3.4 Technique Centres

3.4.1 International GNSS Service (IGS)

The International GNSS Service (IGS, where GNSS stands for Global Navigation Satellite System) was established in 1994 with a mission to provide the highest quality GNSS data and products for scientific use. The IGS provides a variety of 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 2017 that are of interest to IERS are summarized within this report. The information was compiled from the 2017 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 2017. It is available for download from the publications section of the IGS website www.IGS.org.

Routine Operational Activities

IGS network stations are maintained and operated globally by many institutions. This global network makes 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 in RINEX 2 format, or the full set of potential signals/measurements for all available GNSS in RINEX 3 format. IGS tracking data, which is held by each of the five global Data Centers on permanently accessible servers, increased in volume over the last year by more than 3.2 Tb (26.5 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 into official IGS products on an operational basis including a quality control procedure. Nearly 3.6 Gb IGS Final, Rapid, and Ultra-rapid product files (GPS and GLONASS) as well 28 Mb IGS real-time and 175 Mb for IGS MGEX products are made available weekly. Additionally, ionosphere (5.5 Mb

per day) and daily troposphere files (3 Mb per day) for more than 300 stations are produced.

The level of interest of users in IGS products is best exemplified by the download statistics, indicating typically over 290M files (47.5 Tb) downloads during the year (CDDIS statistics). The Central Bureau assumes responsibility for day-to-day management of the service, interaction with station operators, and answering of the order of 150–200 questions and requests from users per month. These activities are performed all year and day-by-day, with high redundancy and reliability, through the pooled resources of more than 200 institutions worldwide.

Network Status

The Central Bureau monitors a globally distributed network of 504 select GNSS tracking stations that operate according to the IGS guidelines. More than one third of them are providing an extended set of observations for the new GNSS constellations. Approximately 195 IGS stations provide real-time data streams to support the IGS real time activities.

Since GPS week 1934 (29 January 2016), the IGS has been using the IGS14 realization of the ITRF2014 reference frame. It contains the coordinates and velocities for 252 stations, where only a globally well distributed subset of 51 stations are used as so-called core sites for the datum definition when generating the IGS products. For 113 of them the coordinates are affected by the change of the related antenna phase center model. The geographical distribution of the stations is shown in Figure 1 .

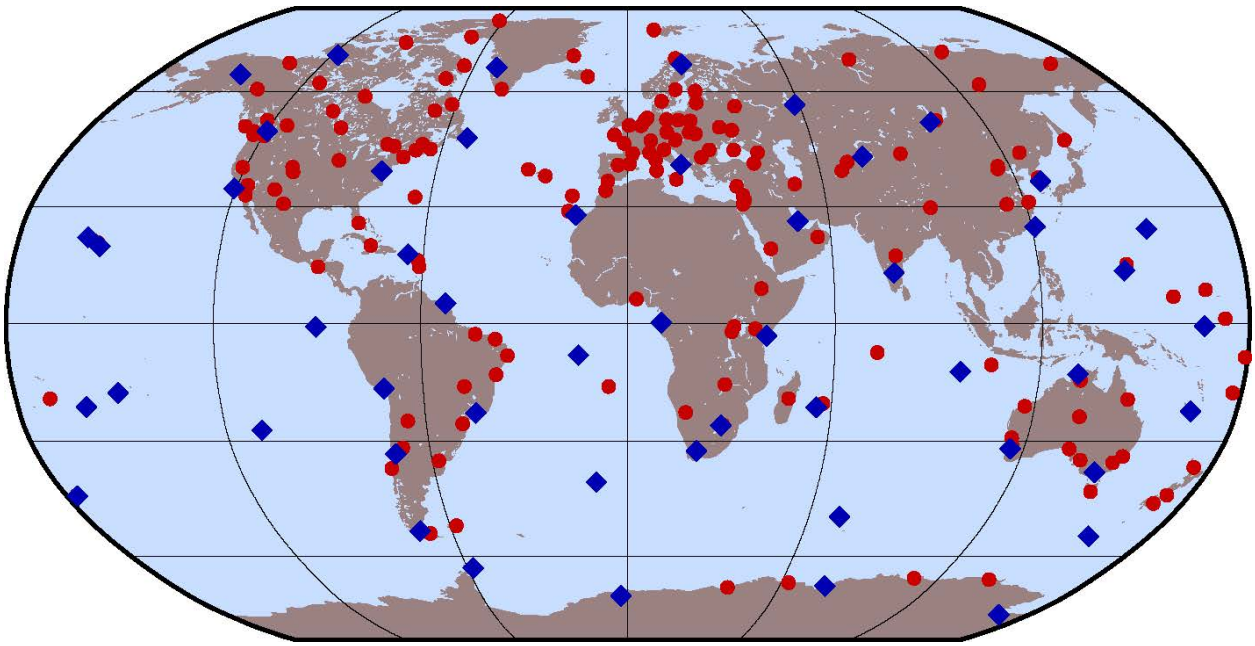

Fig. 1: *Geographical distribution of the stations with given coordinates and velocities in IGS14 realization of the ITRF2014 reference frame. The blue diamonds indicate the location of the 51 core stations that are used for the datum definition when generating the IGS products.*

Analysis and Core Product Generation

The IGS core products have continued to be routinely combined and delivered to users in a timely manner through 2017. 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 acc.igs.org. The ACC also coordinates the 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, and so forth.

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 in the Analysis Center Coordinator Section of the IGS Technical Report.

Installing the combination software on two Amazon cloud computers has proven itself in daily use, in particular because two institutions (GA and MIT) are coordinating this activity.

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 Real-Time 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. Four RT-ACs include GLONASS as well. 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 separate, 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 10 cm 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 rts.igs.org.

Multi-GNSS Extension

The Multi-GNSS Experiment (MGEX) is considered a key project that will enhance IGS capabilities to support the emerging satellite navigation systems. It has proceeded with high priority since its launch in February 2012. At the Governing Board meeting in February 2016 it was raised to the status of a Pilot Project. In order to keep the well established acronym it was renamed to *Multi-GNSS Extension (MGEX)*.

It was decided at the IGS 2014 workshop in Pasadena, California, USA, that the related dataflow of RINEX 3 files with an extended set of observations be integrated into the legacy dataflow. This activity was coordinated by the Infrastructure Committee and did involve all relevant components of the IGS (station manager, data and analysis centers, and several working groups). Currently about 40% of the IGS stations deliver their data in RINEX 3 format using the new longer station IDs, as foreseen in the RINEX 3 format description.

The focus of MGEX is now on the data processing. Several ACs provide solutions for the new satellite systems with different latency, completeness, and using different strategies. More information on the current status can be found on the website www.igs.org/mgex. This site also contains selected comparisons demonstrating the current performance of the different contributions.

Formats and Standards

The joint IGS/RTCM RINEX Working Group is responsible for maintenance of the RINEX format. The latest adapted version is RINEX 3.03. 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 RINEX 3 format within the IGS. In the current phase the new and longer station IDs are incorporated into the various product file formats. Additional potential changes in the file formats (mainly driven by the needs of the MGEX Pilot Project) are currently under discussion.

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.*

		Sampl. Interv.	Accuracy	Latency	Submission	Target Avail.
GPS Satellite Ephemerides / Satellite & Station Clocks						
Broadcast (for comparison)	Orbits Sat. clocks	1 s	≈100 cm ≈5 ns RMS ≈2.5 ns SDev	real time	continuous	99.99%
Ultra-Rapid (predicted half)	Orbits Sat. clocks	15 min	≈5 cm ≈3 ns RMS ≈1.5 ns SDev	predicted	4x daily at 03, 09, 15, & 21 UTC	95%
Ultra-Rapid (observed half)	Orbits Sat. clocks	15 min	≈3 cm ≈150 ps RMS ≈50 ps SDev	3–9 hours	4x daily at 03, 09, 15, & 21 UTC	95%
Rapid	Orbits Sat. & sta. clocks	15 min 5 min	≈2.5 cm ≈75 ps RMS ≈25 ps SDev	17–41 hours	daily at 17 UTC	95%
Final	Orbits Sat. & sta. clocks	15 min 5 min	≈2.5 cm ≈75 ps RMS ≈25 ps SDev	12–18 days	weekly every Thursday	99%
Real-time	Orbits Sat. clocks	5–60 s 5 s	≈5 cm ≈300 ps RMS ≈120 ps SDev	25 seconds	continuous	95%
GLONASS Satellite Ephemerides						
Ultra-Rapid (predicted half)	Orbits	15 min	≈10 cm	predicted	4x daily at 03, 09, 15, & 21 UTC	95%
Ultra-Rapid (observed half)	Orbits	15 min	≈5 cm	3–9 hours	4x daily at 03, 09, 15, & 21 UTC	95%
Final	Orbits	15 min	≈3 cm	12–18 days	weekly, every Thursday	99%
Geocentric Coordinates of IGS Tracking Stations						
Positions of real-time sta.	horizontal vertical	daily	≈3 mm ≈6 mm	1–2 hours	daily	99%
Final positions	horizontal vertical	daily	≈3 mm ≈6 mm	11–17 days	weekly every Wednesday	99%
Final velocities	horizontal vertical	daily	≈2 mm/yr ≈3 mm/yr	11–17 days	weekly every Wednesday	99%

Earth rotation						
Ultra-Rapid (predicted half)	PM PM rates LoD	daily	≈200 μas ≈300 μas/day ≈50 μs	predicted	4x daily at 03, 09, 15, & 21 UTC	95%
Ultra-Rapid (observed half)	PM PM rates LoD	daily	≈50 μas ≈250 μas/day ≈10 μs	3–9 hours	4x daily at 03, 09, 15, & 21 UTC	95%
Rapid	PM PM rates LoD	daily	≈40 μas ≈200 μas/day ≈10 μs	17–41 hours	daily at 17 UTC	95%
Final	PM PM rates LoD	daily	≈30 μas ≈100 μas/day ≈10 μs	12–18 days	weekly every Thursday	99%
Atmospheric parameters						
Final tropospheric zenith path delay with N, E gradients		5 min	≈4 mm (ZPD)	< 4 weeks	daily	99%
Final ionospheric TEC grid 5 deg (lon) × 2.5 deg (lat)		hourly	≈2–8 TECU	≈11 days	weekly	99%

Governance

Since the beginning of 2015 Gary Johnston has been the chair of the IGS Governing Board. Other members of the governing board have been replaced for various reasons during the year 2017. 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 2017: first 23 April, for a business meeting during the EGU General Assembly in Vienna, Austria; a second business meeting on 02 July prior the IGS Workshop in Paris, France; and finally on 10 December for its regular end-of-year meeting prior to the AGU Fall Meeting in New Orleans, Louisiana, USA. The IGS Executive Committee – consisting of Rolf Dach, Gary Johnston, Chuck Meertens, Ruth Neilan, Chris Rizos, and with regular participation of Steve Fisher, Allison Craddock and of WG Chairs as required – met several times in 2017 by teleconference.

At the December meeting the IGS Governing Board elected Allison Craddock as the new secretary of the Central Bureau replacing Steve Fisher who stepped down from this position in the second quarter of 2017.

Strategic Planning

The current IGS Strategic Plan covers the period 2017–2020.

IGS Workshop

The IGS 2017 Workshop was hosted by l'Institut National de l'Information Gèographique et Forestière (National Institute of Geographic and Forest-

ry Information) and Le Centre National d'Ètudes Spatiales (National Centre for Space Studies) at the location of the University of Paris-Diderot in Paris, France. Almost 300 participants from over 30 countries attended the workshop. The main theme "Pathways to improved precisions" was reflected in the scientific program that reviewed the history and provided an outlook into the future of the IGS. The workshop also featured a special keynote lecture on the Galileo system, given by Marco Falcone of the European Space Agency (ESA). Falcone's complete presentation, as well as videos of all other plenary presentations, PDFs of posters, as well as the recommendations are available on the IGS website: http://www.igs.org/presents/workshop2017.

The next IGS Workshop will be held from 29 October to 2 November, 2018 in Wuhan, China hosted by University Wuhan.

Outreach

The IGS is 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. The trial project of ICG Monitoring and Assessment Task Force (IGMA) has been established, co-organized by IGS and ICG. 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 were numerous IGS-related publications released in 2017. Please visit http://www.igs.org/library .

Rolf Dach