Multi-GNSS and other science issues in the IGS

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based on material provided by
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20\textsuperscript{th} PNT Advisory Board Meeting
November 16, 2017
Crowne Plaza, Redondo Beach and Marina Hotel
300 N Harbor Drive
California, Cal 90277
USA
Contents

- Status of GNSS, November 2017: Approaching the state of 3+ fully deployed systems
- Endorsement of IGS activities by PNT and the IGS White Paper on GNSS metadata.
- Effect of metadata on orbit quality
- [Earth Rotation Parameters (ERPs) from GPS and GLONASS and from GLONASS-like GPS-sub-systems]
83 GNSS & RNSS satellites (w/o GEOs) are routinely analyzed at CODE and other IGS ACs.

The satellites have different characteristics (semi-major axes $a$, eccentricities $e$, inclinations $i$) and different signals, tracking modes.

QZS-1,-2,-4 and Galileo FOC-1,-2 satellites are in elliptical orbits ($e \approx 0.075$, $e \approx 0.16$, respectively)

Currently, there are 31 satellites in the GPS constellation, 24 in GLONASS, 17 in Galileo, 9 in Beidou-2 (3+6*), 2 in QZSS.

*) plus five GEOs, + 7 sats in Beidou-3

Galileo approaches full constellation in 2018/19 time frame, 2 more satellites in QZSS become available soon.
The IGS network: The International Terrestrial Reference Frame (ITRF) is based on hundreds of permanent GNSS sites and on tens of SLR and VLBI sites (positions within 1 cm, velocities within 1 mm/year).

The IGS currently tracks all GNSS.
On June 29, 2017, at its 19th meeting, the Advisory Board adopted the following endorsement:

- The PNT Advisory Board takes note of the IGS White Paper on ‘Satellite and Operation information for the Generation of Precise GNSS Orbit and Clock Products’ and endorses it as a minimum set of information required for the highest accuracy of GNSS applications, and encourages the open sharing of technical information on GNSS important to the international scientific community consistent with national security and intellectual property constraints.

On behalf of the IGS I would like to thank the PNT advisory board for this endorsement of IGS activities.
The IGS White Paper on

Satellite and Operations Information for the
Generation of Precise GNSS Orbit and Clock Products

by Oliver Montenbruck

is now available in the IGS knowledge base under

http://kb.igs.org/hc/en-us/articles/115000802772

The paper is a living document. Its most recent version documents the latest release of metadata for QZSS and Galileo.
Impact of satellite metadata on POD

Missing satellite metadata is a limiting factor for accuracy of estimated orbits and clocks, therefore the disclosure of …

Galileo IOV (Dec. 2016) and FOC (Oct. 2017) metadata by the GSA QZS-1 and QZS-2 information by JAXA in several steps in 2017 … is very much appreciated!
# Impact of satellite meta data on POD

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<th>Test</th>
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<th>QZS-1</th>
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**Impact albedo:** +1.8 cm

**Impact antenna thrust:** 1 cm/100 W

**Impact SC mass:** 2.2 cm/1000 kg (macro model over-scaled)

Pulses might shift the SLR offset

Impact of satellite meta data on POD
Impact of satellite metadata on POD

Model changes active in CODE MGEX solution since GPSWEEK 1962

Orbit improvement confirmed by external validation

(SLR validation provided by the IGS MGEX: http://mgex.igs.org)
GPS is currently “gold standard” in science. To maintain this position, official values concerning antenna phase center (frequency dependent) & panel model are necessary from the GPS, as well. Official confirmation of mass and attitude models matters, as well.
Summary

Metadata for Galileo and QZSS improve orbits (and most likely the quality of other parameters).

→ Metadata are not a luxury, but a “must” for scientific GNSS application.

Laser reflectors are badly needed, as well, in particular for validating orbit quality, ERP quality, etc.

Currently 80+ satellites are routinely tracked by the IGS-MGEX.
Earth Rotation Parameters (ERPs)

Left: motion of the Earth’s pole in inertial space
Right: polar motion on Earth’s surface (1994.25-2017.83); 1” ≈ 30 m
Earth Rotation Parameters (ERPs)

Left: Length of day differences w.r.t. mean sidereal day, derived from GNSS (blue) and from meteorological data (red). Right: corresponding spectra. Annual, semi-annual, 1/3-annual lines due to momentum exchange between solid Earth and Atmosphere, 14- and 27-day lines in GNSS spectrum due to tidal effects.

→ Periodic motion due to well-defined forces. So far so good …
Earth Rotation Parameters (ERPs)

GLONASS spectra of polar motion show spurious spectral lines at 120 days, GPS does not.

When splitting up the GPS constellation into one consisting of the odd (o) and one of the even (e) orbital planes, GPOo and GPSe show similar effects (bottom figures).

Combining two 3-plane systems, e.g., GPOo & GLONASS (=RGo, top Figures), these effects are greatly mitigated.

Constellation matters, multi-GNSS can improve quality of GNSS ERPs.
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Galileo probably reaches operational status in 2018/19 time frame. It will be interesting to see Galileo-specific ERPs!

With GPS, Galileo, and GLONASS there will be three fully operational systems, which are capable to monitor independently the geodetic & geophysical parameters accessible to GNSS (ERPs, ITRF, ionosphere).

Currently 80+ satellites are routinely tracked by the IGS-MGEX.
Literature


The IGS

The creation of the IGS was initiated in 1989 with I.I. Mueller, G. Mader, B. Melbourne, and Ruth Neilan as protagonists.

The IGS became an official IAG service in 1994.

The IGS first was a pure GPS Service, it was renamed as the International GNSS Service in 2004.

Today the IGS is a truly interdisciplinary, multi-GNSS service in support of Earth Sciences and Society.

Since its creation the IGS Central Bureau is located in the USA with Ruth Neilan as director – who stands for providing continuity and leadership.
IGS White Paper on Satellite and Operations Information for Generation of Precise GNSS Orbit and Clock Products

O. Montenbruck on behalf of the IGS Multi-GNSS Working Group

Abstract

The International GNSS Service (IGS) provides precise orbit and clock solutions for GNSS satellites that support a wide range of science and engineering applications with numerous benefits for society at large. All IGS data and products are made freely available to the scientific community and the general public. To best fulfill its mission, the IGS depends on information from the GNSS providers concerning the characteristics of individual types of satellites as well as their operations. This white paper describes 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.

Montenbruck et al (2017) IGS White Paper on Metadata asking system providers for information concerning mass, center of mass, antenna & reflector data, solar panels, radiated power, satellite attitude, and maneuvers

→ White paper was endorsed by PNT!