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International GNSS Service (IGS) Status Update

Presented to the National Space-Based Positioning, Navigation, and Timing (PNT) Advisory Board

5 December 2018

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International GNSS Service (IGS)

- A voluntary federation of over 200 international agencies
- **Promotes and provides open** and **free** access to high quality GNSS data and analysis products
- Providing **high precision GNSS data, products and services,** including: GPS + GLONASS combined orbits, GPS clocks, GLONASS clocks
- Supports realization of the International Terrestrial Reference Frame

Recent Significant IGS Events and Changes

- Ruth Neilan (IGS representative to ICG and PNT) retired from JPL in March 2018, Allison Craddock appointed by JPL as Central Bureau Director and confirmed by the IGS Governing Board in April 2018
- New **IGS Strategic Plan published** in February 2018 and is available at: https://kb.igs.org/hc/en-us/sections/200287408

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GNSS Performance Monitoring
ICG-IGS Joint Trial Project (IGS-IGMA)

- Background and Objective
  - Trial project of the **ICG Monitoring and Assessment Task Force (IGMA),** coordinated in partnership with the IGS
  - Monitoring of GNSS constellation status and the quality of navigation signals enables numerous applications, including worldwide time and frequency transfer, and GPS meteorology.
  - High-precision GNSS monitoring of the earth is not possible without GNSS performance monitoring
- Long term objectives:
  - Make all performance standard entries for each GNSS openly available
  - Provide a multi-GNSS service performance standard
- Current Status
  - 12 Groups have responded positively to Call for Participation
  - Initial results have been gathered and a **standard methodology is in development**

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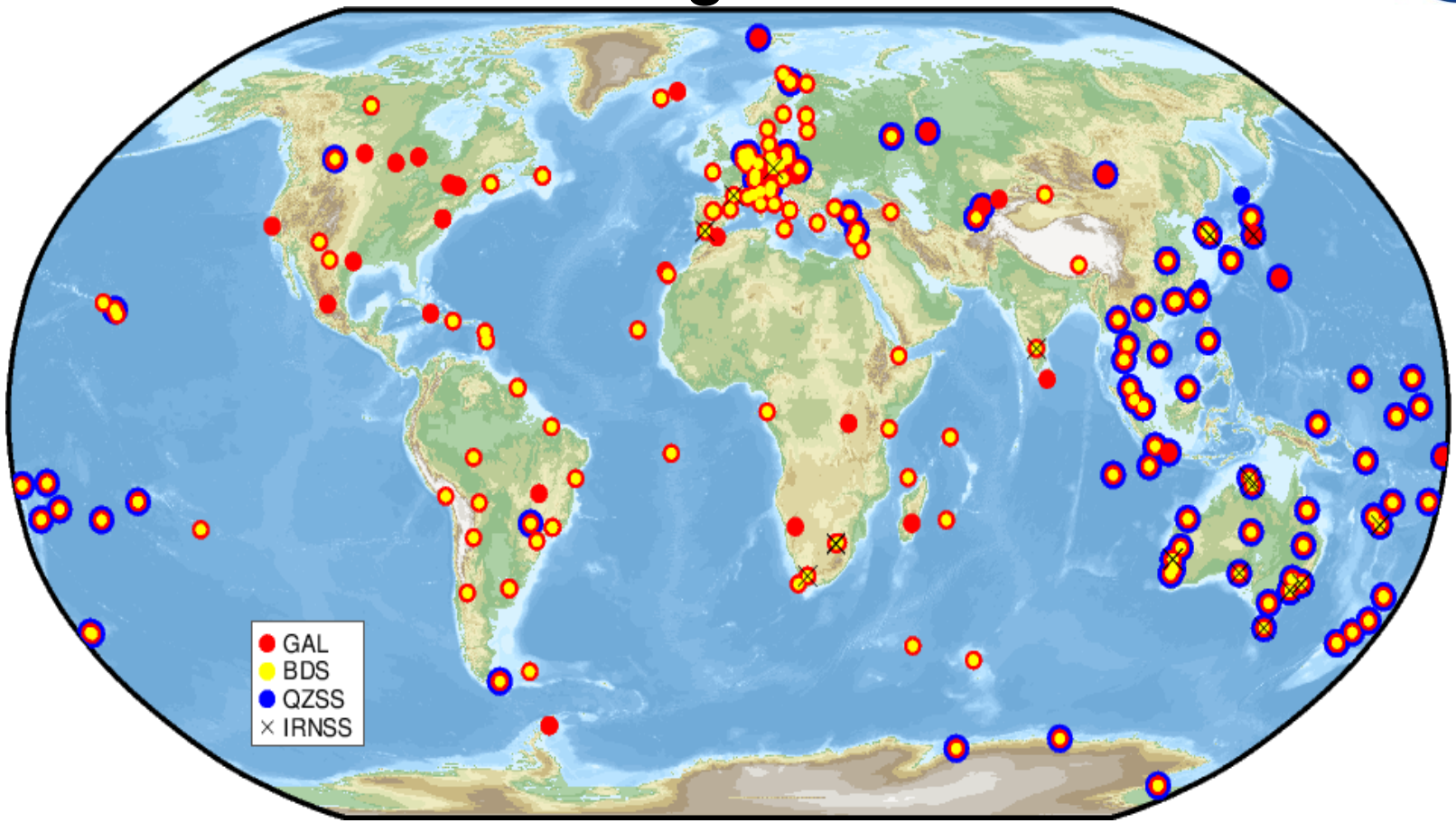
Multi-GNSS Extension (MGEX) White Paper

- The IGS Multi-GNSS Working Group, led by Oliver Montenbruck, released a White Paper, titled **"Satellite and Operations Information for Generation of Precise GNSS Orbit and Clock Products."**
  - The paper discusses the **parameters needed to ensure the highest possible performance of IGS products** for all constellations and motivates the need for provision of satellite and operations information by the GNSS providers.
  - All **information requested** by the IGS is considered to be **sufficiently abstract** such as to neither interfere with the GNSS providers' safety and security interests nor with intellectual property rights.
  - **Download** here: http://bit.ly/MGEXwhitepaper

Complete information available on the MGEX website: http://mgex.igs.org/

The IGS Multi-GNSS Tracking Network



- 235 multi-GNSS stations
- Tracking capability according to site log
- Few stations with new capabilities (IRNSS L5, Galileo E6)
- Various stations tracking BDS-3S/3
- Several multi-GNSS capable stations do not provide RINEX 3 files
- No IRNSS S-band tracking

Slide courtesy of Peter Steigenberger and Oliver Montenbruck, MGEX Pilot Project

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MGEX Achievements, Prospects, & Challenges

- MGEX has recently published a comprehensive paper detailing its achievements in the last five years, future prospects, and challenges.
- **"The Multi-GNSS Experiment (MGEX) of the International GNSS Service (IGS) – Achievements, prospects and challenges,"** published in Advances in Space Research, Volume 59, Issue 7, 1 April 2017, Pages 1671–1697, discusses:
  - Multi-GNSS products derived from the IGS monitoring station network
  - Work towards full integration of new constellations into routine GNSS processing
  - Progress made within the MGEX project including BeiDou, Galileo, and QZSS for precise point positioning, atmospheric research, and other applications.
  - Biases; standards and conventions
- Due to copyright restrictions, a pre-print previous version of the article is available here: http://bit.ly/MGEXasr

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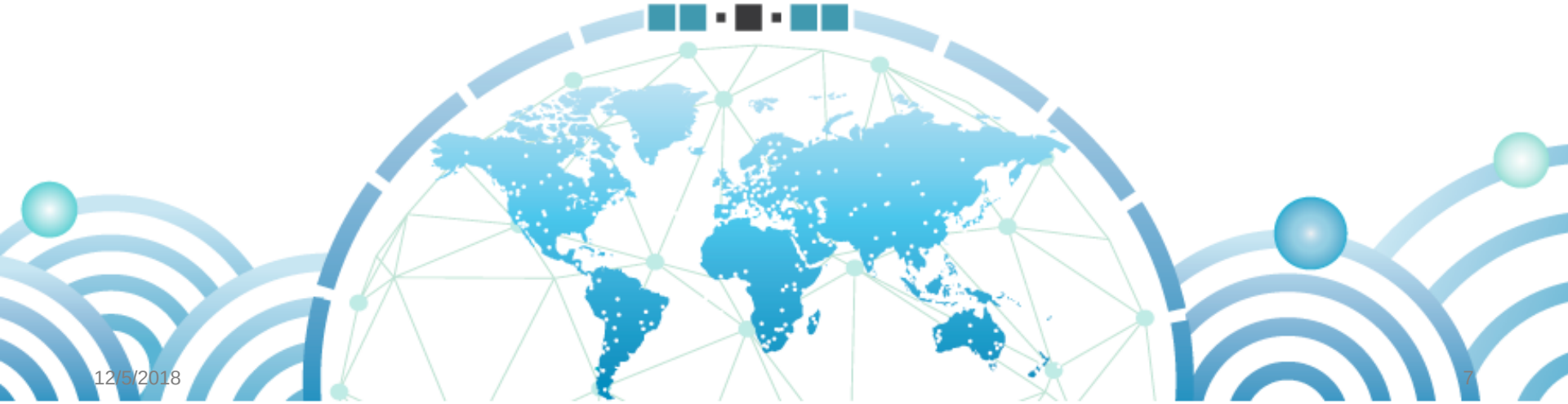
IGS Workshop 2018

29 October to 2 November

Wuhan, China

Multi-GNSS through Global Collaboration



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New IGS WG on PPP Ambiguity Resolution

The current IGS products are high quality, but are not fully compatible with PPP-AR and lack multi-GNSS support.

A new IGS working group that will focus on PPP with ambiguity resolution (PPP-AR) was established at the IGS Workshop in Wuhan, China last week. It will be Chaired by Simon Banville from NRCan in Canada.

According to the IGS RINEX-RTCM Working Group, the key requirements for PPP-AR and instant convergence are:

- Satellite orientation must be considered for a consistent clock correction (yaw angle for the wind-up effect)
- Code and phase biases should be provided for all signals
- Accurate Centre of Mass to Phase Centre offset measurements must be known
- Continue to improve orbit modeling for multi-GNSS orbit combination (IGS)
- GPS should consider supporting E6 In summary, we think that multi-GNSS and multi-frequency PPP-AR is the future of positioning, and the IGS and constellation service providers should enable these developments.

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RINEX 3.04 Officially Approved by IGS

The RINEX GNSS data format is a standard that is jointly managed by the IGS RINEX Working Group and the IGS Governing Board, together with the Radio Technical Commission for Maritime Services - Special Committee104 (RTCM-SC 104) on Differential Global Navigation Satellite Systems (DGNSS). This relationship was formed between IGS and RTCM to ensure that RINEX would continue to be freely available.

- The release of RINEX 3.04 was officially approved by the IGS Governing Board at the IGS Workshop in Wuhan last week.
- Key changes in this version is adjusting for new signals
- An official announcement with full details will be released via the IGSmail mailing list and IGS website by the end of this year.

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*At the request of the **International Laser Ranging Service** (ILRS, a sister service within the International Association of Geodesy) the IGS has issued two official recommendations.*

IGS Recommendation to the ILRS 2018.1

encouraged the extension of SLR stations supporting high-altitude tracking, specifically in the Asia-Pacific region, and the transition to kHz laser systems enabling shorter normal point duration

IGS Recommendation to the ILRS 2018.2

*addressed the increasing load on ILRS stations caused by the **increasing number of GNSS satellites equipped with laser retroreflectors** by recommending that observatories give **priority to dedicated campaigns for tracking of selected GNSS satellites** at the expense of a reduced background tracking activity while using remaining tracking resources to select and track the remaining GNSS satellites in a randomized manner – the latter of which to be defined at the discretion of the observatory.*

Real Time GNSS Service (RTS)

- Currently, IGS combined products are limited to clocks and orbits for GPS, with GPS+GLONASS products still classed as experimental.

- **IGS real-time orbit products are based on the ultra-rapid predictions.** Thus, all information that helps to improve the IGS orbit products are needed, and of this, **access to complete and accurate satellite metadata (information pertaining specifically to the physical properties of GNSS satellites) remains an issue.**

- **It was recommended at the 2018 IGS Workshop that the IGS Real-Time Service should prepare for the transition to a true multi-GNSS service.** In order to accomplish this, a number of prerequisites need to be fulfilled, such as the availability of predicted orbits for all constellations, the availability of processing, combination and validation capabilities as well as the selection of a suitable transfer format.

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IGS Analysis Centers Preparing for GPS III

- L5 receiver calibrations
  - Potentially available in January
  - This will help derive satellite L5 values
- SLR reflectors
  - This will verify orbit modelling -- *thanks!*
- Satellite metadata (physical properties)
  - Available for Galileo
  - Available for Beidou
  - GPS?

Upcoming Events

- AGU, December 2018

G51A Scientific Applications Enabled by the International GNSS Service (IGS) and by Improvements to GNSS Products I

Friday, 14 December 2018
08:00 - 10:00
Marriott Marquis - Marquis A-C

G43D Scientific Applications Enabled by the International GNSS Service (IGS) and by Improvements to GNSS Products I Posters

Thursday, 13 December 2018
13:40 - 18:00
Walter E Washington Convention Center - Hall A-C (Poster Hall)

- Next IGS Workshop expected to take place **August 2020** in Boulder, Colorado, USA.
  - The Workshop will be hosted jointly by UNAVCO and UCAR.
- A dedicated Analysis Center workshop has been proposed for **15-17 April 2019** at GFZ in Potsdam, Germany.
- Proposals for hosting the **2022** IGS Workshop will be considered mid-2019.

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Thank you!

Standardization of Real Time Open Formats

- There is still no approved standard for phase 1 SSR dissemination (orbits and clocks) for Galileo, Beidou and QZSS. Phase biases and iono/tropo for all constellations have also not been approved.
- There is a need for real-time open formats for the IGS real-time activities in an MultiGNSS environment.
- State Space Representation (SSR) of errors of satellite orbits and clocks, atmospheric states (troposphere, ionosphere), biases etc. is a viable solution.

State Space Representation (SSR) technology provides essential benefits for scalable real-time GNSS applications

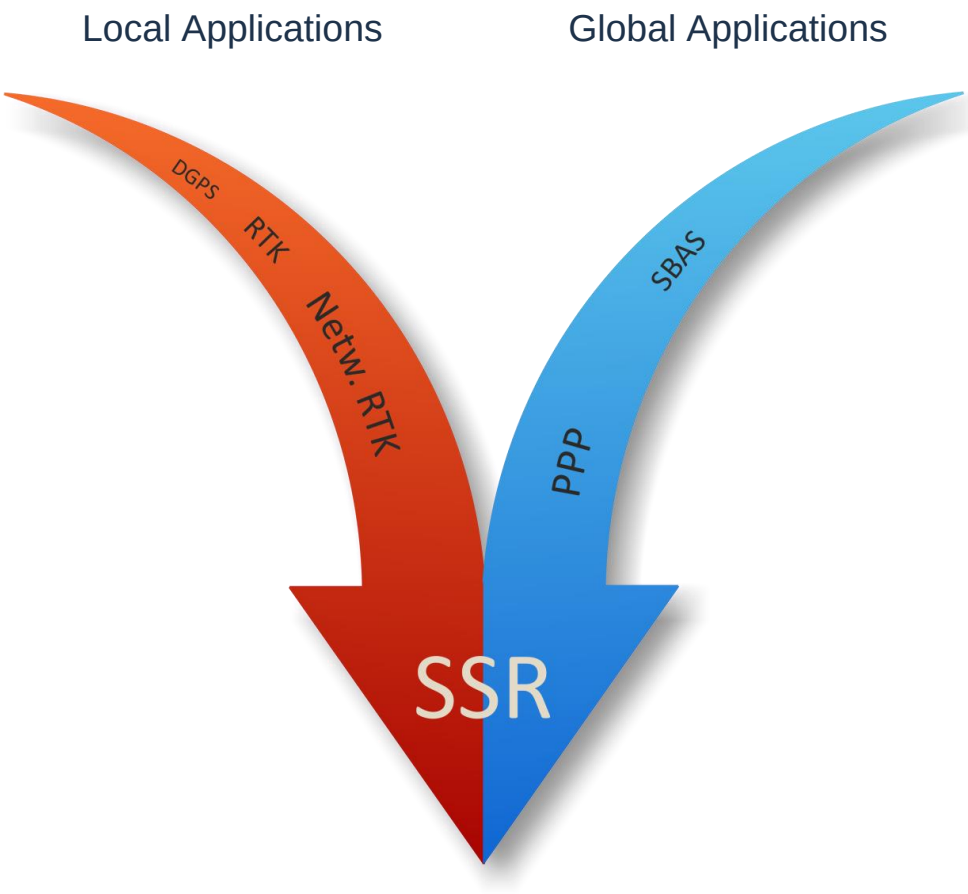
- broadcast GNSS corrections
- minimized bandwidth
- scalable GNSS services concerning
  - variety of GNSS and signals
  - positioning accuracy
  - service areas
- backward compatibility to GNSS applications

SSR – Fusion of GNSS Augmentations

GNSS augmentation with **SSR combines** the **accuracy of RTK** with the **broadcast** and low bandwidth benefits **of PPP**.

It is backward compatible to all legacy augmentation methods and can be **universally** adopted **to any reference station network**, no matter if

- global or regional
- high density or low density
- single, double or triple frequency.



Slide courtesy of Gerhard Wübbena, Jannes Wübbena, Temmo Wübbena, Martin Schmitz; GEO++
Presented at IGS Workshop 2017

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Full MGEX article citation:

- Oliver Montenbruck, Peter Steigenberger, Lars Prange, Zhiguo Deng, Qile Zhao, Felix Perosanz, Ignacio Romero, Carey Noll, Andrea Stürze, Georg Weber, Ralf Schmid, Ken MacLeod, Stefan Schaer, The Multi-GNSS Experiment (MGEX) of the International GNSS Service (IGS) – Achievements, prospects and challenges, *Advances in Space Research*, Volume 59, Issue 7, 1 April 2017, Pages 1671-1697, ISSN 0273-1177, http://dx.doi.org/10.1016/j.asr.2017.01.011.
- (http://www.sciencedirect.com/science/article/pii/S0273117717300418)
- Keywords: IGS; MGEX; BeiDou; Galileo; QZSS; Orbit and clock

IGS Recommendation to the ILRS 2018.1

Considering

the increasing number of GNSS satellites in geosynchronous and geostationary orbit and the special challenges for determination and validation of the respective orbits;

the IGS encourages

the extension of SLR stations supporting high-altitude tracking, specifically in the Asia-Pacific region, and the transition to kHz laser systems enabling shorter normal point duration.”

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IGS Recommendation to the ILRS 2018.2

Recognizing

the increasing load on ILRS stations caused by the increasing number of GNSS satellites equipped with laser retroreflectors

and

the priority of geodetic laser satellites and as well as the needs from other missions;

considering, furthermore,

the importance of SLR tracking for orbit validation and analysis of GNSS satellites

as well as

the need to achieve a homogeneous coverage of all GNSS constellations, satellite types, orbital planes and individual spacecraft;

the IGS recommends that the ILRS

retains the general prioritization of geodetic laser satellites before GNSS satellites and satellites from other missions

and

on request by the **GNSS providers** or the **GNSS user community** gives priority to dedicated campaigns for tracking of selected GNSS satellites at the expense of a reduced background tracking activity

and

uses remaining tracking resources to select and track the remaining GNSS satellites in a randomized manner, where each station can freely select a set of GNSS satellites for tracking on a weekly basis.