International GNSS Service Charter for the Analysis Centers and Associate Analysis Centers

Definition of Analysis Center and Associate Analysis Center Activities

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Background

The IGS analysis products are formed from a combination of the results submitted by the IGS Analysis Centers (ACs). The combination of the Analysis Center products are carried out by the IGS Analysis Center Coordinator (IGS ACC). To the extent that the effect of data and mismodeling among different Analysis Centers are independent, properly weighted combinations of results can be superior. In this way, the IGS products benefit in precision, accuracy, stability, reliability, and robustness compared to the results of any individual AC.

It is thus advantageous to encourage participation by a new AC whenever its results would improve the quality and/or robustness of the combination. The ACs that produce the IGS Final Products are particularly important because their results are essential for the formation and maintenance of a highly accurate and consistent IGS Reference Frame, and hence the contribution of the IGS to the International Terrestrial Reference Frame (ITRF). For many geophysical studies, the models used in the processing of the IGS final products (atmospheric delay propagation models and higher-order ionospheric correction) are necessary to avoid artifacts in the geophysical interpretation. Also, since the final products use a minimum constraint system, site position estimates in the network are not affected by non-modeled motions at individual sites.

Since combination strategies normally assume that the weighted average result is preferred, it is important for the IGS and the ACs to be aware of potential common mode errors, which can degrade the accuracy of the IGS combined products compared to those of an individual AC. For this reason, the IGS must continuously encourage efforts to calibrate and test the absolute performance of its products.

Core Products

The IGS core products currently consist of:

- **Weekly Final products**, which are:
    - GNSS (GPS, Galileo, and GLONASS with Beidou expected to be added) satellite ephemerides and clock corrections, tabulated at specified intervals for each day (in standard formats)
    - The clock corrections shall be accompanied by phase bias and attitude values for the satellites in order to allow an ambiguity resolution by PPP whenever possible (in standard formats)
    - Earth orientation parameters (polar motion, polar motion rate, and length-of-day, estimated at daily intervals, in standard format)

  - Station clock corrections, tabulated at specified intervals for each day (in standard format)
  - Station positions estimated at daily intervals for the global tracking networks (SINEX format)

  Final products are determined for each GPS week of data and delivered to the IGS global data centers within a specified deadline (currently 13 days after the end of that week). The Final products are reprocessed every several years (most recently 2008, 2014, 2020) based on the most up-to-date models and analysis strategies.

- **Daily Rapid products**, which are:
  - GNSS satellite ephemerides and clock corrections, tabulated at specified intervals for each day (in standard formats)
  - Earth orientation parameters (polar motion, polar motion rate, and length-of-day, estimated at specified intervals in standard format)
  - Station clock corrections, tabulated at specified intervals for each day (in standard format)

  Rapid products are determined for each day of data and delivered to the IGS global data centers within a specified deadline (currently 17 hours after the end of that day). Finite constraints are applied to station position estimates for the IGS core sites (after verifying their validity).

- **Ultra-Rapid products**, which are:
  - GNSS (GPS, Galileo, and GLONASS) satellite ephemerides and clock corrections, tabulated at specified intervals (in standard format)
  - Earth orientation parameters (polar motion, polar motion rate, and length-of-day in standard format)

  Ultra-rapid products are determined several times per day (currently four times per day) and delivered to the IGS global data centers within a specified deadline (currently 3 hours after the last epoch of the adjusted time interval). They include a 24 hours adjusted and a 24 hours predicted part. Station position constraints are the same as in rapid solutions.

The Final products from each AC must be fully self-consistent. The detailed specifications for the Final products are established by the Analysis Center Coordinator, in consultation with the ACs and the IGS Reference Frame Coordinator. The Final products, when combined with proper weighting, allow for the definition and maintenance of the IGS Reference Frame [Kouba et al., 1998].

The Rapid and Ultra-rapid products from each AC must apply the current IGS Reference Frame. The Analysis Center Coordinator, in consultation with the ACs and the IGS Reference Frame Coordinator, establishes the detailed specifications for these products.

Other Products

In addition to the Core Products listed above, the IGS generates other analysis products such as tropospheric zenith delays, tropospheric horizontal gradients and ionospheric products. Furthermore, the IGS maintains an IGS time scale, satellite and receiver code biases, and satellite and receiver antenna corrections.

Analysis Centers (ACs)

The IGS Analysis Centers are those groups, recognized by the IGS Governing Board, that commit to delivering to the IGS some or all of the Core Products listed above promptly and reliably (e.g., clock estimates and related biases are not strictly required of those ACs that process differenced observables, but they are nevertheless encouraged). The ACs make available and keep up-to-date an information file describing analysis strategies and models. They inform the community (e.g., through IGS Mail) of any significant processing changes they have made.

The IGS Analysis Center Coordinator and the Reference Frame Coordinator combine the final products of the ACs to form the IGS Reference Frame accessed by the user community. All other IGS products are combined as well. The AC contributions must be maintained consistent with this frame, and they facilitate the realization of the IGS Reference System.

Analysis Center Coordinator (ACC)

The IGS Analysis Center Coordinator is responsible for monitoring the quality of products submitted by individual analysis centers, and combining them to produce the official IGS products. The IGS ACC also has the overall responsibility for coordinating the changes, developments and improvements within the contributing analysis centers to produce the IGS products using the latest models and standards.

Associate Analysis Centers (AACs)

Associate Analysis Centers are those groups, recognized by the Governing Board, that produce specialized or derived products. AAC functions will be designated as the scope of the IGS evolves and new products emerge.

Currently, the following types of AACs are recognized:

- **Regional Network Associate Analysis Centers (RNAACs)**
  RNAACs contribute station position estimates for regional sub-networks of tracking stations from a combination of weekly data sets (in SINEX format). The RNAAC products must adopt the current IGS Reference frame, including appropriate GNSS ephemerides.
- **Global Network Associate Analysis Centers (GNAACs)**
  GNAACs combine the station position estimates contributed by the ACs and RNAACs (in SINEX format) to form global combinations for each week of data. A specified GNAAC combines the global combinations to form the official IGS combined network result, an essential element of the IGS Reference Frame. The IGS Reference Frame Coordinator has responsibility for this latter combination.

AACs are responsible for contributing to products such as ionospheric maps and tropospheric-related products. There are also AAC activities for specific tasks with different scheduling requirements (e.g., TIGA or real-time). Such AACs also contribute to an IGS Committee or an IGS Pilot Project and support the corresponding Product Coordinator.

Product Coordinators

Product Coordinators with their associated Committees augment the IGS products with an important, ongoing, long-term product, e.g., troposphere products, or ionospheric maps. Such products are obtained by an appropriately weighted combination of the corresponding inputs provided by the individual AACs contributing to the product.

New IGS Analysis Centers or Associated Analysis Centers

An Analysis Center can submit their request to become an IGS Analysis Center or Associated Analysis Center by email to acc@igs.org. The IGS ACC will then start the process of evaluating

the suitability of the AC to be recognized as an IGS Analysis Center or Associated Analysis Center.

An aspiring AC/AAC must demonstrate a long-term commitment as well as satisfactory performance of product delivery, solution quality, and independence in producing the products from all the other current Analysis Centers. In particular, the precision and reliability of the solutions must be commensurate with the quality of the current AC/AAC solution products.

Independence from other Analysis Centers can be demonstrated by using an independent processing software than the other ACs or significantly different processing methods (e.g., algorithms for network selection and observation modeling) from other centers that use the same processing software. Different processing software is the preferred independence metric.

The AC Coordinator will, by mutual agreement with AC/AAC candidates, evaluate and test the quality and timeliness of the prospective AC/AAC products. This evaluation should be based on a long test period of at least three months. This evaluation can be performed offline or can be performed by including the AC solution as unweighted in the combinations to derive comparison statistics for that AC with respect to the combination and other AC solutions. In the case of the Final products, similar tests need to be done by the reference frame coordinator to ensure the introduction of the AC to the definition of the reference frame does not negatively impact the IGS reference frame.

An AC/AAC officially attains the IGS AC/AAC status only when accepted by the IGS Governing Board, upon recommendation of the AC Coordinator after consultation with the other ACs. Similarly, a product coordinator must demonstrate this commitment and quality of solutions for the specialized products of the IGS that are not maintained by the ACC.

A new AC/AAC must supply the CB with contact information and a completed AC/AAC information file.

If an AC is already contributing to the Final products, an IGS Governing Board approval is not required for that AC to be included in Rapid and/or Ultra-Rapid products, but instead the AC coordinator can decide to include the products of that AC in the Rapid and/or Ultra-Rapid combinations after performing the three-month test period.

The AC coordinator can decide to temporarily unweight certain products of an AC from the combined solutions if the products from that AC have a negative impact on the combined products. In such cases, the AC coordinator informs the relevant AC of the decision, continues working with the AC and monitoring the quality of the AC product, and can include the AC product back into the combination when the AC product retains an acceptable level of quality.

The AC coordinator can request approval from the IGS Governing Board to permanently unweight or exclude an AC solution from the combinations. The AC coordinator should provide documentary evidence to show that the AC does not continue to demonstrate a commitment

and/or satisfactory performance of product delivery and/or solution quality. Upon approval by the Governing Board, the AC solution can be excluded or unweighted permanently from the combined solutions. An AC can request to be included back in the combinations after it was removed permanently from the combinations, in which case the above processes for a new Analysis Center need to be carried out before the AC can be included in the combinations again.

Resources needed to be an Analysis Center

The generation of different IGS products requires different levels of computer hardware and personnel commitment. In general, processing can be performed on modern desktop computers, but for redundancy and reprocessing, multiple multi-core hardware is desirable. Cloud-based computational platforms are another option that have become widely popular more recently mainly due to the flexibility of their use, such as scalability.

The processing time and disk space required to generate SINEX position files (finals), orbit files, and clock files depend on the number of stations and number of constellations processed.

Disk space is the easiest to assess. The bulk of disk storage is the RINEX data and with RINEX 3/4, multi-GNSS files, the storage required would increase. For individual stations with 30-sec sampled data, RINEX files can exceed 35 Mbytes in size, while a GPS-only file can be as small as 2 Mbytes. With the IGS moving to multi-GNSS, the expectation should be that all uncompressed RINEX files will be 10-70 Mbytes (15-sec sampling provided by some data collectors). For 100 stations, storage of RINEX alone will be 5 GBytes per day, and intermediate files needed during processing will likely double this value. For storage of multiple days and weeks of data, several TBytes of storage should be available. For reprocessing efforts with over 2 decades of data, these data volumes will be tens to hundred TBytes either to be stored or backed up for future processing. In addition, metadata information has to be maintained based for example on station-specific site logs.

Processing time in terms of CPU hours is more difficult to assess because this will depend heavily on the number of stations and number of satellites in the multi-GNSS constellation. The latter can vary from 32 for a GPS-only solution to over 100 for a full GPS, Galileo, GLONASS, and BDS solution. The processing must also be done in network mode and the parameter space with station coordinates, atmospheric delay, clock, and phase ambiguities can easily create state vectors that have 20000-30000 elements in them. Various methods can be used to reduce vector size using pre-elimination and back substitution approaches but all methods need CPU cycles to implement.

Networks and constellations can be subdivided and processed with sequential methods, or parallel multi-core with shared memory approaches can be used. The one strict requirement of any processing software is that **one day of data must take less than 24 hours to process**. For

ACs wanting to generate ultra-rapid products, the processing time must be less than 3 hours including data download. Current Analysis Centers generating final orbits process between 80 and 600 stations with the average from 9 centers being about 230 stations. Most ACs run their analyses on multi-core, multi-node clusters that distribute the load over multiple systems to speed up the processing. As a general guideline, each day of data can be expected to take 1-2 hours of wall clock time to process.
In addition to data storage and processing power, an AC also needs fast and reliable internet to transfer data from global and regional data centers for processing. Even with fast internet, data transfer can take several hours and again is most often parallelized (with one caution that some data centers only allow a limited number of connections from a single IP address).

Time commitments and the effective number of employees needed to operate the AC vary depending on the product type and the amount of automation and autonomous operation that is possible with the software implementation. On a weekly basis, a fully autonomous implementation for the processing of the Final products requires the least resources because this processing is carried out weekly and the AC can choose when the processing is done. While submission of final products needs to be done within 13 days of the end of the GPS week, the AC can choose when precisely to make the runs and specifically for the runs to be made during normal working hours. By planning to submit results before the 13-day deadline, the AC can have ample time to correct any problems in the processing. Many current ACs submit results as early as 5 days after the end of the GPS week. The advantage of waiting longer is that more stations from remote areas are likely to have data available at the time of processing.

For the ACs producing Final products, the large commitment of resources comes every 5-6 years when reprocessing campaigns are organized. Depending on setup, these campaigns use large amounts of data storage and computing resources (generally high-performance cluster systems) for months to over a year to reprocess now more than 30 years of GNSS data.

Significant resources are also needed to update and validate software for new models that are recommended for the re-processing campaign. Care is also needed to ensure operational processing is not impacted by updated models to be used in the reprocessing. When a new ITRF version is implemented, there is also the added load of running parallel old and new ITRF analyses.

The time commitments for rapid and ultra-rapid solutions tend to be more steady (i.e., no reprocessing campaigns), but they are more time-critical. With rapid processing, there is less than 17 hours after the end of the UTC day to process and correct any processing issues. Depending on the time zone of the AC, after-business hours activities may be needed. Rapid products are generated 7 days per week, and hence, weekend and holiday activities may be needed. The ultra-rapid products are even more time-sensitive with products generated every 6 hours, 7 days per week. Any problems in the processing, such as failed computer nodes, internet

access issues, and general load issues on clusters and large file systems, need to be addressed in just a few hours and possibly any local time. These time constraints for rapid and ultra-rapid processes most likely require an equivalent full-time person to be dedicated to the processing operations.

Associate analysis centers are typically less computing-resources intensive since they tend to deal with higher-level products that do not need processing of raw GNSS data. Time commitments can also be large depending on the timeliness needed for the products being generated. Details of the resources needed for these activities will depend on the specific product being generated.

References

Kouba, J., J. Ray and M.M. Watkins, IGS Reference Frame Realization, Proceedings of the 1998 Analysis Workshop held at ESA/ESOC, Darmstadt, Germany, February 9-11, 1998.

Kouba, J. and T. Springer. 2001, New IGS Station and Clock Combination, GPS Solutions, Vol. 4, No. 4, pp. 31-36.