IGS

SESSION 6

NETWORK MONITORING

IGS Network Monitoring

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Abstract

The IGS network continues to evolve, ever being shaped and influenced by applications. Data quality and integrity within the IGS become even more critical as the network continues to grow each year and there is certain pressure for rapid data and products. Monitoring this process, which is a collective and collaborative operation of nearly 80 agencies, must be approached in mind of interdependence and the commitment to take appropriate action. What can be realized within the IGS is an efficient and rapid monitor and response function. Monitor and control issues differ from this approach since each agency has purview and resources to perform the actual 'control' functions. However, with monitor and response, and close collaboration within the IGS, those people having controls can take appropriate actions. Monitoring within the IGS should expand to cover the satellite system performance, feedback to the IGS components and any advisory necessary to ensure the continued functioning of the IGS at expected levels. These expected levels, which stem from requirements, will need to be defined, especially for the emerging application networks of the IGS.

Introduction

It is first important to ensure that everyone involved agrees to a set of assumptions:

- Data quality and assurance within the IGS network system *begins* at the station level and is critically dependent on station operations, communications, operational centers, data centers and analysis centers.

- Each component of the IGS is responsible for contributing to the quality aspect of the IGS data and products.

- Monitoring the collective network operations of a cooperative group like the IGS depends on observation of similar standards and procedures by each of the contributing agencies. The IGS can and should monitor and respond to the IGS network system, however, each agency should be responsible for the control of their site, operations, or data centers. Therefore, individual agencies can perform monitor and control functions, whereas the IGS Network Coordinator, and the CB, with assistance and support from the Infrastructure Committee, Data Centers and the ACC can monitor and react.

- Timeliness of IGS monitor and response to problems or anomalies may ultimately depend on the use of the station. Stations necessary for rapid products or reference frame definition must be monitored in such a way as to provide for timely notifications to the appropriate IGS components.

Developing Requirements for Stations and Application Networks of the IGS

An application network in this context does not equate with a *regional* network; an application network (alternatively known as a sub-network) is a subset of the IGS stations which is used to support a particular application, such as a specific IGS project. Some examples of existing and developing application networks follow.

Any station contributing to the global, daily rapid products must have low latency high quality observations, must be reliably available (good communications) and are generally also selected as a subset based on their geographic distribution. This has been defined as the IGS Global Network, a subset of the IGS International Tracking Network. (~90 stations currently)

Stations being planned for the LEO network support must have high rate data sampling (<30 sec), hourly to sub-hourly downloads, and low-latency between the receiver and the processing centers. These stations must have reliable communications, and high quality observations including elevation angles below 20 degrees. These instruments may generate simultaneously high rate data (1sec) and the hourly data files (30s) for the IGS. (~25- 30 stations)

GPS stations for long term sea-level monitoring need to be surveyed precisely to the tide gauge benchmark reference location and must be developed within the ITRF. Vertical measurements are critical, hence high quality observations again are very important, while realizing that implementation of the instruments is site specific, geologically dependent and difficult at or near the coastal tide stations. Timeliness of data retrieval is not a key requirement. (~up to 80 stations).

Sea level related stations for altimeter calibration have other requirements. This depends on stable stations achieving vertical accuracy of 1-3 cm within 1 -3 years. Stations are expected to operate for a long period of time, certainly the life of the altimeter missions and any overlapping missions. The station distribution is also different, with the network stations lying on continental perimeters and ocean islands. (~30 stations)

GPS stations for the IGS tropospheric project require precise meteorological instrumentation, particularly the barometric pressure sensor. At this time, there are few requests for rapid turnaround of the zenith path delay (ZPD) from the global network. The results of this type of analysis primarily benefits climatology, however, there are different opinions from the atmospheric experts as to the required timeliness of the data for that climatological purposes (~within a day to within 6 months). Atmospheric applications for weather forecasting lean towards denser arrays in regional areas and are estimated to require 30 minute data download and continuous processing. This application is best supported by the IGS through the production of rapid and high quality global products, i.e., there is little role for the IGS to be involved in such specific regional applications.

GPS stations for ionospheric applications may require a higher sampling rate especially at the poles and along the equatorial regions (where coverage is currently rather limited). To be useful for near-real time purposes, data is required every hour; for ionospheric research and studies, timeliness is not an issue. For ionospheric scintillations, very high-rate tracking loops and perhaps sampling output are needed, and imply on-site preprocessing rather than large datafile transfers.

GPS stations for precise time transfer as in the IGS/BIPM project have requirements that ride on those for the (current) daily global products. There must be collocation at time and frequency laboratories and great care must be taken with environmental stability, instrumental delays (cables, etc.) and relations between station instrumentation. The local ground sites and the satellites must be understood and characterized.

GLONASS collocations within the IGS is currently at the experimental level. One could anticipate that the future of this activity is dependent on a number of factors, especially the stability and robustness of the satellite constellation.

Actions must be taken which lead to identification of network requirements and understanding of user needs; subsequently, monitoring and response can be clarified and developed:

- Develop a matrix of stations available through the IGS and identify stations based on their functional characteristics and capabilities for supporting various applications.
- Identify and specify requirements that the IGS operations and projects place on the system.

In considering the requirements for such application networks, it seems timely to also consider the distinction and relative relationships between the IGS global network and regional networks. Improved information handling must be addressed.

Fundamental Information

Site logs are the long term, fundamental source of information concerning a station. RINEX headers are generated daily and should reflect the correct information as contained in the logs. These must agree otherwise discrepancies arise as have been well documented by the ACs, and quality and consistency become questionable, not only for the those discrepant instances, but for the entire system. The only time when site log information and RINEX header information should differ is the short period of time when a station is undergoing a configuration change. In this case, the normal process is to post an advisory notice to IGSMail and update the site log immediately or within an agreed to and specified period of time.

Development of an automatic site log program is underway within the Infrastructure Committee, with Scripps is taking the lead in this effort. This program would generate site logs for new sites, and accommodate easy editing of the site logs to improve updates to configurations. Currently, sitelogs must be retrieved by the operation agencies and then resubmitted to the CB. We envision a web access tool for submitting logs, for making changes, and editing information which should reduce the turn-around time, and actually improve the standardization of the logs. It is recommended that this should be a standardized program which can be accessed at the CBIS, at any data center or used even in the field for station implementation or epsiodic campaigns. It is vital to preserve the historic integrity of the data and the related information as this data becomes increasingly valuable as time passes. The IGS has contributed greatly to an international standard for a site log information, but more work is needed.

We recommended that the site log of any site used for IGS products or projects be located at on the CBIS. Site logs should be available at or through the CBIS, and a process can be established so that confirmed site logs for any station used in the context of IGS can be kept on the CBIS for easy access. Separate file directories may be needed, but a repository of all logs would be valuable to maintain and provide. For example, if a station's data is being used by an AC for submission to the densification combination, the log file should be available so that all information can be maintained, the RINEX can be verified and the SINEX information generated and consistent. Many reports of inconsistent information stem from the lack of a site log at the CBIS. There are log files existing at global data centers, using the IGS standard log file format, and which do have DOMES numbers, etc. The data are picked up by ACs and used, but there is limited access to the site logs, and hence the fundamental information is missing. The information in the site logs is also needed to generate the SINEX standard template -- and to compare the RINEX headers for verification. There are various reasons why site logs exist at GDCs and not at the CBIS. This issue will be resolved.

Maintaining the official site logs and establishing appropriate links at the CBIS to other repositories of logs (e.g., regional networks) will improve global bookeeping of the fundamental information. It will also help in the allocation of the site identifiers (aka 4-char id), and improve the robustness of the automatic verification programs.

Monitoring, Response and Metrics

As the IGS network develops, increasingly stringent requirements stem from some of the applications. Monitoring is therefore expected to evolve to meet the applications' demands. Two interesting improvements are both at the station level; first, the need for high reliability and low latency, teamed with the tendency toward multi-instrumented sites and today's low-cost computers, have driven efforts to outfit sites with computers and software capable of performing on-site monitoring of data. Such a scheme (previously referred to as "Smart Sites" or "LIM, Local Integrity Monitoring") enables the site itself to immediately notify its controlling Operational Data Center upon noting an undesirable change in data quality or quantity. Rune Hanssen notes that this onsite style of monitoring, as contrasted with Operational Center monitoring, does not consume either communications or Operational Center resources when station operations are nominal. A second station-level improvement to be discussed below is the recognized need for station personnel to be better informed about the IGS' use of their data and to assume an important place in the IGS community.

Data Center Issues and Monitoring Quality Control

Operational Data Centers face a tradeoff in deciding what level of quality control to apply to data prior to transmitting it to a Regional or Global Data Center. Overly stringent application of quality control may result in unnecessary delays in transmission of data, as well as an increased likelihood of data being improperly flagged as abnormal. On the other hand, insufficient quality control clearly may lead to release of data which causes the Analysis Centers at least an annoyance, if not a hindrance in producing a quality product. Operational Centers, therefore, must choose an appropriate level of quality checking and remain vigilant in assuring that it does not evolve into a system of too much or too little quality control in the future.

A set of simple measures can be quickly calculated by an Operational Data Center Data to determine whether datasets are suitable for transmission to a Regional or Global Data Center. Herb Dragert suggests that the following items be monitored on a daily basis: Site ID, Year, Julian Day, start time, stop time, sample rate, number of observations, number of data gaps, number of cycle slips, mean Ionospheric variations (narrow lane noise normalized by sample rate), and mean multipath variation. Nearly all of these measures can be obtained through use of UNAVCO's TEQC software. Twice the nominal variation may indicate a problem. Additionally, much attention has been focused recently on the fact that site documentation does not come from one well-defined source, but several (site logs, SINEX files, RINEX headers, etc.) which may become discrepant with respect to one another. Quality assessment considerably more complicated than these metrics is perhaps better left to later processing, to avoid delay in data availability.

A report to the IGS Infrastructure Committee by Bjorn Engen and Hans-Peter Plag suggests that the optimum method for handling discrepant as well as otherwise poor data is for Operational Centers, Data Centers and Analysis Centers to approach the problem as a community, with each operational unit accepting responsibility for contributing to the monitoring of data. In this community, each party is expected to monitor the data appropriately to its IGS function; and most importantly, to provide targeted feedback downward toward the data source when problems are detected. Engen and Plag note that "to avoid the creation of too many up- and down- messages, a careful consideration of the message exchange structure and format is required," and this proposal will certainly fail if the community produces more noise than signal in terms of useful feedback. Uniform application of monitoring metrics including simple trend analysis as well as absolute measurements is therefore indicated.

The IGS Central Bureau, and in particular the Network Coordinator, will take an active role in this community. An example may be found in the activities of the Network Coordinator for EUREF, who personally and continually checks for discrepant logs vs.

headers, calling upon the Analysis Centers to halt processing of any discrepant site until an announcement is made that the problem has been eliminated (usually through collaboration between station managers and the Network Coordinator). Carine Bruyninx points out that an aspect of the IGSCB that could be greatly improved is of increased feedback especially to stations but including various IGS components. Other suggestions for how the CB may assist in community-building center around an improved CBIS (Central Bureau Information System) which will include a more complete FAQ where users may instantly obtain answers to some of their questions, improved request routing and tracking for those items which require exchanging email with the CB, and perhaps communication vehicles such as newsgroups or chat rooms with scopes varying from general to specific functional entities within the IGS. The Network Monitoring Working Group also suggested yearly "accreditation" of sites, signified by a certificate suitable for display, to encourage a yearly refresher in each site log and review of IGS Guidelines.

Questions to Consider

What metrics should be applied for monitoring of the IGS network?

Is the critical issue the quality of the data (currently) or is it the inconsistency of related information (site logs, RINEX header etc.,)?

What are the threshold ranges of acceptability, performance criteria for station data?

When and where should alert flags be raised?

What are the key indicators that operators and data centers use to signal 'normal' operations?

Can ACs define performance levels of acceptability for data and stations based on the final solutions or the application?

Recommendations

1. Consistent monitoring and response for the IGS stations used for rapid and daily products and for the definition of the IGS ITRF realization must be performed.

2. Application networks requirements must be assessed and the various levels of monitoring and quality control defined.

3. The effort to 'benchmark' the IGS network communications map should be completed and maintained so that data transfers can be defined for the entire network and communications performance and enhancements assessed.

4. The automatic site log generation and editing program should be implemented at the CBIS, and made available at all data centers to facilitate creation and maintenance of official standardized site logs.

5. The CB and GDCs should make a concerted effort to ensure that site logs for data at the GDCs are logged at the CBIS.

6. All site logs for any station used to generate IGS data or products should be logged and maintained at the CBIS. Appropriate links to site logs and fundamental information at regional network centers will be investigated and established.

7. Monitoring statistics, metrics and tools implemented at the CBIS and GDCs will be reviewed and improved.

8. Daily checks of the verification of the site logs to the RINEX headers and SINEX files will be performed with appropriate responses and notifications.

9. If there are discrepancies between the site log and the RINEX header, the IGS Network Coordinator will contact the station manager and work to ensure that the errors are corrected. Advisories to DCs and ACs will be sent.

10. A feedback process to stations and data centers will be aggressively implemented.

11. Develop a plan for addressing issues related to regional network data and the global network or application network data and fundamental information.

12. Stations and/or Operational Data Centers should monitor observational data daily.

13. Network Coordinator should monitor solutions weekly.

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Numerous

References

Working group discussion attendees during the workshop:

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