Network Issues

Position Paper from the 2004 IGS Workshop in Berne, Switzerland

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1 Introduction

The IGS network today consists of 364 stations managed by about 100 different agencies worldwide. The RINEX observations are contributed (generally on a daily or hourly basis) to the IGS Data Centers, which permanently archive the data and make it freely available to all users. The primary customer of the data set is the IGS Analysis Centers, which acquire the data for generation of precise GPS products such as ephemerides, clocks, earth orientation parameters, and station positions and velocities. The IGS Network Coordinator (NC) at the Central Bureau acts as liaison between the station operators and the Analysis Centers, providing necessary station configuration metadata and ensuring the dataset meets the requirements of the analysis. Further details on the current makeup of the network are available in the "Update Since Ottawa Workshop" paper in the Network Issues session.

In this paper we examine several topics currently warranting attention, leading to recommendations for future directions. We have identified (1) classification of the now-plentiful IGS sites for the benefit of users (2) the multiple sources of IGS station configuration metadata available to and used by analysts, (3) the new suite of IGS station operation guidelines, (4) effective notification of station status within the IGS framework of electronic communication, and (5) how to properly introduce north and east eccentricities to IGS SINEX files.

2 Network growth and station classification

Current procedures for new station acceptance are not entirely well defined, thanks to the conflicting goals of inclusiveness and selectivity. Beginning in the past year or so, the NC requests that those submitting new stations state to what IGS product or project the station will make a significant global contribution. Also, it is gently suggested that regional networks submit only a globally relevant small subset to the IGS. However, in the end any station meeting the IGS requirements is accepted if the operator feels strongly that it should be designated an IGS station. This can create a situation where there are several similar sites in a small area, decreasing the number of independent analyses performed on each site. It has been stated that Analysis Centers (ACs) have difficulty keeping up with which site in an area is "best," and presentations by ACs at the Berne Workshop confirmed that new stations are usually not added to the ACs' analysis lists nowadays, except in the case of particularly attractive stations.

During 2002 and 2003, 81 sites were added to the IGS network. An analysis of current usage of these stations is presented in Table 1. Most are associated with either the IGLOS or TIGA projects, and all except a few of the rest are actively being utilized by ACs in product generation. These patterns will be helpful to keep in mind while thinking about the policies and procedures.

Current usage	sites (by 4-character ID)
global	alrt ban2 conz dwh1 glps ohi2 qaq1 reun sach scub thu3 yibl zamb
IGLOS	bogi cagz conz darr davr dlft drej dwh1 ffmj godz helj hert hueg irkj joz2 khaj kir0 kou1 leij lhaz mar6 mat1 mdvj metz mtbg mtka ohi3 reyz str2 sunm thu2 titz vis0 wroc wtzj yarr zamb zimj zimz
TIGA	ajac alrt antc? brst copo? hlfx mars nain
MASER	godz irkj khaj mat1 mdvj nnor opmt usn1
VLBI co-loc	svtl
Some AC usage	aspa daka eurk mizu morp nnor obet ous2 sutm tnml
Usage unclear	baie bake gmas guao kuuj mikl picl tukt vald

Table 1: Current usage of sites added to the IGS network during 2002 and 2003. Complete information on each site is available in the Tracking Network area of http://igscb.jpl.nasa.gov.

First let us ask what is the benefit of the inclusiveness value *in cases where there is no clear benefit to IGS products*? Presumably, to encourage the construction and operation of sites to IGS standards and offer recognition to agencies expending the effort to do so. Such recognition can even result in better funding for the agency within its own organization, a boon to global geodesy and other fields.

If there is agreement that this recognition is the primary reason for inclusiveness, then we can offer a solution that provides such recognition without crowding the IGS network with sites that do not add value to the IGS products (and in fact, dilute the rigor of analysis that IGS sites receive).

A category of Proposed IGS Stations could be the first stop for sites submitted to the IGS. The CB would verify metadata suitability, and collect information on the location of sample data and which products or projects might benefit from this site. This information would be entered in a table of Proposed IGS Stations on the CB web, and an email announcement from the CB/NC would indicate that initial checks find that station is operated to IGS standards and it could be added to the IGS Network on the request of an AC or Associate AC (AAC). At that point, the station operator would be able to point to that web page and announcement to demonstrate that the station has been proposed to the IGS and found to be nominally suitable.

However, a Proposed Station would not actually be added to the IGS network unless at least one IGS analysis expert (AC, ACC, Working Group or Pilot Project chair, or product coordinator) requests it for the benefit of an IGS product or project. After the initial CB checks, analysts would be notified by email of an update to the table and directed to reply if they request that site be added. If there is no such request from an analyst, the site would remain in the Proposed table, where analysts may from time to time review known Proposed sites and request addition of any site, should it later become beneficial to a product. If a site remains on the list for more than a year, the CB would re-verify the information at that point. A demonstration of what a Proposed IGS Station table might look like is presented at http://igscb.jpl.nasa.gov/network/proposed.html

Experience has shown that sometimes new stations present a satisfactory sample set of metadata and sample RINEX, but operational status reveals a pattern of partial data files, etc. New sites coming out of the Proposed status could be termed a "Provisional IGS Site" for the first 90 days,

after which it would become an ordinary IGS site only if stable operation had been demonstrated. Would ACs support the removal of a site if problems arose in the provisional phase?

Besides Proposed and Provisional site categories, another suggested by recent patterns is IGS Project sites. Naturally, stations participating in a sanctioned IGS Pilot Project should have their IGS participation properly acknowledged. However, it should be recognized that upon termination of the project, those stations may not necessarily benefit any IGS activity. This can be seen currently in the cases of TIGA and IGLOS, where the sites admirably participate in these activities, but if TIGA or IGLOS were to end without resulting in an ongoing IGS product, many sites would not actually be useful to any IGS product. Classifying sites as IGS Project sites for the duration of the project would appropriately acknowledge the effort without creating the expectation that they are undoubtedly IGS stations for all time. Upon termination of a Project, the associated sites could become Proposed sites, for review by analysts on which are of continuing benefit to the IGS.

One further obvious category is Inoperational sites. Sites (excepting the obvious TIGA Project sites) transmitting no data within 30 days would automatically be placed into a list of Inoperational sites and the operators notified by email.

These categories address controlling the future growth of the IGS Network, but do not entirely solve the issue of AC "confusion" over which site in a small area is preferred for processing. The IGS guidelines state that it is preferable to maintain one station as "best" (while avoiding unnecessary equipment changes and observing data overlaps when unavoidable), than to operate multiple receivers at a site and submit all to the IGS. It has been further suggested to actually enforce that station operators choose only one "site" per "site" to submit to the IGS. This would not be a complete solution since in some cases separate agencies install sites nearby, and there is no common management to make a choice.

As a further step, a set of approximately 200 sites will be identified, primarily from the rate of usage to generate official IGS products. These "product sites" should include the IGb00 Reference Frame sites, most co-locations with SLR and VLBI, sites with MASERS, and a good selection of hourly sites. Identifying these product sites will serve to communicate their importance to the IGS products, and could help indicate to ACs which sites "should" be analyzed in the absence of overriding reasons.

There is some level of circularity in this approach: usage in products helps determine usage in products. The introduction of new sites is a clear point of complication, since they will present no prior usage in product generation. Product coordinators must monitor the sites analyzed for their product(s), and communicate with the NC and ACs/AACs if they find an important site is being missed.

Introduction of the product site category is still not a complete solution, but will help get a handle on which sites receive regular and rigorous analysis, what sites need operational improvements, and so on. This is a first step and will likely be refined and revised.

In summary, we have discussed the following categorizations:

IGS Proposed Sites Sites proposed to the IGS and found to have suitable characteristics, but not yet requested by any IGS analyst.

IGS Provisional Sites Sites added to the IGS Network in the past 90 days, during which time they must demonstrate adequate operations.

IGS Project Sites Sites associated with a specific limited-duration IGS Project, which would not necessarily remain IGS Sites at the conclusion of the Project unless helping an IGS product.

IGS Product Sites Sites most often used in, and most valuable to, IGS products.

IGS Inoperational Sites Sites not transmitting data in the past 30 days, but which are expected to eventually return to service.

3 IGS Station Metadata

A brief poll of IGS Analysis Centers (AC's) and coordinators was undertaken to understand how they presently ingest station metadata into their analysis processes.

The responses differed in details, but the following can be deduced from the collection.

- Many ACs have internal databases which are compared automatically to some metadata source at the CB, but an operator examines the results and decides on updates manually.
- The site logs, in addition to the SINEX template, are used directly and automatically. In fact, all of the following are used operationally in IGS analysis: site logs, igs.snx, logsum.txt, igs_01.pcv, NGS ant_003.pcv.
- The SINEX template is not used by all ACs and may have been not well advertised since the 1998 AC Workshop in Darmstadt. Additional factors are discussed below.
- The SINEX template has some shortcomings, notably A5 serial number field, absence of some types of information not associated with position/velocity products (such as frequency standards and met equipment), and absence of former sites (the latter easy to solve).
- Several ACs analyze IGS sites simultaneously with other sets of sites, such as a regional network (SCIGN, EUREF). It is an issue how to acquire and combine metadata for different site sets.
- Analyzing different site sets also makes it frustrating to figure out how to do phase center offsets & variations. If getting some from NGS and some from igs_01.pcv, there are differences since igs_01.pcv is not updated when new data is later taken. As a result, some ACs use igs_01.pcv to only a partial extent, and some ACs use no variations at all. The antenna and analysis communities should address this.

Other comments included:

- it would be nice to know what periods of time had no data from the site log or SINEX template.
- it would be useful if the SINEX template had ITRF positions & velocities.
- full automation is not really desired, because it is preferable to have critical parameters under management by humans.
- changed or new log files should be available ASAP for ultrarapid analysis.
- machine readable/tabulatable codes for monument type, geology, other equipment types would be nice.

How did we get here?

Between 1994 and 1998, various IGS Technical Reports and Workshop Proceedings have evidence of encouragement from the Analysis Coordinator for ACs to use a "SINEX header" or "SINEX template" from the CB as the authoritative source of station configuration information. This was not realized uniformly, however, due to (at minimum) delays in the production of such a file.

ACs, therefore, originally had to implement internal collections of station parameters. Nobody likes to undo long-standing functional software, so much of it is still left in place. In some cases, the SINEX template was partially implemented later to cover some instances where it makes some improvement over the other options.

What now?

The analysis community should decide what level of standardization among ACs is required. Additionally, the analysis community is requested to agree on a way forward such that the network element can work toward operational provision of metadata in only a few formats, to reduce complexity.

4 Guidelines

At the 22nd IGS Governing Board meeting, a thorough update of the IGS site guidelines was identified as a pressing priority for a number of reasons. The Network Coordinator formed a first draft based on many preceding documents, including "Standards for IGS Stations and Operational Centers," "Procedures for becoming an IGS Station," "Network Issues" (from the proceedings of the IGS 2002 Workshop in Ottawa), "ISGN Sites Criteria," documents from several IGS Pilot Projects, "Guidelines for IGEX98 Sites," EUREF Permanent Network Guidelines, and IGS Reference Frame Working Group discussions from early 2003. This draft was reviewed by G. Gendt (ACC), C. Bruyninx (EPN NC), R. Ferland (RF Coordinator), J. Ray (AC/RF expert), M. Schmidt (Site ops expert), W. Gurtner (Author of previous guidelines), and C. Noll (DCWG Chair). As appropriate, questions were also asked at an early stage of Z. Altamimi (ITRF expert), H. Drewes (Author ISGN guidelines), D. Stowers (Site ops expert), S. Schaer (AC expert), R. Weber (GLONASS coord), Y. Bar-Sever (Tropo chair), G. Mader (Antenna expert), and M. Rothacher (Antenna expert).

This serves as an example of how the NC can utilize the expertise of usual and additional groups of advisers to assist in network matters. After several rounds of revision with these reviewers, the document was made available for comment from the entire IGS community.

The Governing Board approved (provisionally, and later officially) the document and a program of continuous review and improvement. Update authority is delegated to the NC, with the understanding that significant changes would be discussed with appropriate advisers beforehand (ACC, RF Coord, station ops, WG Chairs, as needed for the topic), and a list of changes made in the preceding period will be made available to the GB at its regular meetings.

Although public comment on the new set of IGS guidelines was solicited, received, and utilized, the workshop provided another opportunity to discuss the guidelines. [1] The following few example guidelines were highlighted in various sessions at the Berne Workshop. The complete set of guidelines is permanently available at http://igscb.jpl.nasa.gov/network/site/guidelines/guidelines.html or http://igscb.jpl.nasa.gov/network/site/guidelines/guidelines.pdf

Local survey requirements

(required) 2.1.4 The eccentricities (easting, northing, height) from the primary marker to the antenna reference point (defined for the antenna type in ftp://igscb.jpl.nasa.gov/pub/station/general/antenna.gra) must be surveyed and reported in site logs and RINEX headers to $\leq$ 1mm accuracy.

(desired) 2.2.18 3-dimensional local ties between the GPS marker, collocated instrumentation (e.g. DORIS, SLR, VLBI, gravity, tide gauge) and other monuments should be re-surveyed regularly to an accuracy of 1mm and reported in ITRF.

[1] Since the Governing Board directed the Network Coordinator to maintain the document in a "continuous improvement" mode, comments are appropriate and welcome at any time.

- The marker-antenna reference point (ARP) eccentricities should be reverified during such a survey.
- Repeat the survey after known motion incidents such as earthquakes.

Radomes

(required) 2.1.6 Avoid using radomes unless required operationally, for instance due to weather conditions, antenna security, wildlife concerns, etc.

(required) 2.1.8 If a radome must be used, an entry for antenna+radome pair must be in the phase center variation file ftp://igscb.jpl.nasa.gov/pub/station/general/igs_01.pcv.

- Exceptions (for historical reasons) are listed in ftp://igscb.jpl.nasa.gov/pub/station/general/uncal_radome.txt
- To use an antenna+radome pair not found in either of these files, contact the CB. A calibration from an independent, recognized laboratory such as NGS (http://www.ngs.noaa.gov/ANTCAL) or Geo++ (http://www.geopp.com) will be required.

Data issues

(required) 2.1.17 Transmission of data to the DC must be verified to be uncorrupted.

(required) 2.1.13 The station operating agency must archive the raw (native binary) GPS data, or arrange for this at a suitable agency such as a partner agency, or an Operational Data Center.

Reference Frame site practices

3.3.1 3-dimensional local ties between the GPS marker, collocated instrumentation (e.g. DORIS, SLR, VLBI, gravity, tide gauge) and other monuments should be re-surveyed at least every two years to an accuracy of 1 mm and reported in ITRF.

3.3.2 Survey measurements, field notes, and reduced results should be preserved and be made publicly accessible

3.3.3 All survey data, but especially ties to other IERS and IGS markers, should be rigorously reduced in a geocentric frame related to ITRF (preferably ITRF itself) and the results be made available in SINEX format (defined at ftp://igscb.jpl.nasa.gov/pub/data/format/sinex.txt), including full variance-covariance information

3.3.4 Moving to another monument must be avoided except in extreme circumstances, requiring prior announcement and submission of overlapping data sets starting one year in advance. Analysis of the two sets is helpful; results should be documented in the site log and in an IGSStation message.

3.3.5 When antenna change is unavoidable, minimize position discontinuities by first operating the new antenna on an nearby ancillary monument, and announce to IGSStation how analysts may get the test data set.

Data completeness items

(desired) 2.2.1 Receiver support for "all-in-view" tracking

(desired) 2.2.2 The receiver tracking cutoff is ideally 3 degrees or less, especially for "all in view" receivers.

(desired) 2.2.7 Support for GLONASS observations is desirable. See Chapter 6, Guidelines for IGS sites with GPS/GLONASS receivers below for further guidance.

(desired) 2.2.21 Receivers should be set to record data from all satellites, including those newly launched or set 'unhealthy'.

5 IGS Network Communication: splitting the IGSMail list

The suggestion to have separate mailing lists for major announcements and station advisories has been made from time to time over the past years, but now the frequency of receiving this request has reached the point of confirming a clear need in the community.

We envision that "announcements" means messages such as IGS Workshops, new IGS stations, product-related announcements, major DC announcements, sessions at conferences, enhancements to web pages or services, etc.

"Station advisories" includes station configuration notices and outage or repair notifications. Although new procedures for RINEX data replacement notification are under discussion in the Data Center Working Group, data replacement messages will also be sent in this mailing list until a new system is in place.

Four options identified for implementation were presented in the preliminary position paper disseminated prior to the workshop, and the scheme shown in Figure 1 was chosen.

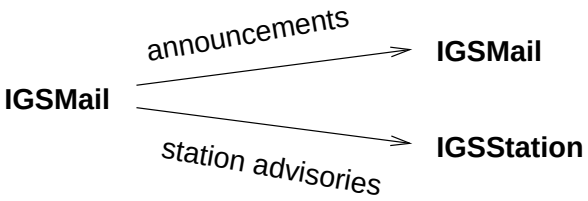

Figure 1: Creation of the IGSStation mailing list

In summary, the new list "IGSStation" will be created for station advisories, and announcements will stay on IGSMail. When IGSStation is created, IGSMail subscribers will be advised to subscribe to IGSStation if they wish to continue getting station advisories

6 A lingering question: North and East eccentricities

This is a tricky issue that needs a solution. Originally (pre-2002) the IGS site logs had no provision for collecting North and East eccentricities in a standardized way. Furthermore, the IGS SINEX template had been hard-coded to write zeroes in these fields, apparently since inception.

There are presently 3 IGS sites with nonzero N, E eccentricities: NYAL ($N = -0.0010$m, $E = 0.0040$m), OBET ($N = 13.7960$m, $E = -5.2640$m), and WUHN ($N = -0.0022$m, $E = -0.0094$m).

Obviously, suddenly changing these from zero to nonzero in the SINEX template could produce a confusing time series. ACs probably have differences in handling (or ignoring) nonzero N or E eccentricities in the SINEX template, site logs, and/or RINEX headers.

We prefer that the SINEX template and products reflect the "best" set of information known about a site, and therefore accurately reflect reported N, E eccentricities.

The community is invited to discuss and recommend a controlled plan for introducing the proper N, E eccentricities into the SINEX template with analysts, RF coordinators, and SINEX product users in mind. This should be done promptly while the number of sites with nonzero N, E eccentricities is small and before the IGS celebrates any more major anniversaries.

7 Recommendations

Five major recommendations were chosen for inclusion in the main Workshop recommendations:

1. New stations proposed to the IGS should be described on a web page and announced to the community by the CB, but added to the IGS network only on the request of an AC or Coordinator.
2. The "Global" station designation should be discontinued. The 99 IGb00 Reference Frame stations will be promoted on station lists and a letter will be written to agencies operating IGb00 stations, noting the significant effort and responsibility and requesting a reaction to the Reference Frame station guidelines.
3. The analysis community should develop a plan to handle North and East eccentricities.
4. The IGSMail list will be split into IGSMail (for messages such as IGS Workshops, new IGS stations, product-related announcements, major DC announcements, sessions at conferences, enhancements to web pages or services, etc.) and IGSStation (for station configuration notices, outage or repair notifications, and RINEX data replacement notification).
5. Monitoring and encouraging compliance to the data recording and transmission guidelines is encouraged.

In addition, the following action items are suggested by this paper:

1. IGS Provisional, Project, Product and Inoperational categories should be pursued as discussed.
2. The Network section of the Terms of Reference should be re-written to reflect the chosen policies on station classification.
3. The analysis community should identify the necessary level of standardization of metadata ingestion, and provide an agreed-upon direction to the NC for future development of metadata products.
4. Former IGS sites should be added to the IGS SINEX template.

8 Acknowledgment

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