

IGS

SESSION 5

DATA CENTER ISSUES

Data Center Issues

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Abstract

The IGS has been operational for nearly five years. Recent demands on the stations and data centers prompts the review of data flow and archiving methodologies. This position paper outlines the current structure and details problems to be addresses as well as questions for future implementation.

Introduction

The International GPS Service (IGS) was formed by the International Association of Geodesy (IAG) to provide GPS data and highly accurate ephemerides in a timely fashion to the global science community to aid in geophysical research. This service has been operational since January 1994. The GPS data flows from a global network of permanent GPS tracking sites through a hierarchy of data centers before they are available to the user at designated global and regional data centers (Noll, 1998). A majority of these data flow from the receiver to global data centers within 24 hours of the end of the observation day. Common data formats and compression software are utilized throughout the data flow to facilitate efficient data transfer. IGS analysis centers retrieve these data daily to produce IGS products (e.g., orbits, clock corrections, Earth rotation parameters, and station positions). These products are then forwarded to the global data centers by the analysts for access by the IGS Analysis Coordinator, for generation of the final IGS orbit product, and for access by the user community in general. The IGS, its data flow, and the archival and distribution at one of its data centers will be discussed.

Current Status of Data Centers and Data Flow

The flow of IGS data (including both GPS data and derived products) as well as general information can be divided into several levels (Gurtner and Neilan, 1995) as shown in Figure 1:

- Tracking Stations
- Data Centers (operational, regional, and global)
- Analysis Centers
- Analysis Center Coordinator

- Central Bureau (including the Central Bureau Information System, CBIS)

The components of the IGS dealing with flow of data and products will be discussed in more detail below.

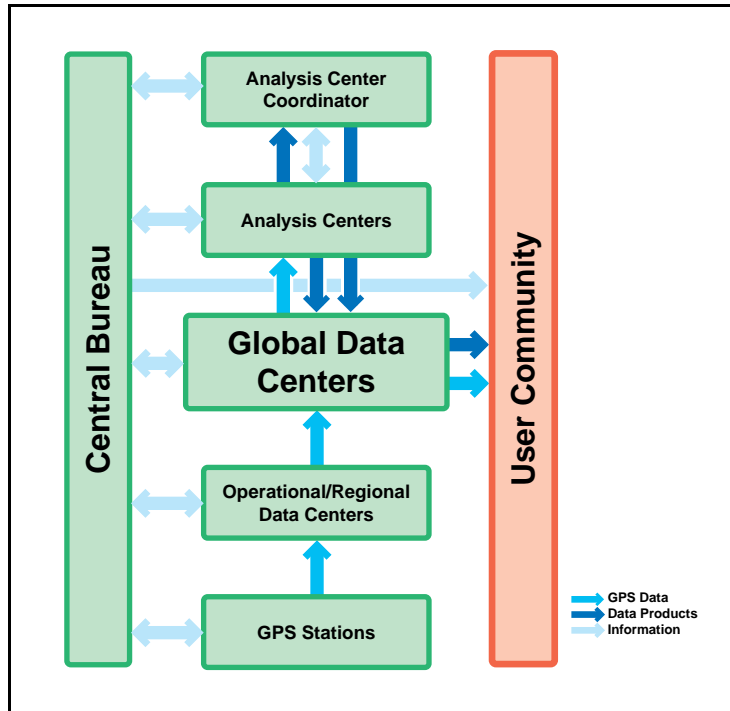


Figure 1. Flow of IGS Data and Products

Tracking Stations

The global network of GPS tracking stations are equipped with precision, dual-frequency, P-code receivers operating at a thirty-second sampling rate. The IGS currently supports nearly 200 globally distributed stations. These stations are continuously tracking and are accessible through phone lines, network, or satellite connections thus permitting rapid, automated download of data on a daily basis. The IGS has established a hierarchy of these 200 sites since not all sites are utilized by every analysis center (Gurtner and Neilan, 1995). A core set of over eighty sites are analyzed on a daily basis by most centers; these sites are called global sites. Sites used by one or two analysis centers for densification on a regional basis are termed regional sites. Finally, sites part of highly dense networks, such as one established in southern California to monitor earthquake deformation, are termed local sites. This classification of IGS sites determines how far in the data center hierarchy the data are archived. For example, global sites should flow to the global data center level, where regional sites are typically archived at a regional data center only.

Data Centers

During the IGS design phases, it was realized that a distributed data flow and archive scheme would be vital to the success of the service. Thus, the IGS has established a hierarchy of data centers to distribute data from the network of tracking stations: operational, regional, and global data centers. Operational data centers (ODCs) are responsible for the direct interface to the GPS receiver, connecting to the remote site daily and downloading and archiving the raw receiver data. The quality of these data are validated by checking the number of observations, number of observed satellites, date and time of the first and last record in the file. The data are then translated from raw receiver format to a common format and compressed. Both the observation and navigation files (and meteorological data, if available) are then transmitted to a regional or global data center within a few hours following the end of the observation day.

Regional data centers (RDCs) gather data from various operational data centers and maintain an archive for users interested in stations of a particular region. IGS regional data centers have been established in several areas, including Europe and Australia.

The IGS global data centers (GDCs) are ideally the principle GPS data source for the IGS analysis centers and the general user community. GDCs are tasked to provide an on-line archive of at least 100 days of GPS data in the common data format, including, at a minimum, the data from all global IGS sites. The GDCs are also required to provide an on-line archive of derived products, generated by the IGS analysis centers and associate analysis centers. These data centers equalize holdings of global sites and derived products on a daily basis (at minimum). The three GDCs provide the IGS with a level of redundancy, thus preventing a single point of failure should a data center become unavailable. Users can continue to reliably access data on a daily basis from one of the other two data centers. Furthermore, three centers reduce the network traffic that could occur to a single geographical location. Table 1 lists the data centers currently supporting the IGS.

Data and Product Holdings

All data centers archive data from the network in daily files by station and in RINEX format. These data consist of separate files of observation, broadcast ephemeris, and meteorological measurements. The current IGS network consists of nearly 200 sites; the number of sites archived at each GDC per day varies, depending upon each center's sponsor and user community obligations as well as hardware capabilities. In 1997, Hatanaka compression software was introduced to the IGS data centers and by 1998 became the operational method for storing and exchanging data within the IGS. This software, when combined with standard UNIX compression, reduces the size of the original daily RINEX file by at least a factor of eight and has thus reduced network traffic and time of download for the IGS community.

Table 1. Data Centers Supporting the IGS

Operational Data Centers	
ASI	Italian Space Agency
AUSLIG	Australian Land Information Group
CNES	Centre National d'Etudes Spatiales, France
DSN	Deep Space Network, USA
DUT	Delft University of Technology, The Netherlands
ESOC	European Space Agency (ESA) Space Operations Center, Germany
GFZ	GeoForschungsZentrum Germany
GSI	Geographical Survey Institute, Japan
ISR	Institute for Space Research, Austria
JPL	Jet Propulsion Laboratory, USA
KAO	Korean Astronomical Observatory
NIMA	National Image and Mapping Agency (formerly DMA), USA
NMA	Norwegian Mapping Authority
NOAA	National Oceanic and Atmospheric Administration, USA
NRCan	Natural Resources Canada
RDAAC	Russian Data Analysis and Archive Center
SIO	Scripps Institution of Oceanography, USA

Regional Data Centers	
AUSLIG	Australian Land Information Group
BKG	Bundesamt für Kartographie und Geodäsie, Germany
JPL	Jet Propulsion Laboratory, USA
NOAA/GO DC	National Oceanic and Atmospheric Administration, USA
NRCan	Natural Resources Canada

Global Data Centers	
CDDIS	Crustal Dynamics Data Information System, NASA GSFC, USA
IGN	Institut Géographique National, France
SIO	Scripps Institution of Oceanography, USA

Due to the increased interest by the IGS user community for near real-time GPS data, hourly data files were introduced at the CDDIS in mid-1998. Currently, over thirty sites are providing hourly data files, with an approximate 15 minute delay, to the CDDIS. The data are retained in the individual hourly files for three days at which time they are deleted. At this time, no quality control checks are performed on the hourly files. The

daily files containing data from the full 24-hour period are supplied by the data sources in the usual fashion.

Since the start of the IGS, the ACs have generated precise orbit files in SP3 format. These files are archived at all GDCs. Since GPS week 0723 (November 1993), the IGS Analysis Coordinator has provided the official IGS orbit to the GDCs and the CBIS. This orbit is typically available ten days after the end of the GPS week. A predicted (since March 1997) and rapid (since March 1996) orbit product are also generated by the Analysis Coordinator and available from the GDCs and the CBIS.

In January 1997, GFZ began supplying the GDCs with a combined troposphere product consisting of weekly zenith path delay (ZPD) estimates from the individual ACs. The product consists of weekly ZPD files, at a sampling rate of two hours, for about 100 globally distributed sites.

As of June, 1998, several IGS Analysis Centers are supplying daily, global ionosphere maps of total electron content (TEC) in the form of IONEX files to the GDCs. A daily IONEX file includes twelve two-hour snapshots of the TEC and optionally corresponding RMS information.

Current Data Flow and Timeliness of Data Delivery

Table 2 shows the current flow of IGS sites from station to global data center. The information in this table is based on data archived at the CDDIS since July 1998 (host cddisa.gsfc.nasa.gov). Only sites with logs available at the CBIS are reflected in this list. The table shows that ~45% of the data are delivered within one hour, 65% within three hours, and 75% within six hours.

Data Center Issues

QC of Current and Historical Data

Global Data Centers need to establish common quality control mechanisms to insure common quality data sets among themselves. To do this we need to define what procedures data centers must apply to the data before the data becomes public on their archive. The following describes what SOPAC has implemented (or implementing) in their archiving of RINEX data.

- 1) equivalent file sizes on remote server and local server after FTP transfers
- 2) strict compliance with the current RINEX format (RINEX vN)
- 3) header information checking against known site info (IGS log file) or data

NOTE: We already assume that the site has been established as an IGS site, i.e., a log file has been submitted to the CBIS and a DOMES number has been assigned.

Table 2. IGS Data Flow and Median Delay (by Station)

Station	Site Name	OC/LDC	RDC	GDC	Delay	No. Days	Station	Site Name	OC/LDC	RDC	GDC	Delay	No. Days	
ALBH	* Albert Head		NRCan	CDDIS	1	98	MDOT	* McDonald		JPL	CDDIS	1	98	
ALGO	* Algonquin		NRCan	CDDIS	1	98	MDVO	* Mendeleev	DUT	BKG	IGN	24	96	
AMCT	* Colorado Springs, CO		NRCan	CDDIS	1	96	MEDI	* Medicina	ASI	BKG				
ANKR	* Ankara		BKG	IGN	34	69	METS	* Metsahovi	NMA	BKG	IGN	8	82	
AOA1	* Westlake, CA		JPL	CDDIS	1	98	MKEA	* Mauna Kea, HI		JPL	CDDIS	1	98	
AOML	* Key Biscayne, FL		NOAA	CDDIS	1	97	MOIN	* Limon		JPL	CDDIS	0	0	
AREQ	* Arequipa		JPL	CDDIS	6	95	MONP	* Monument Peak			SIO	4	97	
ASC1	* Ascension Island		JPL	CDDIS	1	98	NANO	* Nanose		NRCan	CDDIS	1	98	
AUCK	* Auckland		JPL	CDDIS	1	97	NICO	* Nicosia		BKG	IGN	21	93	
AZU1	* Azusa, CA		JPL	CDDIS	1	86	NLIB	* North Liberty, IO		JPL	CDDIS	1	98	
BAHR	* Bahrain	NIMA		CDDIS	3	91	NOTO	* Noto	ASI	BKG				
BAKO	* Bakosumatal			SIO	4	90	NOUM	* Noumea			IGN	2	93	
BARB	* Barbados		NOAA	CDDIS	1	42	NRC1	* Ottawa		NRCan	CDDIS	1	97	
BARH	* Bar Harbor, ME		NOAA	CDDIS	1	3	NSSP	* Yerevan		JPL	CDDIS	35.5	89	
BILL	* Temecula, CA			SIO			NTUS	* Singapore			IGN	3	80	
BLYT	* Blythe, CA			SIO			NYA1	* Ny Alesund		BKG	IGN	2	86	
BOGT	* Bogota		JPL	CDDIS	2	94	NYAL	* Ny Alesund		BKG	IGN	2	92	
BOR1	* Borwicz	ISR	BKG	IGN	3	97	OAT2	* Oat Mountain, CA		JPL	CDDIS	1	98	
BRAN	* Burbank, CA			SIO			OBER	* Oberpfaffenhofen	GFZ	(none) BKG	CDDIS IGN	4	93	
BRAZ	* Brasilia		JPL	CDDIS	0	0	OHIG	* O'Higgins		BKG	IGN	2	88	
BRMU	* Bermuda		NOAA	CDDIS	1	94	ONSA	* Onsala		BKG	IGN	8	89	
BRUS	* Brussels		BKG	IGN	2	96	PENC	* Penc		BKG				
CAGL	* Cagliari	ASI	BKG				PERT	* Perth	ESOC		CDDIS	3	98	
CARR	* Parkfield, CA		JPL	CDDIS	1	98	PETR	* Petropavlovsk-Kamchatka	RDAAC (none)		CDDIS SIO	7	94	
CAS1	* Casey		AUSLIG	CDDIS	7	77	PIE1	* Pie Town, NM		JPL	CDDIS	1	98	
CASA	* Mammoth Lakes, CA		JPL	CDDIS	1	98	PIN1	* Pinyon Flat, CA			SIO	4	97	
CAT1	* Catalina Island, CA		JPL	CDDIS	1	98	PIN2	* Pinyon Flat, CA			SIO			
CHAT	* Chatham Island		JPL	CDDIS	9	94	POL2	* Bishkek		JPL	CDDIS	22	93	
CHIL	* Chilao, CA			SIO			POTS	* Potsdam	GFZ	(none) BKG	CDDIS IGN	4	95	
CHUR	* Churchill		NRCan	CDDIS	1	95	PRDS	* Priddis		NRCan	CDDIS	1	97	
CICE	* Ensenada		JPL	CDDIS	1	98	PVEP	* Palos Verdes, CA			SIO	4	97	
CITI	* Pasadena, CA		JPL	CDDIS	1	98	QUIN	* Quincy, CA		JPL	CDDIS	1	94	
CLAR	* Claremont, CA			SIO			RAIO	* Milzpe Ramon			SIO	54	6	
CMF9	* Sylmar, CA			SIO			RCM6	* Richmond, FL		NOAA	CDDIS	1	72	
COCO	* Cocos Island		AUSLIG	CDDIS	8	80	REYK	* Reykjavik		BKG	IGN	3	69	
COSO	* Ridgecrest, CA			SIO			ROCH	* Pinemeadow, CA			SIO			
CRFP	* Yucaipa, CA			SIO			ROCK	* Simi Valley, CA			SIO			
CRO1	* St. Croix		JPL	CDDIS	1	96	SANT	* Santiago		JPL	CDDIS	1	97	
CSN1	* Northridge, CA		JPL	CDDIS	13	30	SCH2	* Schefferville		NRCan	CDDIS	1	98	
DAM1	* Sylmar, CA			SIO			SCIP	* San Clemente Island, CA			SIO			
DAM2	* Sylmar, CA			SIO			SELE	* Almaty		JPL	CDDIS	88	86	
DAV1	* Davis		AUSLIG	CDDIS	4	95	SEY1	* Seychelles		JPL	CDDIS	0	0	
DGAR	* Diego Garcia		JPL	CDDIS	7	90	SFER	* San Fernando		BKG	IGN	21	95	
DHLG	* Durmid Hill, CA			SIO			SHAO	* Shanghai		JPL	CDDIS	1	98	
DRAO	* Perinton		NRCan	CDDIS	1	97	SIO3	* Scripps			SIO	4	97	
DUBO	* Lac du Bonnet		NRCan	CDDIS	1	98	SN11	* San Nicholas Island		JPL	CDDIS	23	37	
EBRE	* L'Ebre		BKG	IGN	10	86	SOF1	* Sofia		BKG				
EISL	* Easter Island		JPL	CDDIS	1	98	SOL1	* Solomons Island, MD		NOAA	CDDIS	1	98	
EPRT	* Eastport, MD		NOAA	CDDIS	1	5	SPK1	* Saddle Peak, CA		JPL	CDDIS	1	98	
FAIR	* Fairbanks, AK		JPL	CDDIS	1	91	STJO	* St. John's		NRCan	CDDIS	1	98	
FLIN	* Flin Flon		NRCan	CDDIS	1	78	SUTH	* Sutherland		JPL	CDDIS	1	83	
FORT	* Fortaleza		NOAA	CDDIS	3	90	SUWN	* Suwon-shi	NGI		CDDIS	1	96	
GALA	* Galapagos Island		JPL	CDDIS	36	89	TABL	* Wrightwood, CA			SIO			
GLSV	* Kiev			IGN	5	88	TAEJ	* Taejon	KAO		CDDIS	1	96	
GODE	* Greenbelt, MD		JPL	CDDIS	1	98	TAIW	* Taipei	GSI		CDDIS	0	0	
GOL2	* Goldstone, CA	DSN	JPL	CDDIS	1	93	THTI	* Thule	CNES		IGN	29	42	
GOLD	* Goldstone, CA	DSN	JPL	CDDIS	12	97	THU1	* Thule		JPL	CDDIS	1	98	
GOPE	* Ondrejov	ISR	BKG				TID2	* Tidbinbilla	DSN	JPL	CDDIS	1	98	
GOUQ	* Gough Island		AWI	CDDIS	57	49	TIDB	* Tidbinbilla	DSN	JPL	CDDIS	12	95	
GRAS	* Grasse	CNES		IGN	5	89	TORP	* Torrance			SIO			
GRAZ	* Graz	ISR	BKG	IGN	3	97	TOUL	* Toulouse	CNES		IGN			
GUAM	* Guam		JPL	CDDIS	1	98	TRAK	* Irvine			SIO			
HARK	* Pretoria	CNES		IGN	5	93	TRO1	* Tromso	NMA	BKG	IGN	2	93	
HARV	* Harvest Platform		JPL	CDDIS	4	92	TROM	* Tromso	NMA	BKG	IGN	2	60	
HERS	* Herstmonceux		BKG	IGN	2	95	TSKB	* Tskuba	GSI		CDDIS	2	98	
HFLK	* Innsbruck	ISR	BKG				UCLP	* Los Angeles, CA		JPL	CDDIS	1	80	
HNPT	* Cambridge, MD		NOAA	CDDIS	2	97	UCLU	* Uculet		NRCan	CDDIS	1	98	
HOB2	* Hobart		AUSLIG	CDDIS	7	88	UPAD	* Padova	ASI	BKG				
HOFN	* Hohn		BKG	IGN	24	93	USC1	* Los Angeles, CA		JPL	CDDIS	1	98	
HOLB	* Holberg		NRCan	CDDIS	1	98	USNA	* Annapolis, MD		NOAA	CDDIS	2	98	
HOLC	* Pearlblossom			SIO			USNO	* Washington, D.C.		NOAA	CDDIS	1	98	
HOLP	* Hollydale			SIO			USUD	* Usuda		JPL	CDDIS	1	98	
HRAO	* Hartbeesthoek		JPL	CDDIS	1	83	VESL	* Sanae	AWI		CDDIS	57	53	
IAVH	* Rabat		JPL	CDDIS	86	58	VILL	* Villafranca	ESOC	(none) BKG	CDDIS IGN	3	97	
IISC	* Bangalore		JPL	CDDIS	2	98	VNDP	* Vandenbergh, CA			SIO	4	88	
IRKT	* Irkutsk		RDAAC DUT	(none) BKG	CDDIS IGN	21	95	WES2	* Westford, MA		NOAA	CDDIS	1	97
JOZE	* Jozefoslaw	ISR	BKG	IGN	11	32	WHC1	* Whittier, CA		JPL	CDDIS	1	98	
JPLF	* Pasadena, CA		JPL	CDDIS	1	95	WHIT	* Whitehorse		NRCan	CDDIS	1	98	
JPLM	* Pasadena, CA		JPL	CDDIS	1	98	WIDC	* Sky Valley, CA			SIO			
KELY	* Kellyville		NOAA	CDDIS	1	98	WILL	* Williams Lake		NRCan	CDDIS	1	98	
KERG	* Kerguelen	CNES		IGN	5	90	WLSN	* Mt. Wilson, CA		JPL	CDDIS	9	95	
KIRU	* Kiruna	ESOC	(none) BKG	CDDIS IGN	3	94	WLSR	* Whistler		NRCan	CDDIS	2	98	
KIT3	* Kitab	GFZ	(none) BKG	CDDIS IGN	10	97	WSRT	* Westerbork		BKG	IGN	2	97	
KOKB	* Kokee Park, HI		JPL	CDDIS	1	90	WZTR	* Wettzell		BKG	IGN	2	97	
KOSG	* Kootwijk	DUT	BKG	IGN	2	98	WZTZ	* Wettzell		BKG				
KOUR	* Kourou	ESOC		CDDIS	2	95	WUHN	* Wuhan		NOAA	CDDIS	1	96	
KSTU	* Krasnoyarsk	GFZ	(none) BKG	CDDIS IGN	60	95	XIAN	* Xian		JPL	CDDIS	16	82	
KUNM	* Kunming		JPL	CDDIS	0	85	YAKA	* Yakutsk	RDAAC (none)		CDDIS SIO	7	96	
KWJ1	* Kwajalein		JPL	CDDIS	1	98	YAKZ	* Yakutsk	RDAAC (none)		CDDIS SIO	8	92	
LAMA	* Olsztyn	ISR	BKG				YAR1	* Yaragadee		JPL	CDDIS	1	96	
LBCH	* Long Beach, CA		JPL	CDDIS	1	98	YELL	* Yellowknife		NRCan	CDDIS	1	98	
LEEP	* Hollywood, CA			SIO			ZECK	* Zelenchukskaya			IGN	41	91	
LHAS	* Lhasa		BKG	IGN	3	97	ZIMM	* Zimmermanwald		BKG	IGN	2	96	
LONG	* Irwindale, CA			SIO			ZWEN	* Zveringorod	GFZ	(none) BKG	CDDIS IGN	22	92	
LPGS	* La Plata	GFZ		CDDIS	22	96								
MAC1	* Macquarie Island		AUSLIG	CDDIS	4	94								
MAD2	* Madrid	DSN	JPL	CDDIS	1	97								
MADR	* Madrid	DSN	JPL	CDDIS	12	93								
MAG0	* Magadan	RDAAC (none)		CDDIS SIO	23	70								
MALI	* Malindi	ESOC		CDDIS	2	94								
MAS1	* Maspalomas	ESOC	(none) BKG	CDDIS IGN	1	97								
MATE	* Matera	ASI	BKG	IGN	4.5	95								
MATH	* Lake Mathews			SIO										
MCM4	* McMurdo		JPL	CDDIS	1	98								

Totals: 198 stations, 85 global stations, 162 archived at CDDIS
 Notes: * indicates global stations
 | notation indicates duplicate flow of data
 Delay column indicates median hourly delay after end of UTC day to CDDIS
 No. Days column indicates number of days reflected in statistics (01-Jul-98 through 06-Oct-98)
 0 indicates no data received for time period
 blank indicates data not archived at CDDIS

These checks are necessary for data being collected hourly/daily, as well as for historical data.

The implementation of these for current data collection is straightforward. Files size checking (1) can be done by interrogating the remote server holding the data, or by the data file metadata being published and then checked (as proposed in the Seamless Archive implementation) by the center making the data originally available. Strict compliance with the RINEX vN data format (2) can be easily made by using UNAVCO's teqc utilities or any home grown RINEX file checker that is RINEX vN aware. Header information checking (3) is a little more tedious but necessary to maintain an archive with data consistent with its metadata. Header information must be compared against known site information. If discrepancies exist, archive operators would be informed.

In the case of a valid site change, log files should be published (by site operating agency) to note the change. If the discrepancy indicates that the site info is not valid, then it is the GDC's responsibility to attempt to get the operating agency of the site to correct the problem. If the problem cannot be remedied by the site operating center -either the data no longer exists or resources are unavailable - then it is the responsibility of the GDC to correct the problem in the data/metadata. This should only be done as a last resort to insure correct and quality data.

The re-checking of historical RINEX data has brought attention to file size differences, RINEX format non-compliance and incorrect header information. The same checks to current data are applied to historical data. Files size checking (1) is by far the most difficult task. If the data that was originally provided to the GDC are on-line, the check is as simple as comparing remote and local file sizes. If the data are off-line, the remote archive would be asked to make available to the GDC an archive index list; this list would contain file statistics for all off-line data. This list can then be used to do the file size comparisons. RINEX vN (2) compliance is the same as current data collection – pass the data through a RINEX format checker. Header checking is done the same for current historical data as for current data.

What does the GDC do when it finds corrupt data, which cannot be replaced by the site's operating agency? It is then the GDC's responsibility to correct the problems in the data, make comments of the changes in the header, and re-publish the data. The GDC's must be ultimately responsible for the quality of the data in their archive.

Seamless Archive for Data Discovery

Storing GPS data at distributed archives provides users with benefits such as speedier local access, and regional or research-specific data support, but it can also increase confusion when supposedly identical files contain different header information or file content, regardless of how slight the differences. These problems will increase along with

increases in regional networks. A cooperative arrangement which improves coordination of data holdings between GPS archives, combined with a basic but similar user interface, would provide data users with easier access to GPS data and metadata by allowing them to simply contact one center, instead of contacting all of them separately. We call this concept of an interoperable multi-archive system the “GPS Seamless Archive Center” or GSAC.

The strategy for a seamless GPS archive was developed by participants from ten archive centers at a workshop sponsored by the UNAVCO Facility on 11-12 November 1997 (Table 3). A summary of this workshop can be found at URL <http://www.unavco.ucar.edu/community/events/meetings/>. The primary output product from the workshop is the definition of tables used to identify specific data holdings, and mechanisms to access data from any data center in a standard manner. Although not specifically focused on the IGS data, we propose that identical methods would provide uniform access to any of the Operational, Local, Regional or Global Data Centers, and help resolve data identity, delivery and time-delay issues. Each participant in the GPS Seamless Archive Centers will maintain their individuality and bring their own strengths into play, yet provide the user community with a familiar and consistent data access look-and-feel to all archive holdings by providing standardized data access. The workshop concluded that a process and necessary software tools must be developed to define where data might exist (monument location tables), and for what time ranges. A summary description and some software tools can be found at the URL <http://www.unavco.ucar.edu/data/gsac/gsac.html>. Having this information in distributable tables means that historical information is as readily available as recent information – if a file changes, for example, due to discovery of an incomplete download which is later corrected, then the table can be updated when the file is replaced. The process of identifying data existence, data file holdings, and changes would be standardized. Regardless of the size of the data provider, identical tools and processes would be used, improving data quality and usability.

These tools can be operated by anyone wishing to participate in the GSAC process. GSAC specifications are used to create specific tables showing data holdings for each archive. The tables are stored in a well-defined manner to simplify information exchange. Some GSAC’s will advertise their own data, but for data-user’s convenience, other GSAC’s will collect these “advertisements” and provide a common interface to search and retrieve data from any of the GSAC data areas. A data requester can go to any GSAC, search the holdings-tables of all GSAC archives, and make a data request to the archive with the desired data. An overview of the GSAC concept is given in Figure 2. A follow-on GSAC meeting will be held in early 1999 to define data request mechanisms that will allow users to obtain data from any GSAC, regardless of where the data may physically reside.

Table 3. GPS Seamless Archive Participants

GPS Seamless Archive Center (GSAC)	GSAC Metadata via FTP Access (as of Aug'98)
CDDIS (NASA GSFC)	ftp://cddisa.gsfc.nasa.gov/pub/GSAC
IRIS/DMC	N/A
JPL	
NCEDC/BARD (Berkeley/Stanford/USGS)	ftp://quake.geo.berkeley.edu/pub/GSAC
NGS/NOAA	
PANGA (Cent. Wash. Univ.)	
PANGA (Univ. Washington)	
PGC/WCDA	ftp://sikanni.pgc.nrcan.gc.ca/pub/GSAC
SCEC	ftp://ramsdén.ucsd.edu/pub/GSAC
SOPAC	
UNAVCO	ftp://ftp.archive.unavco.ucar.edu/pub/GSAC
Univ. Texas-Austin	N/A

Future Directions

Y2K

How will the new millennium affect data archives? Issues to think about are: file directory structure, file naming, and data time stamping. There needs to be a way of uniquely identifying data by date. The filename doesn't do this (we are limited to a two-digit year). Timestamps in the RINEX data are two-digit year. File directory structures between archives are dissimilar and usually do not have four-digit years.

If we address each issue individually we will find that modifying the file name and the timestamps is unnecessary. We must only address the file directory structure on each GDC. If the file directory tree contains data broken down by a four-digit year, then we have a means of differentiating truly by year. The data file naming convention becomes inconsequential. The timestamp of the data records in the RINEX file will cause no problem due to the required header field "TIME OF FIRST OBS" which is Y2K compliant. The change to Y2K compliant directory structures is simple, easy to implement, and will ultimately lead to less confusion in data storage. The same approach can apply to products and the GPS week 1000 issues, i.e., by making sure products data are stored by GPS weeks using four digits and not three.

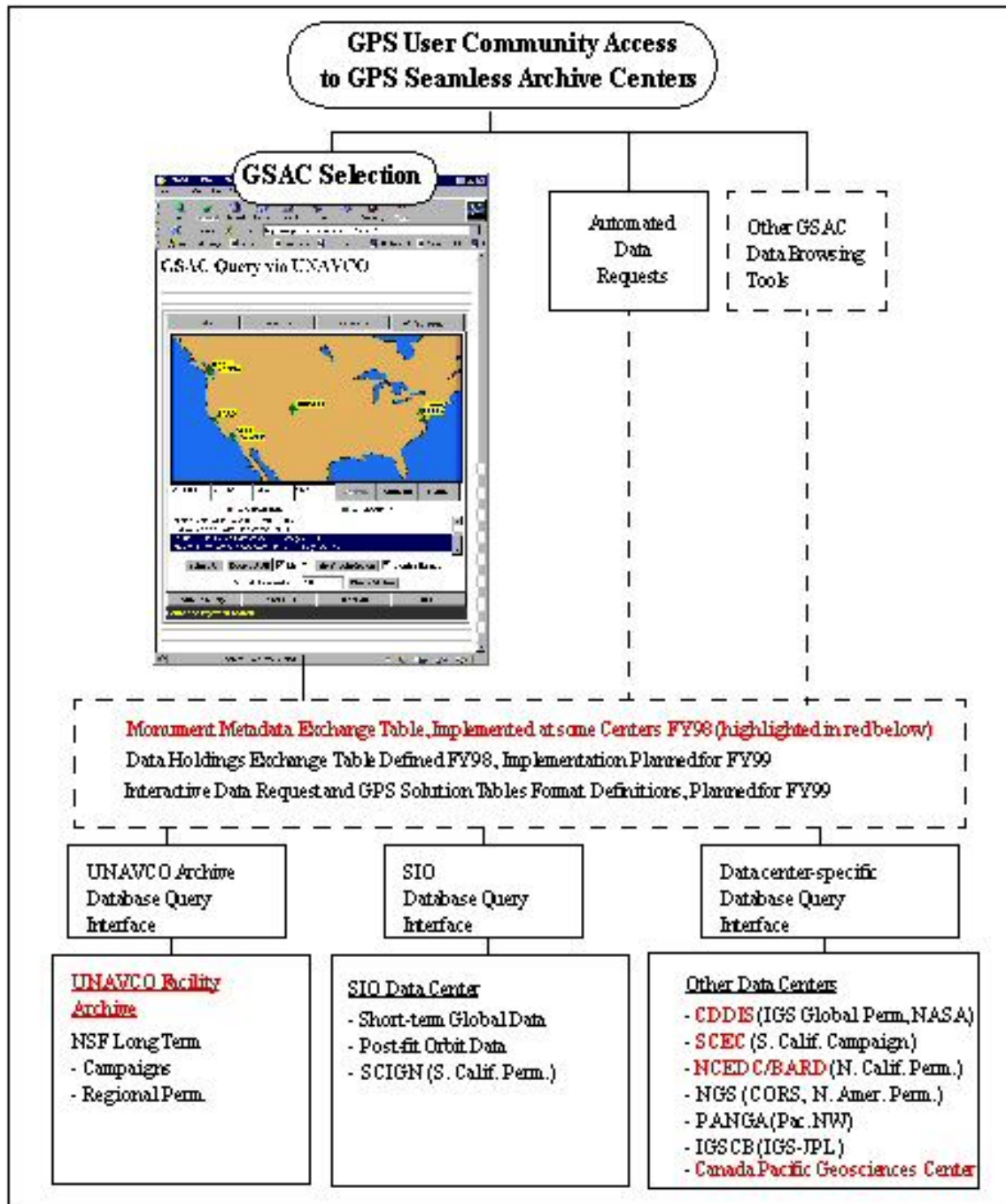


Figure 2. GPS Seamless Archive Center overview. Red indicates monument metadata exchange tables have been implemented

Data Types

GDCs should archive a common set of data types. The list of data types needs to be established. This common list by no means limits the GDC from archiving other types, but rather, provides a minimal framework. This will lessen confusion among users when navigating multiple GDCs holdings.

Data Flow vs. Data Push

There is great concern in GDCs modifying the content of data distributed or collected from RDCs or ODCs. This can cause GDCs to have different data sets. In addition, it is difficult to notify the GDCs of the re-publishing of data, and then the re-distribution from GDC to GDC. To remedy this situation a defined data flow and method of archive population needs to be established.

It has been suggested that each RDC or ODC push data to one GDC. The GDC would then push the data to the remaining GDCs. This would create a well-defined path for data flow. In the case of corrupt data or metadata, the RDC would be asked to resubmit the data to the GDC, who would then push the re-submitted data to the remaining GDCs. In the event that the RDC or ODC can not correct the problem, the GDC responsible for that data (defined by the data flow) would correct the problem and submit the data to the other GDCs. This defined flow negates the need for archive interrogation for data existence and re-submissions, handles QC issues and data re-publishing efficiently, and can be used to help troubleshoot latency problems. This method will also insure that the same data set appears on each GDC. In addition, the GDCs should adopt Seamless Archive practices of insuring that data between the archives are equivalent (using md5 and file size checking).

Data Centers Specs and Quality Control

Specifications

The components of the IGS are diversely defined in their role and duties, the level of precision is not homogeneous. More precise and detailed specifications are needed for data centers, presently only little more than the role of each type of data center is defined. For each level of data center, a clear and comprehensive list of items to comply with is needed. The users and applications of the IGS are growing at a fast pace, the IGS service itself must evolve to reflect this. In order to be in phase with this and to be able to anticipate, a continuous process of reviewing, refining and modifying the specs should be established. Input should be searched from all parts of the IGS (data and analysis centers, users, etc.), even complaints should be encouraged. Analysis centers for example should

be asked to provide a list of things they expect from data centers (whether or not they actually get them).

A preliminary list of the items that should be documented:

- 1) set of data and formats archive at data center
 - list of stations
 - list of products
 - list of other data
- 2) reporting
 - what should be reported, how (mail, web, ftp), time period, report layout, normalization
 - list of technical characteristics that should be published (extend the data center description form)
- 3) operational constraints
 - delays
 - number of concurrent accesses
 - Internet link rate and quality
 - quality checks

Quality Control

There are already some quality checks running about many things in the IGS, but as far as data centers are concerned there are no precise and routine evaluation procedures. Each data center has its own set of internal procedures. There are some raw checks done by the IGS CB but this is not enough; in order to get a clear view of what is going on and what should be improved or modified, the IGS needs to define and run a new set of evaluation procedures.

Each center has its own strong points and weak points, a monthly or weekly evaluation procedure should help improve the overall quality of service to users and to other components of the IGS. This should not be oriented as a good guy/bad guy discrimination process but as an objective and reliable reference for each center to help them refine their contribution.

Network

The IGS network should be considered as a component of the IGS itself. There should be a clear role in the IGS organization taking in charge the set up and evolution of the network. As is more and more the case in computer technology, the network itself is a major component of the overall structure. All centers participating in the IGS have a little part in the network but no one is in a place to take this in charge, even the global data

centers. This is becoming more and more important as near real time activities are emerging. Some points in which more control and information are needed:

- data flow paths, minimizing duplicate paths, optimizing delays (as when a new station is integrated, there is a need to define the path and enforce it)
- backup paths and procedures (they are very rarely tested, in part because the network is reliable but the worst can always happen)
- assessing network performances and limits (also in a proactive way, similar to what is done in classic LAN network administration)
- users should be included in the picture. There is no point in having the best network for IGS internal management and not for users (e.g., a fair amount of users in Europe seems to access the service through a U.S. global center. This fact implies that something must be wrong somewhere)
- raise a flag when something is wrong (e.g., an unusually low data rate between selected centers, sub-optimized data path, etc.)
- plan for future experiences and evolutions (can the network deal with future plans, if not what should be done)

Knowing Our Community

We can only guess what is the IGS user community, we cannot get the big picture. This is too bad because we could improve the IGS by a better knowledge of our users, who they are, how many they are, what they use the IGS for, what they think of the service in general, etc.

The IGS has become involved in many fields as are its users; having more information about them is becoming a requirement to maintain and improve the service in the future.

Data centers already have a rough idea (the level of detail may vary, depending upon the techniques used for providing the data, anonymous or named ftp, for example), this can be used in a first step to establish an initial version of a user database.

In a second step, users should be encouraged to reference themselves in our user database; i.e., the CB could establish a page on the IGS web site to welcome comments and opinions. An IGS users mailing list could also be planned (maybe just think about it and see if it is feasible). This has to be coordinated with the PR activities presently done by the CB as part of its role.

Recommendations

- Stations should comply with established station guidelines. A recent IGS document authored by the IGS Infrastructure Committee on station guidelines will soon be available on the CBIS web site.

- Stations and data centers should review current data flow with the intent to improve timeliness.
- All stations used in routine AC analysis should deposit log files in the CBIS.
- Under the IGS “umbrella”, data centers should only archive data from official IGS sites. Network and data center contacts should work with stations that submit data to ensure all required documentation is complete and available through the CBIS.
- Data centers should implement data holding verification routines to ensure equality in data holdings.
- Data centers should consider common directory structure to aid users in downloading data from multiple centers.
- SIO should further study procedures for quality-checking historic data.
- IGS data centers (at all levels) should participate in seamless archive activity.
- The various components of the IGS should establish and test backup data flow paths.
- A continuous process involving all parts of the IGS should be established to review and refine the standards of each component involved in the data flow activity. In a first step, the role and duties of the global and regional data centers have to be redefined with respect to the development of near real time activities in the IGS.
- The IGS CB should define and run, in a periodic way, a set of quality control routines to evaluate the quality of service and assess the compliance of each data center with respect to the IGS standards.
- An IGS network manager or a working group on network management within the IGS should be appointed. The main point is to be able to evaluate, plan, and adapt the network in a context of rapid changes and increasing activity. The attributions have to be clearly defined, they would encompass the whole IGS network (i.e., stations, data centers, analysis centers, and users).
- The IGS should obtain a clearer view of who our users are and what they need. Any part of the IGS involved with a user interface activity (CB, data centers, scientific meetings, etc.) contact and feedback from users should be queried. A user database, CBIS web page, and a mailing list should be set up to support this.

References

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Status of Compact RINEX

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Introduction

The compact RINEX format (Hatanaka, 1996a, b) was introduced to IGS in January 1998 after the testing period. The status and feedback for the compression programs in 1998 are listed in Table 1. In this short article, the author tries to summarize the good and weak points of the format based on the feedback from users.

The Good and Weak Points of the Compact RINEX Format

A good point of the compression format is, of course, high compression rate. The compressed files are in ASCII text format, and, by combining with UNIX compress, the file size becomes about 1/8 of that of original RINEX files in the case of 30 second sampling. The format is almost completely compatible (or equivalent) with the RINEX ver. 2 observation file format. Since the header information in the original file is conserved without modification, it's easy to confirm the content. The compression program ends up with error, when format error or corruption in an original RINEX file is detected, so, as a side effect, the compression program works as a format checker. The Compact RINEX format is applicable to the RINEX observation files of GLONASS/GPS as well, and used for the data exchange in IGEX campaign.

The problems mentioned in the most of the feedback are not related to the format itself, but to bugs in the programs or errors in original RINEX files. There was one comment mentioning the weak point of the compression scheme concerning the integrity. The compression scheme takes differential operation: values of n-th order time-difference are saved in a Compact RINEX file together with their initial values. Consequently, if once continuity of data sequence is lost by data corruption or something, the remaining part of the data can not be salvaged. (Note that it's often the case for UNIX-compressed files that some data after the corruption are recovered.) This shortcoming could be minimized by initializing the compression procedure of all data periodically, every 100 epoch for example, but with slight increase of file size. Then the data after the epoch of the entire-initialization can be salvaged by assuming that number of data types is not changed during corruption. Although the Compact RINEX format was designed to allow this procedure, it is not implemented into the compression/decompression programs yet. The implementation of this function is scope of development in near future.

Table 1. Status history and Q and A log of Compact RINEX format and programs since the introduction of the format to IGS.

date	description
1998.01.14	Introduction of CRINEX to IGSCB (IGSmail #1785) (ver.2.2beta)
1998.02.07	Q: Error in converting RINEX Ver.1 files. A: CRINEX format is compatible with RINEX ver.2 files, not with ver.1. Comment: This should be indicated in error message.
1998.02.07	Q: Error in converting RINEX files containing cr/lf pair. A: The files are compressed by an old version of the software (Ver.1.8) which has a bug which happens when applied to DOS files on non-DOS system.
1998.03.02	Implementation of CRINEX in JPL (IGSmail #1821)
1998.05.06	Q: My RINEX file can't be compressed by RNX2CRX. A: There is a format error. Check RINEX converter.
1998.06.19	Q: RNX2CRX can't convert the sample RINEX file in the RINEX documentation. A: A bug in dealing with event flag without # of line. Use new version (Ver. 2.3beta).
1998.06.23	Update the program in IGSCB to Version Ver. 2.3beta.
1998.07.31	Q: Are there OS/2 version of tools? A: No. Try compiling the programs from the source codes.
1998.07.31	Q: The execution of the binaries crashes. The binaries are copied through WWW. A: The size of the file is not the same as the original one. There seems to be something wrong with the compatibility of the WWW browser. Try binary transfer by FTP.
1998.08.01	Q: How to decompress corrupted CRINEX files? A: It's impossible to decompress the part of the data after the corruption. Data integrity is a weak point of CRINEX format.
1998.09.17	Q: Trouble in compressing GLONASS/GPS file from Z-18 receiver. A: Format error in the RINEX files. Check RINEX converter.
1998.10.29	Q: Trouble in compressing GLONASS/GPS file from Z-18 receiver. (IGEXmail #0048) A: Suppose the same problem as previous (IGEXmail #0050)

Conclusion

Judging from above discussion, it is concluded that the Compact RINEX format is suitable for data transfer in near real-time or non real-time and data archive, but not for applications in (really) real-time, or for those high integrity is required. Fortunately, the weak integrity of the format seems not very big problem for IGS activities at current.

The compression/decompression programs are available from;

<ftp://igs.cb.jpl.nasa.gov/igs.cb/software/rnxcmp/>

<ftp://terras.gsi-mc.go.jp/pub/software/RNXCMP/>

Acknowledgement

I would like to thank to all of people who sent me questions or comments. Their comments are helpful to find bugs and to improve the programs.

References

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