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International GNSS Service (IGS) Status Update

10th Multi-GNSS Asia (MGA) Conference

International Committee on GNSS Working Group D Session

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Overview

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  - Standardization of Real Time Open Formats
  - SSR – Fusion of GNSS Augmentations

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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) retired from JPL in March 2018, and is no longer associated with JPL or NASA
- 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
    - Orbit accuracies of a few centimeters for any point in time are a requirement, and determination of this is only possible if the properties of all GNSS are known to the best extent possible –or– can be determined in orbit determination processes.
    - Many **parameters** have to be determined by monitoring:
      - Broadcast Ephemeris Accuracy (Orbits and Clocks)
      - SIS User Range Error
      - SIS UTS Offset Error
      - PDOP for GNSSs
- Long term objectives:
  - Make all performance standard entries for each GNSS openly available
  - Provide a multi-GNSS service performance standard

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

- Current Status
  - 12 Groups have responded positively to Call for Particaption
  - Initial results have been gathered and a **standard methodology is in development**
  - IGS-IGMA recommends to the service providers to make the following info available:
    - the **antenna phase center** values of all the GNSS systems
    - Know for which signal(s) the clocks are given/valid
    - the attitude yaw of the satellites, in particular during eclipse, that is used for the broadcast ephemerides
- Future work includes:
  - Review and enhance comparison of broadcast ephemerides
  - Start converting orbit and clocks to common location and compare
  - Develop and implement clock comparison strategy
  - SISURE and UTC to follow after orbit and clock comparison is resolved

Multi-GNSS Extension (MGEX) Pilot Project

- MGEX work focuses on integration of the evolving global and regional satellite navigation systems Galileo, BeiDou, QZSS, and NavIC (IRNSS) into the IGS data archives and operational products.
- Integration of the multi-GNSS observation data was completed in 2016, but improving the product quality of the emerging GNSS to achieve the same quality as for the legacy GPS and GLONASS is still an ongoing process
- 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

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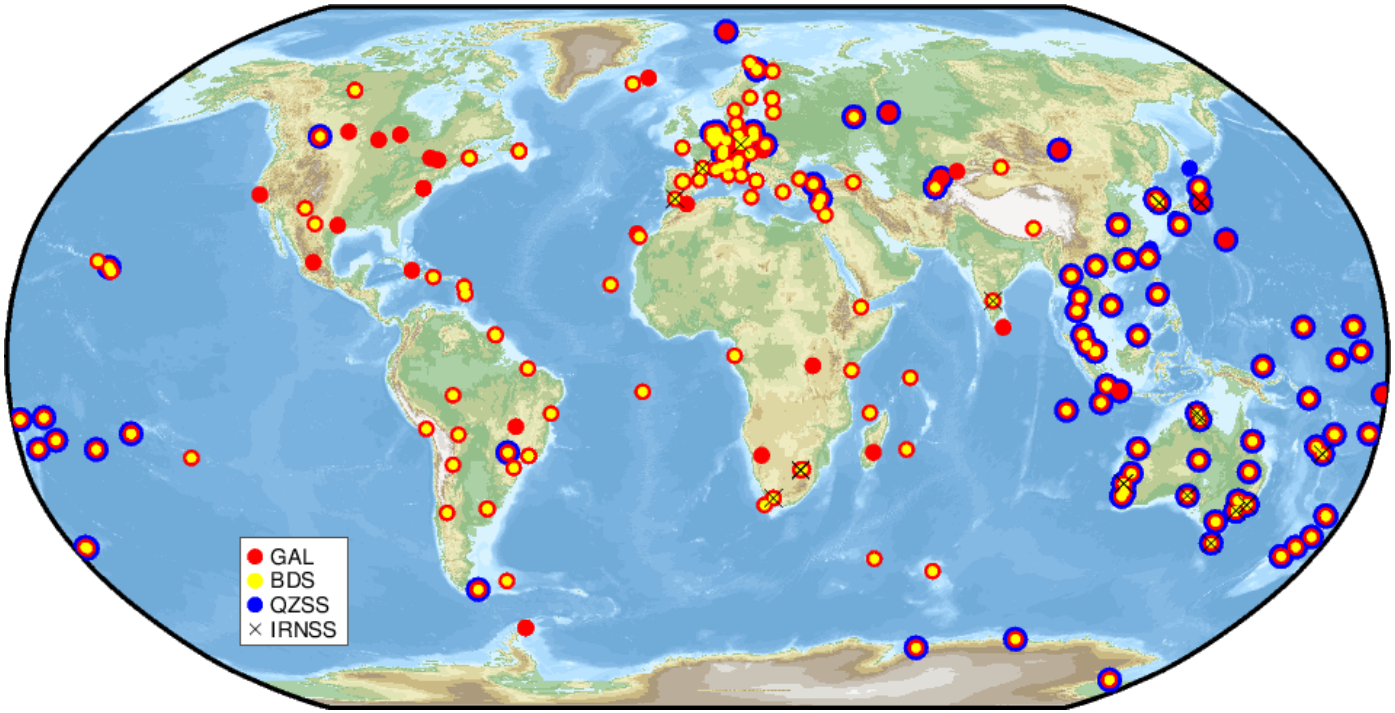
The IGS Multi-GNSS Tracking Network



- 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

MGEX Achievements, Prospects, and 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

Update from MGEX

According to the IGS MGEX Pilot Project lead, there currently is:

- Very good performance of Galileo products (5 cm 3D RMS consistency of individual ACs; 5 cm SLR residuals)
- Less good performance of BeiDou-2 products (mixed MEO/IGSO/GEO constellation; mostly regional)
- BeiDou-3 not yet covered despite a large number of satellites in orbit (very few IGS stations support tracking; insufficient for proper product generation)
- Multi-GNSS Orbit and clock product combination is still missing (IGS does not currently support combined GLO clocks) but first efforts of GFZ will be presented at the IGS Workshop in Wuhan
- Compilation of satellite metadata is ongoing (but painful). First IGS satellite metadata SINEX file published. Good status for Galileo and QZSS, poor support so far for GLONASS and BeiDou.
- Proper modeling of modified (rate-limited) yaw steering near Sun-s/c-Earth co-linearities becomes increasingly complex due to vast number of different s/c types. Need to move forward with attitude (quaternion) interface.
- Ground antenna calibrations still missing. Robots available, but IGS needs to develop independent capabilities for processing of robot measurement campaign.

Proposed 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) will be proposed at the IGS Workshop in Wuhan, China next week.

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.

Real Time GNSS Service (RTS)

- The combined products are only for clocks and orbits for GPS and GPS+GLONASS (still classed as experimental).
  - Some multi-GNSS AC solutions are available, notably CNES and GFZ. The CNES stream is disseminating biases but these are not monitored and compared.
  - ESA ESOC plans to generate a multi-GNSS solution but this is not disseminated at this stage.
- 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.
  - Satellite meta data information is an issue.
  - Galileo has published this data in the meanwhile (see https://www.gsc-europa.eu/support-to-developers/galileo-satellite-metadata), but others did not.

Real Time GNSS Service (RTS) Resources

- An overview of the monitoring is available at http://www.igs.org/rts/monitor, including orbit and clock performance and the combination solutions PPP performance.
- PPP monitoring of all the solutions is available on the BKG site at https://igs.bkg.bund.de/ntrip/ppp.

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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

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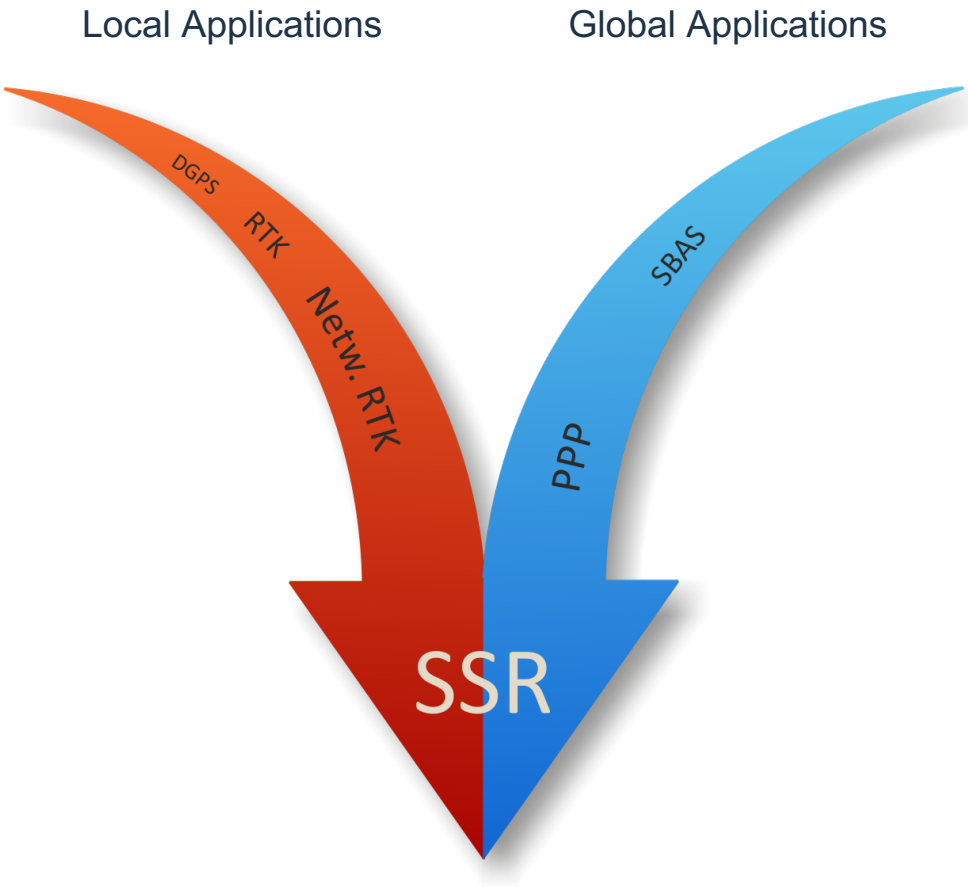
SSR – Fusion of GNSS Augmentations

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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Thank you!