3.4 Technique Centres
3.4.1 International GNSS Service (IGS)

International Global Navigation Satellite Service 2015

The International Global Navigation Satellite System Service (IGS) was established in 1994 with a mission to provide the highest quality Global Navigation Satellite System (GNSS) data and products for scientific use. The IGS provides numerous products to the scientific community. Products of particular interest to the IERS include the Earth rotation parameters as well as global tracking station coordinates and velocities (typically obtained from a reprocessing effort), which serve as the GNSS technique contribution to the realization of the International Terrestrial Reference Frame (ITRF). In the generation of operational products, the IGS adopts the latest realization of the ITRF and IERS conventions, and thus provides its user community with direct access to these IERS products.

IGS activities and developments in 2015 that are of interest to IERS are summarized within this report. The information herein was compiled from the 2015 IGS Technical Report, which includes detailed report sections by the heads of all of the IGS Components and Working Groups. The Technical Report should be consulted for more detailed information regarding the IGS activities in 2015. It is available for download from the publications section of the IGS website <www.IGS.org>.

Summary of Routine Operational Activities

IGS network stations are maintained and operated globally by many institutions, making tracking data openly available at different latencies – from daily RINEX files to real-time streams – for public use. These data contain either the legacy GPS and GLONASS observations, or the full set of potential signals/measurements for all available GNSS. IGS tracking data, which is held by each of the four global Data Centers on permanently accessible servers, increased in volume over the last year by more than 1 TB (15 million files). Many of these data are also redundantly provided through the IGS regional Data Centers.

The IGS Analysis Centers and Associate Analysis Centers utilize tracking data from between 70 to more than 350 stations to generate and control the quality of highest-precision products up to four times per day. Product Coordinators combine these contributions to the so-called IGS product on an operational basis and assure their quality. Nearly 700 IGS final, rapid, and ultra-rapid product files (GPS and GLONASS), as well as 140 ionosphere files, are made available weekly; additionally, daily troposphere files for more than 300 stations are also produced.

The interest of users in IGS products is documented by the download statistics that records typically over 150 000 file (25 Gb) downloads per day (CDDIS statistics). The Central Bureau

assumes responsibility for day-to-day management of the service, interaction with station operators, and answering to a typical number of 150–200 questions and requests from users per month. All these activities are performed all year and day-by-day, with high redundancy and reliability based on the pooled resources of more than 200 institutions worldwide.

Network Status

The Central Bureau monitors a globally distributed network of 491 select GNSS tracking stations that operate according to the IGS guidelines, 127 of them are providing an extended set of observations in the frame of the IGS MGEX project. Approximately 118 IGS stations provide real-time data streams so support the IGS Real Time Pilot Project activities. Currently 36 stations have the status of a proposed site.

The IGS has been using the IGb08 realization of the ITRF2008 reference frame for its products since GPS week 1709 (7 October 2012). This contains coordinates and velocities of 232 stations, where only a globally well distributed subset of 91 stations are used as so-called core sites for the datum definition when generating the IGS products.

Analysis and Core Product Generation

The IGS core products have continued to be routinely combined and delivered to users in a timely manner through 2015. To ensure continued production of high-quality IGS products, the Analysis Center Coordinator (ACC) performed high-level oversight and quality control of Analysis Center (AC) products, combination performance, and maintenance of the ACC website with updated plots. Also performed was coordination among ACs to assimilate changes made by them and to ensure that the best analysis models and procedures are used, along with coordination among the other relevant IGS components, preparation of component reports.

Despite a few minor delivery delays caused by power or network outages of the combination server, all of the IGS core products met availability targets (Table 1). The product reliability and quality of the IGS Ultra-rapid and Rapid products has remained similar to previous years. To improve the reliability of the GLONASS Ultra-rapid product, more AC contributions are needed. Details regarding the effects of these factors on the IGS products are described within the Analysis Center Coordinator Section of the IGS Technical Report.

An important activity for the ACC in the second half of the year 2015 was the preparation of the transition of the coordination activities from NGS to GA+MIT. This is related to a move of the software components, and in order to simplify the technical aspect for the future, the combination software was installed on Amazon cloud computers. At this point, we thank NGS for taking on the task of the ACC over two terms (a total of 8 years).

Table 1: IGS core products and availability targets. Availability is defined as the percentage of time that accuracy, latency and continuity of service meet target specification.

		Sampling Interval	Accuracy	Latency	Submission	Target Availability
GPS Satellite Ephemerides / Satellite & Station Clocks						
Broadcast (for comparison)	Orbits	1 s	~100cm	real time	continuous	99.99%
	Sat. clocks		~5 ns RMS ~2.5 ns SDev			
Ultra-Rapid (predicted half)	Orbits	15 min	~5 cm	predicted	4x daily at 03, 09, 15, 21 UTC	95%
	Sat. clocks		~3 ns RMS ~1.5 ns SDev			
Ultra-Rapid (observed half)	Orbits	15 min	~3 cm	3-9 hours	4x daily at 03, 09, 15, 21 UTC	95%
	Sat. clocks		~150 ps RMS ~50 ps SDev			
Rapid	Orbits	15 min	~2.5 cm	17 - 41 hours	at 17 UTC daily	95%
	Sat. & stn. clocks	5 min 17 - 41 hours	~75 ps RMS ~25 ps SDev			
Final	Orbits	15 min	~2.5 cm	12 - 18 days	weekly, every Thursday	99%
	Sat. & stn. clocks	sat: 30s; stn: 5 min	~75 ps RMS ~20 ps SDev			
Real-time	Orbits	5-60 s	~5 cm	25 seconds	continuous	95%
	Sat. clocks	5 s	300 ps RMS; 120 ps SDev			
GLONASS Satellite Ephemerides						
Final	Orbits	15 min	~3 cm	12 - 18 days	weekly, every Thursday	99%
Geocentric Coordinates of IGS Tracking Stations						
Positions of real-time stations	Horizontal	daily	3 mm	1-2 hours	daily	99%
	Vertical		6 mm			
Final positions	Horizontal	daily	3 mm	11-17 days	weekly, every Wednesday	99%
	Vertical		6 mm			
Final velocities	Horizontal	daily	2 mm/yr	11-17 days	weekly, every Wednesday	99%
	Vertical		3 mm/yr			
Earth Rotation						
Ultra-Rapid (predicted half)	Polar motion	daily integrations at 00, 06, 12, 18 UTC	~200 µas	predicted	4x daily at 03, 09, 15, 21 UTC	99%
	Polar motion rate		~300 µas/day			
	Length of day		~50 µs			
Ultra-Rapid (observed half)	Polar motion	daily integrations at 00, 06, 12, 18 UTC	~50 µas	3-9 hours	4x daily at 03, 09, 15, 21 UTC	99%
	Polar motion rate		~250 µas/day			
	Length of day		~10 µs			
Rapid	Polar motion	daily integrations at 12 UTC	~40 µas	17 - 41 hours	at 17 UTC daily	99%
	Polar motion rate		~200 µas/day			
	Length of day		~10 µs			
Final	Polar motion	daily integrations at 12 UTC	~30 µas	12 - 18 days	weekly, every Thursday	99%
	Polar motion rate		~150 µas/day			
	Length of day		~10 µs			
Atmospheric parameters						
Final tropospheric zenith path delay with N, E gradients		5 minutes	4 mm (ZPD)	< 4 weeks	daily	99%
Final ionospheric TEC grid		hourly; 5 deg (lon) x 2.5 deg (lat)	2-8 TECU	~11 days	weekly	99%
Rapid ionospheric TEC grid		hourly; 5 deg (lon) x 2.5 deg (lat)	2-9 TECU	< 24 hours	daily	99%

Second Reprocessing Campaign (IG2)

The second reprocessing campaign (IG2) has mainly been carried out by the ACs during the year 2014. The processing follows the minimum analysis standards (see items delineated in black on the IG2 web page at <http://acc.igs.org/reprocess2.html>).

In February 2015, the results were submitted by the ACs to the CDDIS product server. To ensure a timely contribution to the ITRF2014, the reference frame working group chair gave priority for the combination to the daily SINEX files containing station coordinates and Earth orientation parameters. The combined SINEX files from the 2nd reprocessing initiative have been made available to the IERS after an intensive quality evaluation, in order to allow the relevant groups to generate the ITRF2014 candidate solutions.

The combination of the orbit and clock products from the 2nd reprocessing is planned to be done outside the operational structures of the IGS.

Multi-GNSS Experiment

The Multi-GNSS Experiment (MGEX), considered a key project that will enhance IGS capabilities to support the emerging satellite navigation systems, has proceeded with high priority since its launch in February 2012. The focus of this cornerstone experiment is the data flow, the understanding of observables, the characterization of tracking equipment, and the generation of products.

During the last few years the dataflow has been successfully established. The transition to RINEX3 files with an extended set of observations into the operational structures of the IGS was prepared at the IGS 2014 workshop in Pasadena, California, USA. This activity is coordinated by the infrastructure committee and involves all relevant components of the IGS (station manager, data and analysis centers, and several working groups).

The focus of MGEX is now on the data processing. Several ACs provide solutions for the new satellite systems with different latency, completeness, and strategies. More information on the current status can be found on the webpage <http://mgex.igs.org/>. This page also contains some comparisons demonstrating the current performance of the different contributions. The very successful Workshop on GNSS Biases, held in Bern, Switzerland on 5 and 6 November 2015 addressed very significant issues related to the implementation of multi-GNSS within IGS. One important result is the agreement to an exchange format for GNSS biases.

The launch of a Multi-GNSS Pilot Project is targeted in 2016.

Real-time Service

The IGS Real-time Service (IGS-RTS) was launched in April 2013. Real-Time GNSS observation data from a global observation network is provided via the IGS-RTS observation casters. Eight RT Analysis Centers (RT-AC) and two RT Combination Centers (RT-CC) contribute to the service. The IGS-RTS provides real-time orbit and clock corrections for GPS. In addition, experimental orbit

and clock corrections are available for GLONASS, BeiDou and Galileo as well as code and phase biases and ionospheric corrections. Two RT-CCs combine orbit and clock corrections to three combined product streams: two GPS-only product streams and one stream containing GPS+GLONASS corrections. At present, the positioning performance using Precise Point Positioning (PPP) is at the level of 10cm and will be improved as more correction data become available. All IGS-RTS observation and product data streams are based on open RTCM standards. The service is focused on supporting geophysical applications, such as natural hazards monitoring in the framework of GGOS, but it will also support a large variety of applications in positioning, navigation, time transfer, system monitoring, and others.

More information and an updated status of the service can be found on the RTS website at <http://rts.igs.org>.

Formats and Standards

The joint IGS/RTCM RINEX Working Group is responsible for maintenance of the RINEX format. The latest adapted version is RINEX3.03. While tracking data from GNSS-capable equipment shall be solely available in RINEX 3 after a target date to be specified, tracking data from legacy receivers will continue to be available in RINEX 2 for the foreseeable future.

The IGS Infrastructure Committee has established a transition plan to the general usage of RINEX3 format within the IGS. This first step involves the station manager, the data centers and analysis centers and shall be realized during the year 2016. In the next step, the formats for result and exchange files shall also support the new longer station IDs, as foreseen in the RINEX3 format description. Thanks to the alternative file naming convention for RINEX3 data, both versions can coexist in one and the same directory in the IGS data centers.

Governance

At the beginning of 2015 Gary Johnston became the chair of the IGS Governing Board, replacing outgoing chair Urs Hugentobler. Other members of the governing board have been replaced as well. The current list of members can be seen at the web page <http://www.igs.org/about/gb>.

The IGS Governing Board met three times in 2015: first on 12 April, for a business meeting during the EGU General Assembly in Vienna, Austria; a second business meeting on 23 June, during the 26th IUGG General Assembly in Prague, Czech Republic; and finally on 13 December for its regular end-of-year meeting prior to the AGU Fall Meeting in San Francisco, California, USA. The IGS Executive Committee – consisting of Urs Hugentobler, Gary Johnston , Chuck Meertens, Ruth Neilan, Chris Rizos, Tim Springer and with regular participation of Steve Fisher and of WG Chairs as required – met several times in 2015 by teleconference.

Strategic Planning

The current IGS Strategic Plan covers the period 2013–2016. During the year 2015, two dedicated sessions of the governing board with interested guests were organized in order to discuss the future vision of the IGS. The visions and other concerns brought up in these meetings will be reflected in the next IGS Strategic Plan 2017–2020.

IGS Workshop

The IGS 2014 Workshop was hosted by the NASA Jet Propulsion Laboratory at the campus of California Institute of Technology (Caltech) in Pasadena, California, United States. More than 200 participants from more than 25 countries attended the workshop. The main theme "Celebrating 20 Years of Service" was well reflected in the scientific program that did review the history and also provided an outlook into the future of the IGS: A short workshop summary may be found in IGSMAIL #6635. The workshop presentations, posters and recommendations can be found on the IGS website at <http://www.igs.org/workshop/>.

No workshops were held in 2015. The IGS 2016 Workshop was hosted by Geoscience Australia, Land Information New Zealand, and the University of New South Wales in Sydney, Australia. A full summary of the Sydney workshop will be included in the 2016 report.

The next IGS Workshop will be held 3–7 July 2017 in Paris, France, and hosted jointly by l'Institut national de l'Information Géographique et Forestière (National Institute of Geographic and Forestry Information) and Le Centre National d'Études Spatiales (National Centre for Space Studies).

Outreach

The IGS is well represented on the GGOS Coordinating Board. It also plays a leadership role in the International Committee on GNSS (ICG), in particular by co-chairing Working Group D on Reference Frames, Timing and Applications, and by participating in the planning for the international GNSS Monitoring and Assessment System (iGMAS). The IGS is also well represented in the International Earth Rotation and Reference Systems Service (IERS) and in IAG Sub-Commission 1.2 on Global Reference Frames, in the RTCM SC104, and others.

There are numerous IGS-related publications released in 2015. Please visit <http://www.igs.org/library> for the directory as maintained by the IGS Central Bureau and based on the input information from the components.

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