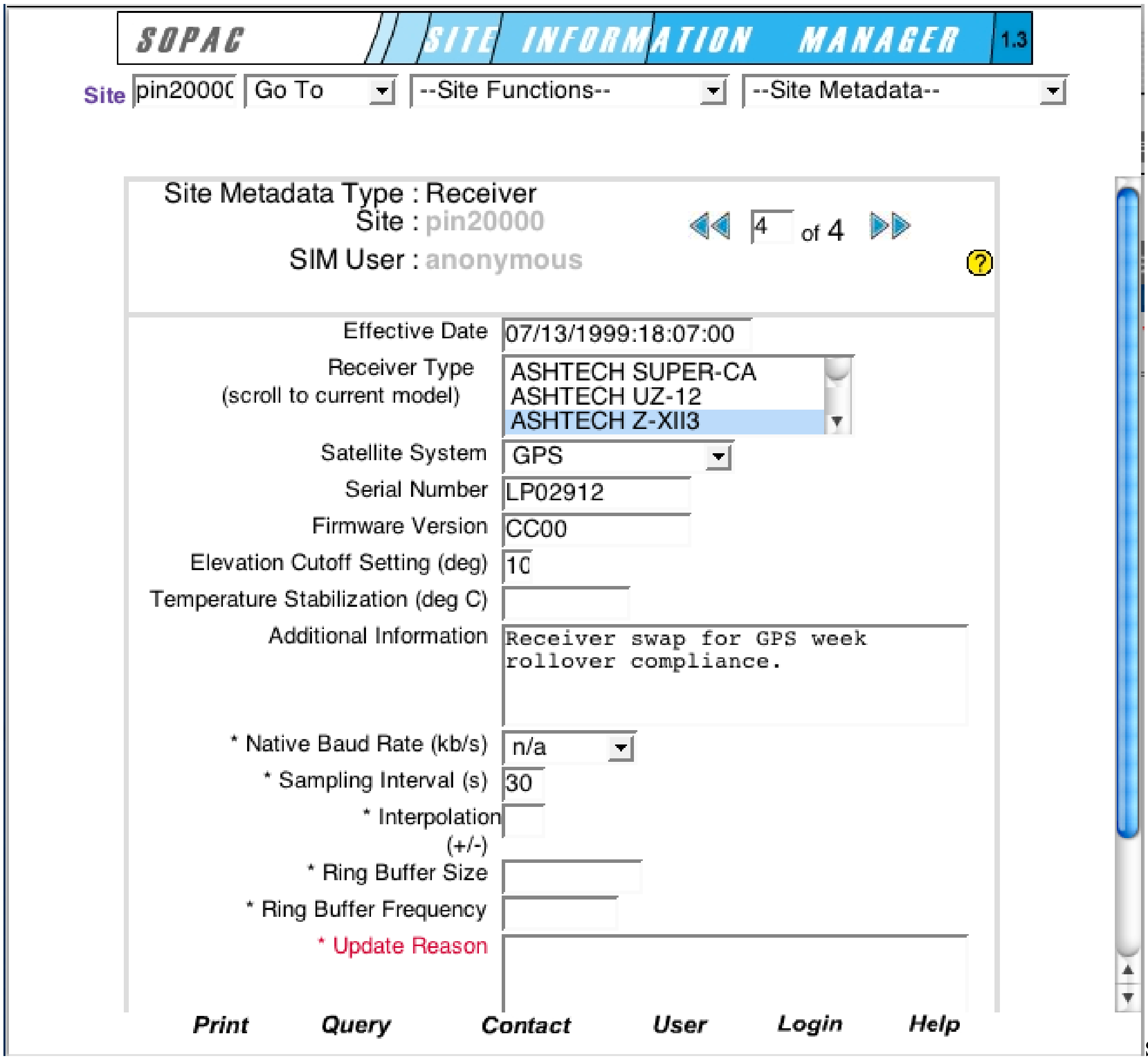
**Information Management**

SOPAC has been dedicated to providing the GPS community with useful and timely information describing GPS data, or various components related to the use of GPS data for scientific research, education, government and commercial applications since the early 1990s. At the center of nearly all of SOPAC's information management activities is an Oracle 9i relational database. This database is used to model information critical to the functioning of SOPAC and to the assortment of GPS-related activities it performs. Interfaces to the database are many, and vary with the context and regularity with which particular information set is affected. However, one application in particular has received the most development resources over the past several years – SOPAC's Site Information Manager.

*Site Information Manager (SIM)*

For information associated with GPS sites (or geodetic monuments) SOPAC's primary management tool is the Site Information Manager[3] (Figure 7), a web-based application that allows users to insert, update or delete information associated with one or more GPS

[3]The SIM launches and runs in a separate browser window, accessible from http://sopac.ucsd.edu/scripts/SIMpl_launch.cgi.




sites

**Figure 7.** SOPAC's Site Information Manager (SIM) is a web-based database application that allows users to insert, update or delete information content associated with one or more GPS sites

they have been granted access rights to by a SOPAC staff member. The interface itself uses the same (or very similar) terminology, value domains (such as equipment model codes) and layout as an IGS Site Information Log. SIM users, among other things, can find or specify the site they wish to view/edit and then make changes (assuming they have the necessary access rights) to any information in the SOPAC database associated with the selected site, and supported in the SIM. This information then propagates directly into a variety of functions at SOPAC, many of which serve the interests of the IGS, including:

- Complete IGS site log generation from the SOPAC database on request (by a SIM user).
- Automated generation and submission of SCIGN site logs (for certain sites) to the IGS.
- Parsing/validation of IGS site logs during ADM archival processes.
- Translation of SCIGN raw GPS data files using UNAVCO's teqc utility.

- Creation of publicly-available SINEX products and GAMIT station.info configuration files for GPS analysis.

Over the past 4 years the SIM has undergone numerous updates, to conform to changes in the IGS site log format and to serve a more extensive pool of application contexts at SOPAC. This important interface has served as an invaluable asset in numerous capacities at SOPAC and continues to evolve as needed.

*Automated Information Collection*

Much of what ADM (described previously) does, with regard to the IGS, is to automate important tasks such as the parsing of IGS site logs. Whenever a new (or modified) site log appears at one or more ftp archives visited by ADM it is collected and parsed with respect to information present in SOPAC's production database – much of which is managed/overseen by SIM users. Any differences in content are automatically rectified with respect to the database, or shipped to a SOPAC staff member via email for confirmation. This information is then immediately available to most SOPAC applications, including GAMIT's station.info generation, ALL site information-based applications on SOPAC's websites and SOPAC's regular operational GPS analysis.

The relationship between data file collection (and subsequent provision) and ancillary metadata has received a large amount of SOPAC's development time over the years, as more and more inter-operative and collaborative functions have evolved at SOPAC. Furthermore, the benefits reaped by such development have aided SOPAC significantly in developing a more efficient and effective GPS analysis environment, for local (in-house) and public users alike.

**Future Plans**

In 2003 SOPAC plans to construct a Geographic Information Systems (GIS) lab to support its research and public interface activities. This lab will contain several Dell workstations (running a Windows operating system) and a central data server. All hosts will have a suite of ESRI and Leica Geosystems software installed locally, in conjunction with application development packages (Microsoft Visual Studio) and graphical development environments (Macromedia MX and Adobe). These resources will be used by SOPAC staff members and students to enhance and extend the set of online applications provided to the GPS community through SOPAC's primary websites.

Plans for 2003 and 2004 also include the development of Extensible Markup Language (XML) schemas and supporting applications for numerous GPS-related activities including the automated creation and distribution of IGS Site Information Logs, passive GPS campaign field logs and possible enhancements to GSAC information exchange mechanisms.

### Contact Information

For more information about SOPAC, or any of its IGS-related functions please contact: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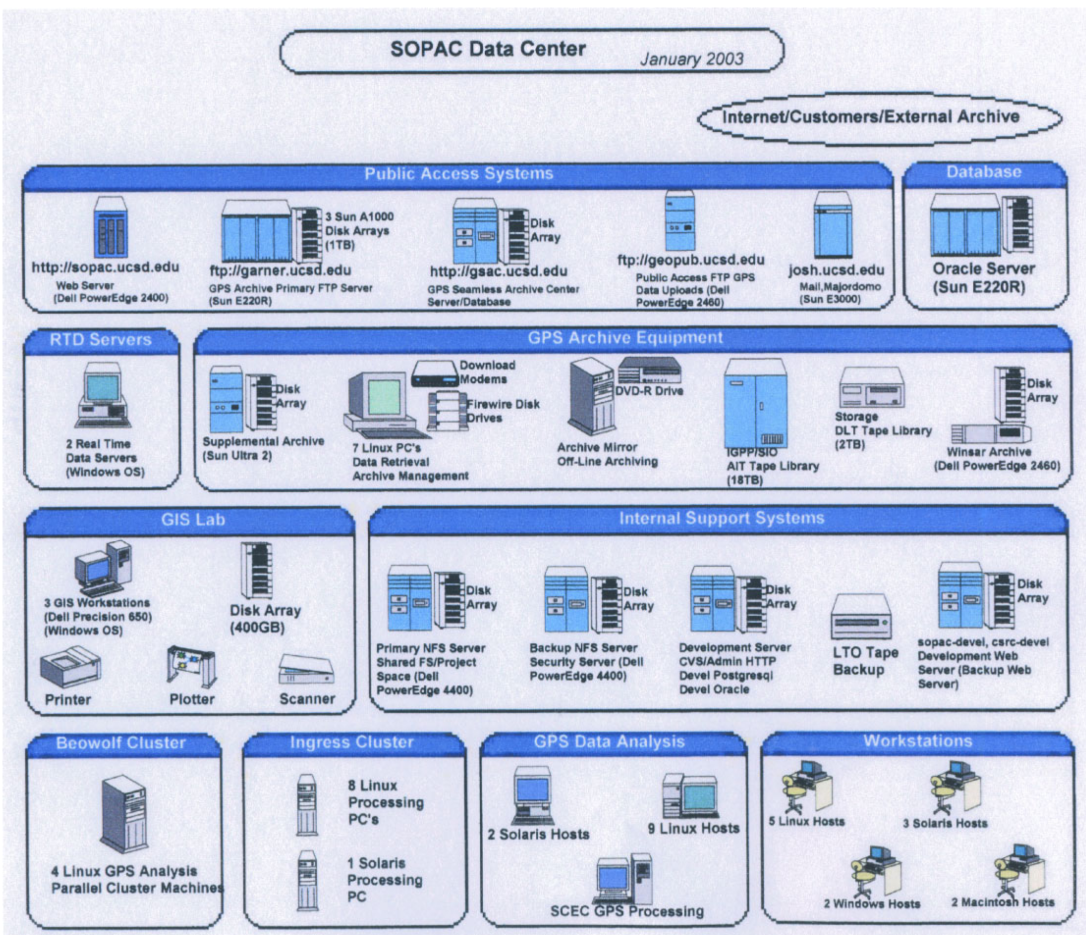
or visit SOPAC's main public website at: http://sopac.ucsd.edu.

### Acknowledgments

We want to thank our IGS colleagues for sharing data, metadata, and metadata with us, and our customers for continuing to use (and stress) our archive. We acknowledge the Southern California Integrated GPS Network and its sponsors, the W.M. Keck Foundation, NASA, NSF, USGS, SCEC, for providing data used in this study. Funding also provided by NSF (through UCAR/UNAVCO), NOAA's Forecast Systems Laboratory, and NOAA's NGS (through the JIMO program to the California Spatial Reference Center).

### Appendix. Systems Architecture of SOPAC's Data Center



IGS

# REGIONAL/OPERATIONS CENTERS

# BKG Regional IGS Data Center Report 2002

*Heinz Habrich*

Federal Agency for Cartography and Geodesy, Frankfurt, 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 a European institution operates these stations. The received data are uploaded to the Global Data Centers (GDCs), and are also made available to other users. BKG holds the data files from different projects in separate directories in order to handle the project related restrictions, e.g., the project specific user access. A project independent access is additionally realized through a list of all stations and links to the corresponding subdirectories. The operability of the data center is continuously adapted to meet newest requirements. In 2002 the data center was further development through the cooperation with the IGS Data Center Working Group, the preparation of the participation in GSAC, and the design of a new server concept.

## Activities in 2002

In 2002 about 10 new GPS/GLONASS stations has been established in Germany by BKG and provide observations in a real-time data stream. These data streams are compiled to hourly files and copied to the data center. It increases the number of GPS/GLONASS stations in Germany significantly. The wholesaler software kid of the GPS Seamless Archive Center (GSAC) as provided by SOPAC has been installed at BKG for test purposes. A first small data holding catalogue was generated and confirms the functionality of the software installation. It is planned to run the complete wholesaler software within the new server concept (see section below). BKG is furthermore represented in the newly established IGS Data Center Working Group.

## New Server Concept

BKG decided in 2002 to develop and realize a new server concept for the data center. The objective is to make the access to the data center more comfortable for the users as well as for the administrator. It should be possible to get all information by usage of the http protocol. Also the administration of the data center should easily be possible by the generation of helpful status overviews and the execution of predefined repair batches. For that purpose the LAMP (Linux operation system, Apache web server, MySQL data bank and PHP script language) server concept will be used. The new server will not change the disk file structure and thus batch programs for ftp downloads may still be used. LAMP enables to show dynamic web pages for the current content of the data base. A test server has been installed in 2002 and has demonstrated the functionality of the concept (http://igs2.ifag.de). It is planned to put the new server in operation before the end of 2003. Figure 1 shows the new designed 'check-import-like' statistic. It shows up with sensitive fields for the station code, color pad and day of year to request detailed information. Figure 2 shows the 'station' and 'receiver' menus, which are dynamically generated from the SQL data base.

## Outlook

If the new server concept will be realized, BKG expects to run a very robust, flexible and comfortable data center. The participation in GSAC will be a proper global extension to the European data. It is currently not possible to correctly value the importance of real time data streams for the future. Anyhow, BKG will be prepared to introduce real time applications into the data center.

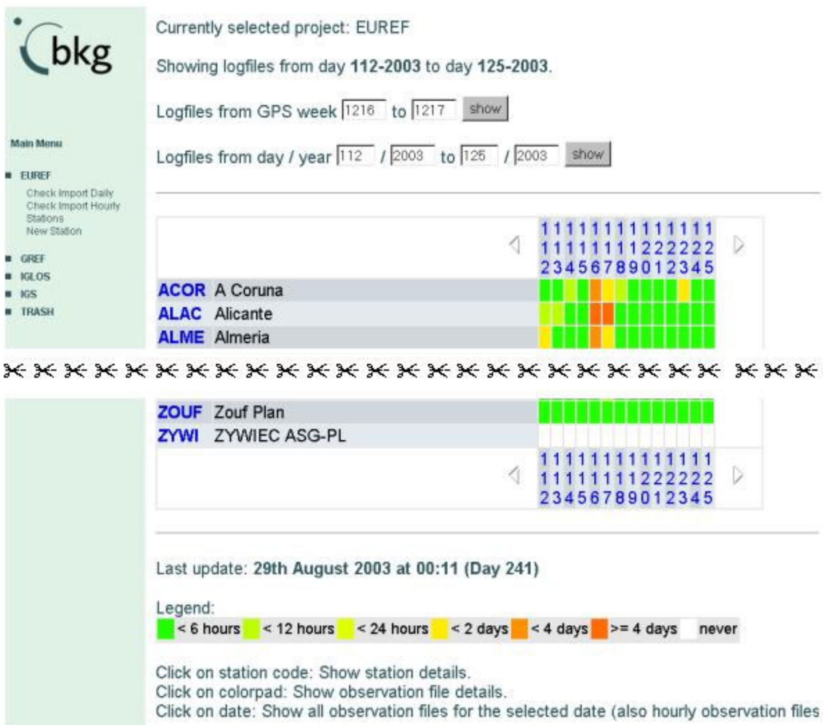



Figure 1: New 'check-import' statistic

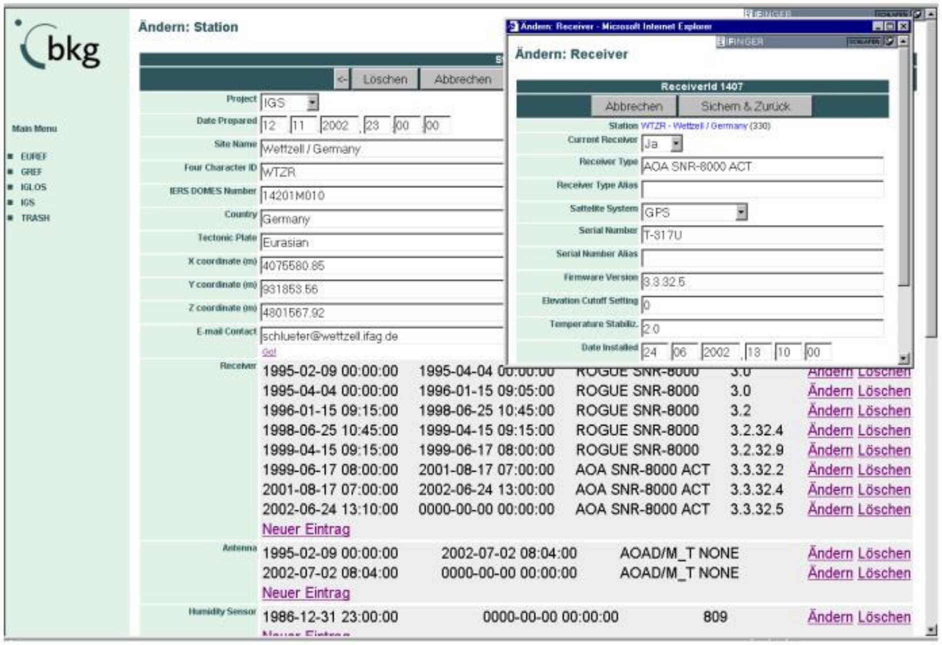



Figure 2: Selected 'station' and 'receiver' menu

# HartRAO Regional Center Report 2001-2002

*Ludwig Combrinck*

Space Geodesy Programme
Hartebeesthoek Radio Astronomy Observatory
e-mail: ludwig@hartrao.ac.za

## Introduction

HartRAO is located north of Johannesburg, South Africa, in a valley of the foothills of the Witwaters mountain range. HartRAO uses a 26 metre equatorially mounted Cassegrain radio telescope built by Blaw Knox in 1961. The telescope was part of the NASA deep space tracking network until 1975 when the facility was converted to an astronomical observatory. The radio telescope is collocated with an IGS GPS station HRAO and a Satellite Laser Ranging (SLR) station MOBLAS6 (Figure 1). HartRAO is the IGS Regional Data Centre for Africa and a TIGA associate analysis centre.

Figure 1. The 26 metre radio telescope used for geodetic VLBI. Solid panels have been fitted as part of a surface upgrade, which is expected to be complete by end 2003. In the foreground is the antenna of the IGS station HRAO and to the right is the NASA SLR MOBLAS6. The collocation of these three geodetic systems makes HartRAO an important contributor to global space geodesy.

### Database

Currently, data of about 40 IGS stations are archived, including the combined broadcast files and IGS precise ephemeris. The data is accessible via anonymous ftp to *geoid.hartrao.ac.za* or via the web page *http://www.hartrao.ac.za/geodesy/data.html*

### Database Structure

Data is stored in the format yyyy/doy/station and usage of the web based data archive is user friendly. Access via anonymous ftp is after log on, by changing directory to *rinex/yyy/doy*. The combined broadcast (navigation) files are stored in the same directory.

IGS precise ephemeris (*.sp3) files are located in the directory *products/gpsweek,* these files commence with GPS week 0938. Rinex and combined broadcast files date to day 001, year 2000. If there is a requirement for earlier files, this can be arranged by contacting the author. We would also be willing to store data (e.g. local surveys, campaigns etc.) for local users as long as the data is available to all users.

All files are gzipped. There is a gzip utility available from the same web page. Hatanaka compression is not used at the moment, although older data will eventually be stored after having been compressed using the Hatanaka algorithm. Only 24 hour RINEX files are archived at the moment, but it is envisaged that a subset of the archive will be stored as one hour files within the near future. Typical file download traffic during 2001 was about 100 files per day. This is minute in comparison to most other data centers, but this figure continues to grow and indicates a greater use of IGS data and products on the African continent.

### TIGA

TIGA related metafiles and information can be found on the web page
*http://www.hartrao.ac.za/geodesy/web_TIGA/index.html*

Information about the Tiga Observing Stations (TOS) as well as tide gauge specific type information is stored here. Access to data retrieval is provided to accommodate users.

A map provides a graphical interface to photos and details of several TOS installations.

Two TOS stations have been installed by HartRAO, SIMO (Simonstown) (Figure 2) and RBAY (Richardsbay).

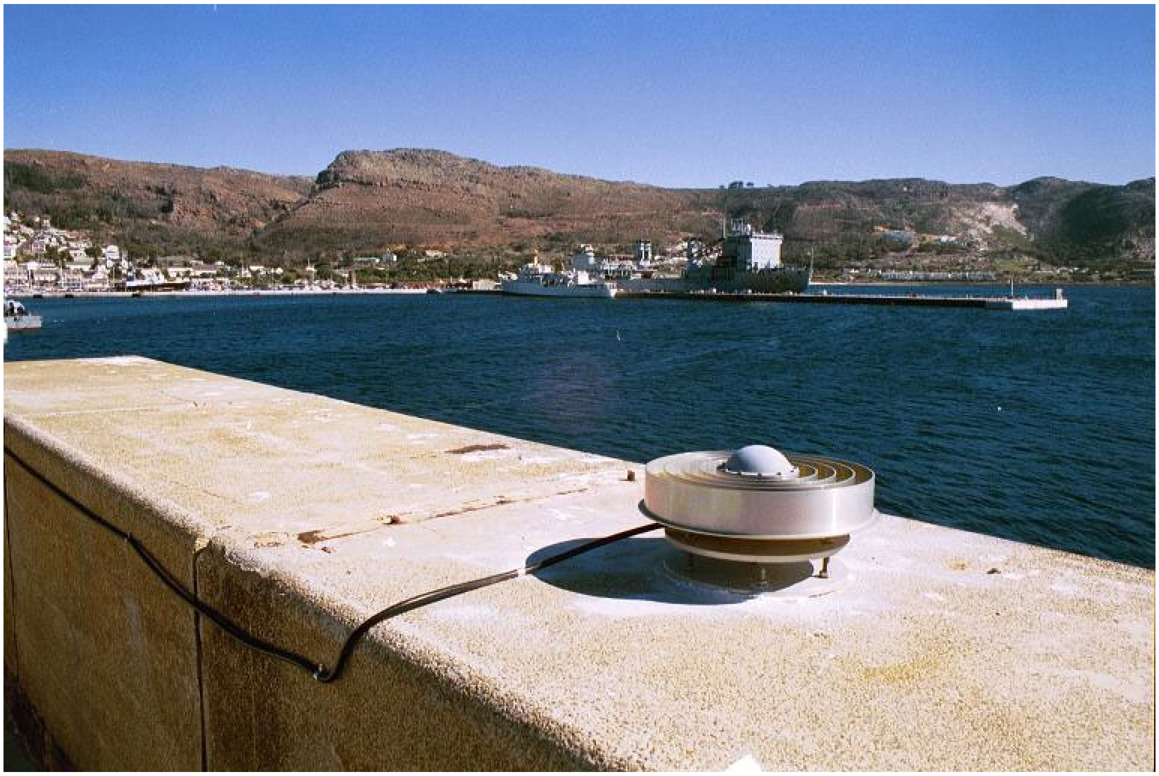


Figure 2. The GPS antenna of SIMO, an IGS TOS station located at Simonstown, South Africa.

**Computer Hardware**

The regional data server consists of a dual processor 450 Mhz Pentium III equipped with two twenty Gb disks and one forty Gb disk. Backups are done on 40 Gb DAT tapes. The same server is used for data processing and JPL has an account on the machine to enable access to RBAY through a multi-layered firewall. Although the server meets all present requirements as far as data archiving is concerned, it does not meet processing requirements. It is therefore necessary to obtain a more advanced computer to enable processing of data, which needs to be completed within a specific timeframe. A cluster of PCs will be acquired during 2003 to facilitate processing.

**SADC GPS Network**

In collaboration with GFZ Potsdam, the old regional station NAMI (an old SNR8) installed by HartRAO/JPL which is located in Windhoek (see 2000 report) was selected for an upgrade. Installation of a modern GPS station will take place during 2003. An IGS station was installed at Lusaka, Zambia (Figure 2) at the offices of the Surveyor General. The station has been providing reliable data and is used regionally (Combrinck and Nsombo, 2002) and by several IGS Analysis Centers. A paper was presented (Combrinck 2002) at the IGS workshop in Ottawa, Canada during April 2002, which described the current connectivity and networking opportunities in Africa with a view towards real-time GPS.

In South Africa, only SUTH and HRAO provide real-time streaming data. In collaboration with NRCan, it is planned to install a real-time station at MAUN (Botswana) during 2003. We are in the process to equip Malawi, Mozambique (2003), Madagascar, Botswana (2003), Namibia (2003) and Zimbabwe with IGS stations. Members of the IGS who have upgraded existing stations and have redundant equipment available should please contact the author.

A project submission has been made in collaboration with GFZ Potsdam to equip the 14 Southern African Development Community (SADC) countries with at least one IGS GPS station in the next five years. In collaboration with the TIGA IGS pilot study, several tide gauges will also be installed (collocated with GPS). A special effort will be made to install a tide gauge and GPS on Marion Island, which is located between Africa and Antarctica at about -40 degrees south.

Figure 3. The ZAMB GPS antenna monumentation located in Lusaka, Zambia. The antenna is situated on a massive concrete foundation, which extends through a large building. The foundation used to support a large water tank

## Geodetic Institute

In order to bring geodesy closer to home and the African continent, the Geodesy Programme is in the process of establishing a Geodetic Institute. The purpose of this institute at will be to establish strategic alliances and collaborative projects with other African countries.

These projects will be tied in a unifying structure, which will advance and support Africa's role in geodesy. It will support and promote the activities of the IVS, ILRS and IGS. It will also support the objectives of the African Reference Frame (AFREF) through the further development of the SADC GPS Network.

## Research Activities

A project was launched to produce ZTD maps using GPS data and preliminary results were promising. A technique was developed using the GAMIT software to determine vertical motion due to earth tide as measured by GPS. The IGS station SUTH, located at Sutherland and collocated with a superconducting gravimeter was used to evaluate this technique. It is envisaged that a PC cluster to be purchased during 2003 will allow routine processing and further development of this technique (Neumeyer et al. 2002). Currently processing power is too limited to be practical.

## References

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