IGEX-98 Data Flow

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Abstract

The International GLONASS Experiment (IGEX-98) was organized to conduct the first global GLONASS observation campaign for geodetic and geodynamics applications. During the initial planning phases, it was decided to utilize, as much as was feasible, the existing infrastructure of the International GPS Service (IGS), which has been operational for nearly five years. This paper discusses the data flow utilized for IGEX-98, data latency, and the various problems that were found and their impact on the service as a whole.

Introduction

The infrastructure created to support the International GLONASS Experiment (IGEX-98) was modeled after that of the International GPS Service (IGS), thus allowing for a logical, efficient flow of data and information. In fact, many of the participants in IGEX-98 were active contributors to the IGS. A hierarchy of data centers, similar to that used in the IGS, was established to promote reduction in data traffic over electronic networks as well as allowing for redundancy and backup of data holdings. A web site (*http://lareg.ensg.ign.fr/IGEX*) was established early in the planning process to facilitate communication, particularly in the dissemination of standards for stations and data centers.

Participation Summary

The overall participation in the IGEX-98 was greater than expected. Although the official IGEX-98 campaign ran from October 19, 1998 through April 19, 1999, the transmission of data began in late August 1998 and continues to this day. During the 182 days of the campaign, 74 receivers at 62 sites sent data to the IGEX data centers. This figure includes 47 dual-frequency and 20 single-frequency GPS+GLONASS receivers and seven GPS-only receivers (for ITRF collocation purposes). Furthermore, thirty SLR stations tracked eighteen GLONASS satellites during the actual experiment time frame. Nearly 6500 passes and 37K normal points were archived for the six-month period. Detailed listings of these data holdings can be found in [Noll, 1999]. At this time, approximately 35 GLONASS receivers continue to operate and send data to the data centers; the global SLR network also continues to track a subset of GLONASS satellites. The tracking station network supporting IGEX-98 during the campaign period and today is shown in Figure 1.

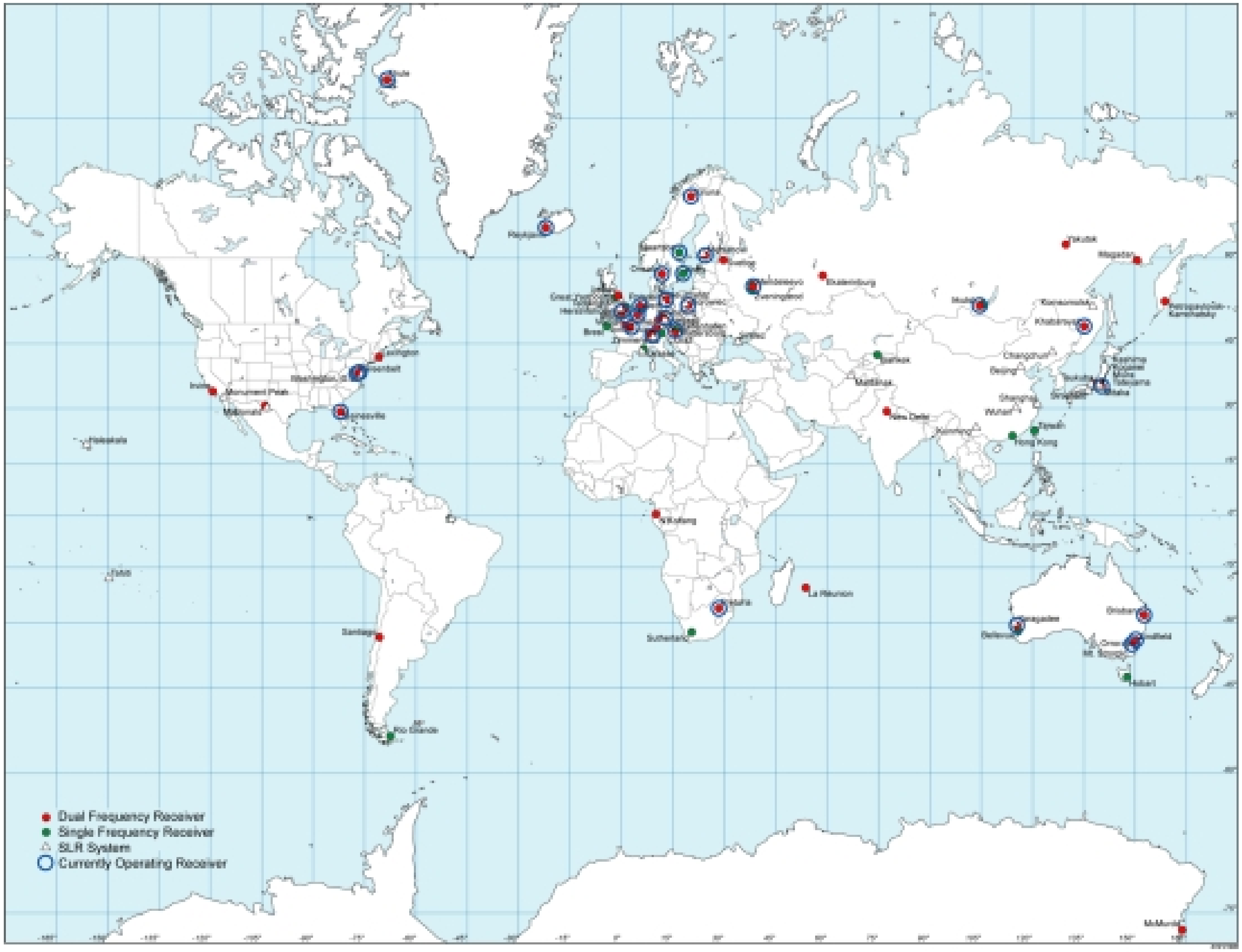


Figure 1. IGEX-98 Network

IGEX Data Centers and Data Flow

Data centers supporting the IGEX-98 were divided into three categories (as in the IGS): operational, regional, and global. Operational Data Centers were responsible for connecting to the tracking station on a daily basis through automated procedures, downloading the daily file, converting the raw receiver data to RINEX, providing an initial check of the quality of the data, and then transmitting these data to regional or Global Data Centers. This check of data quality should also ensure that the station's data prescribes to published standards for RINEX, information in the header agrees with the site log on file, and that the data are readable. Regional Data Centers gathered data from sites in a particular region (e.g., Europe and Australia), and forwarded selected data then to a Global Data Center. Global Data Centers provided access to IGEX data and products to the Analysis Centers and the user community in general. The major data centers that proposed and participated in the IGEX-98 are listed in Table 1.

Table 1. Principle IGEX-98 Data Centers

Acronym	Full Name	Type
AUSLIG	Australian Land Survey and Information Group, Australia	Operational, Regional
BKG	Bundesamt für Kartographie und Geodäsie (BKG), Germany	Operational, Regional
CDDIS	Crustal Dynamics Data Information System, USA	Global
DLR	Deutsches Zentrum für Luft-und Raumfahrt, Germany	Operational
ESA/ESOC	European Space Agency Space Operations Center, Germany	Operational
GFZ	GeoForschungsZentrum Potsdam (GFZ), Germany	Operational
IGN	Institute Geographique National, France	Global
NCKU	Satellite Geoinformatics Research Center, Taiwan	Operational

A general overview of the flow of IGEX data and information is shown in the diagram in Figure 2. As can be seen from this figure, the Global Data Centers were the prime source of IGEX data and products for the user community. Figure 3 represents the data flow on a site and data center basis. Here it is evident that many institutions were involved in the download of data from the network of over seventy receivers.

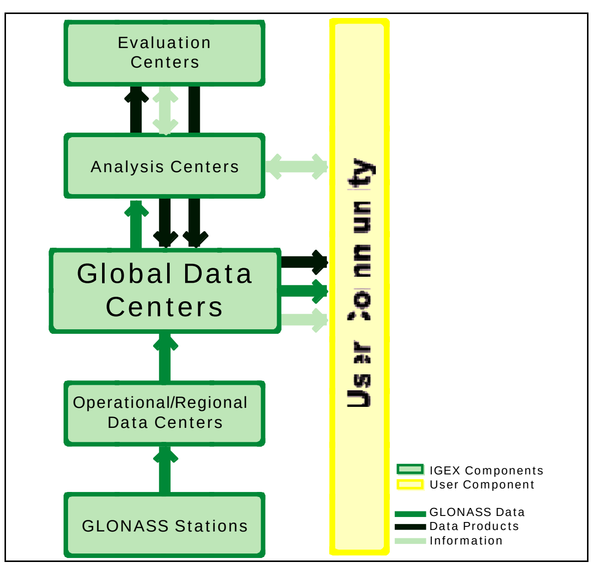
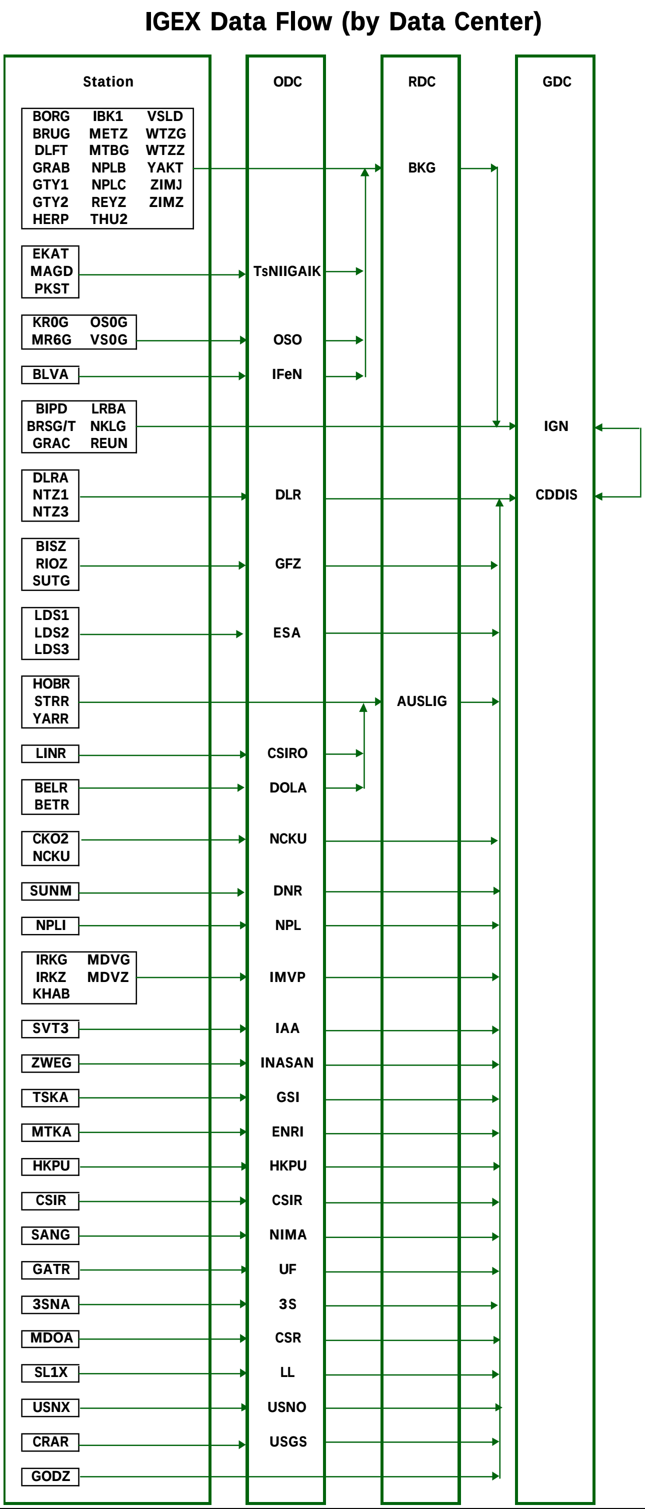


Figure 2. IGEX Data Flow



Acronyms

AUSLIG	Australian Land Information Group
BKG	Bundesamt für Kartographie und Geodäsie, Germany
CDDIS	Crustal Dynamics Data Information System, USA
CSIR	Council for Scientific and Industrial Research, South Africa
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
CSR	Center for Space Research, University of Texas at Austin, USA
DLR	Deutsches Zentrum für Luft-und Raumfahrt, Germany
DNR	Department of Natural Resources, Australia
DOLA	Department of Land Administration, Australia
ENRI	Electronic Navigation Research Institute, Japan
ESA	European Space Agency, Germany
GDC	Global Data Center
GFZ	GeoForschungsZentrum, Germany
GSI	Geographic Survey Institute, Japan
HKPU	Hong Kong Polytechnic University, China
IAA	Institute of Applied Astronomy, Russia
IFeN	Institute of Applied Geodesy/University FAF Munich, Germany
IGN	Institut Geographique National, France
IMVP	Institute of Metrology for Time and Space, Russia
INASAN	Institute of Astronomy, Russian Academy of Sciences
LDC	Local Data Center
LL	Lincoln Labs, USA
NIMA	National Imagery and Mapping Agency, USA
NCKU	National Cheng Kung University, Taiwan
NPL	National Physical Laboratory, India
OC	Operational Center
OSO	Onsala Space Observatory, Sweden
RDC	Regional Data Center
TsNIIGAIK	Central Research Institute of Geodesy, Aerial Surveying, and Cartography, Russia
UF	University of Florida, USA
USGS	U.S. Geological Survey, USA
USNO	U.S. Naval Observatory, USA
3S	3-S Navigation, USA

Figure 3. IGEX Data Flow

IGEX Data and Products

The IGEX data centers provided the user community access to both GLONASS data and the products derived from these data; the IGEX-98 data center at the Crustal Dynamics Data Information System (CDDIS) also archived SLR tracking data from the GLONASS satellites. The GLONASS data (non-SLR) consisted of daily files containing GPS/GLONASS data sampled at a thirty-second rate. In addition to these observation data files, the data centers archived GPS and GLONASS broadcast ephemerides and meteorological data (if available). All data were archived in UNIX-compressed RINEX format, where the observation files were compacted (using the Hatanaka scheme [Hatanaka, 1996]). Each tracking station produced approximately one half Mbytes of data per day in compressed RINEX format. Ideally, the data flowed from the tracking station to the Global Data Centers within 48 hours of the end of the observation day. However, on average, at the CDDIS, ten percent of the data were received within twelve hours; thirty percent within 24 hours.

The GLONASS SLR data consists of round trip pulse time of flight to the satellite. The data points obtained during a typical satellite pass are compressed using sampling over time based upon the presence of some minimum number of data points in the sampling interval, thus creating normal points. These normal point data were available to the user community through the Global Data Centers supporting the International Laser Ranging Service (ILRS) at the CDDIS and the EuroLAS Data Center (EDC) in Germany.

The data files (non-SLR) archived at the IGEX data centers followed the same naming scheme as used by the IGS, **ssssddd#.yyt**.Z where:

- **ssss** is the unique four-character monument ID assigned for the site
- **ddd** is the three-digit day of year
- **#** is a sequence number for multiple files for a single day; this is typically 0, implying the file contains all data for the day
- **yy** is the two-digit year
- **t** is the file type:
    - o is an observation file
    - d is an Hatanaka-compressed observation file
    - n is a GPS navigation (broadcast ephemeris) file
    - g is a GLONASS navigation (broadcast ephemeris) file
    - m is a meteorological data file
    - s is a summary file generated by quality-checking software at the data centers and containing data quality meta-data information
- .Z indicates a UNIX-compressed file

The CDDIS generated daily GPS and GLONASS broadcast ephemeris files; each file contained all navigation messages for the GPS (filename *brdc**ddd**0.**yy**n.Z*) and GLONASS (filename *igex**ddd**0.**yy**n.Z*) satellites recorded by the tracking receivers for that day. Analysts utilized these two files rather than downloading all individual broadcast ephemeris files.

IGEX products were generated operationally by six Analysis Centers (as shown in Table 2) as well as the IGEX Analysis Coordinator. These products consisted of daily GLONASS precise ephemerides (in SP3 format), satellite clock information, and station coordinates (in SINEX format). The files were transmitted to the Global Data Centers for archive and distribution to the general user community. As with the GLONASS data files, the product files utilized the same naming conventions established by the IGS, **ssswwww#.typ**.Z where:

- **sss** is the acronym for the Analysis Center
- **wwww** is the four-digit GPS week
- **#** is the day of the week, e.g., 0 for Sunday, 6 for Saturday, and 7 indicating the data span the entire week
- **typ** is the data type:
    - sp3 is an orbit file in SP3 format
    - eph is an orbit file in SP3 format
    - pre is an orbit file in SP3 format
    - erp is Earth rotation parameter data
    - snx is a file containing precise coordinates in SINEX format
    - ssc is a file containing precise coordinates in SINEX format without supporting matrices
    - sum is a summary file detailing analysis information
- .Z indicates a UNIX-compressed file

All filenames used at the data centers (for both data and products) are in lowercase, with the exception of the .Z indicating a UNIX-compressed file.

Table 2. IGEX-98 Analysis Centers Supplying Results to the CDDIS

Acronym	Source	Time Period
BKG	Bundesamt für Kartographie und Geodäsie (BKG), Germany	Weeks 0980 through present
COX	Center for Orbit Determination (CODE), AIUB, Switzerland	Weeks 0979 through present
ESX	European Space Agency Space Operations Center (ESA/ESOC), Germany	Weeks 0980 through present
GFX	GeoForschungsZentrum Potsdam (GFZ), Germany	Weeks 0983 through 1001
JPX	Jet Propulsion Laboratory (JPL), USA	Weeks 0991 through present
MCC	Mission Control Center (MCC), Russia	Weeks 0980 through present
IGX	Combined IGEX Solution, University of Technology, Vienna, Austria	Weeks 0981 through 0989

Problems Encountered

As with the start of any new program, numerous problems were identified by the data centers while archiving the data sets and making them available to the user community. These problems are summarized in Table 3. A majority of these problems were due to non-conformance to published IGEX-98 documentation, such as missing or incomplete site logs and RINEX header information. Although operators may have considered these discrepancies "minor", conformance to the standards enables data centers, analysis centers, and users to analyze the IGEX data in an efficient, automated fashion and ensures consistency among results from multiple disciplines.

Table 3. IGEX-98 Data Problems Encountered at the CDDIS

Problem "Category"	Description/Examples
Missing site logs	CK02, EKAT, GATR, MAGD, NCKU, NPLI, PKST, YAKT
TEQC	Required modification for GLONASS data type Required modification to handle manufacturer-supplied RINEX converters
File format problems	Compression (GZip used instead of UNEX compress) ASCII used instead of binary in file transfers Extra <CR>s in files
File naming conventions	Upper case instead of lower case .Z not used or used incorrectly to indicated UNIX compressed file Misnamed files (d instead of o)
Empty files transmitted	
RINEX headers	Non-conformance to published standards Missing required lines
Receiver/antenna naming	Non-conformance to recently-published IGS standards
RINEX version	V1 instead of V2
Satellite number 0	Valid output for GG24 receiver Invalid for RINEX format
RINEX converter problems	Time regression error with 3S converter Field overflow (phase data) in Z-18 converter

Many of the problems could have been diagnosed by Operational Data Centers prior to transmission to the IGEX data flow. For the most part, these problems where detected by the CDDIS when quality-control software, in particular UNAVCO's TEQC [Estey, 1998], failed and thus required human intervention in otherwise automated routines. When these problems were diagnosed at the CDDIS, messages were sent to the station or its Operational Data Center detailing the nature of the problem and requesting a re-supply of all files.

Conclusions/Recommendations

In general, the flow of GLONASS data and products in IGEX-98 performed well given the diverse nature of the community involved in the experiment. Some recommendations, however, are in order should IGEX-98 continue in some form in the future:

- Tracking stations should follow prescribed guidelines, thus ensuring timely, automated processing of data by both data and analysis centers.
- Operational Data Centers should be clearly identified and perhaps consolidated to ensure timely and efficient flow of data. Responsibilities of these centers need to be clearly identified. These data centers should perform a more rigorous check on data quality, perhaps standardizing the use of such software packages as UNAVCO's TEQC throughout the IGEX infrastructure.
- Global Data Centers need to ensure consistency among themselves, thus ensuring equalized data holdings for the user community and for backup purposes.

References

Estey, L. “TEQC Summary”, in *IGS Network Systems Workshop Proceedings*, 1999.

Hatanaka, Y. “Compact RINEX Format and Tools”, in *IGS 1996 Analysis Center Workshop Proceedings*, 1996.

Noll, C. “The IGEX Data Center at the CDDIS”, in *Proceedings of the IGEX-98 Workshop*, 1999.