Multi-GNSS SISRE Assessment: What Science can do for Hikers, Bikers and the rest of Mankind

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Based on a paper by

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Reference

The SISRE-related part of the presentation is based on


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or

https://authors.elsevier.com/a/1X1Sb~6OibD1T (till June 30)

Available on-line, 19 pages.
GNSS and SPP

The “normal” users access a GNSS through Single Point Positioning (SPP), providing the instantaneous 3-d position and the time synchronization of the user receiver w.r.t. to GNSS time.

The User Navigation Error (UNE) is a function of the Dilution of Precision (DOP), the Signal in Space Error (SISRE) and the User Equipment Error (UEE).

\[
UNE = DOP \cdot \sqrt{SISRE^2 + UEE^2}
\]
SISRE statistics may be generated, if the ranges $\rho_..$ are calculated …

- (a) with the GNSS-provided broadcast information (satellite ephemerides and clock corrections)
- (b) with accurate satellite positions & clock corrections
- for known user positions $r(t)$ on the Earth and/or in the Earth-near space
Montenbruck et al. (2018) use orbits and clock corrections as obtained from the IGS-MGEX (Multi-GNSS Experiment) as “true” satellite & receiver clock information to generate SISRE statistics.

The statistics of the differences “broadcast—precise ranges” characterize the SISRE-performance of all partially or fully operational GNSS.

The orbit- and clock-contributions to SISRE can be provided separately.
In 2018 about 230 Multi-GNSS stations of the IGS track a combination of Galileo, Beidou, QZSS, in addition to GPS and GLONASS and may be used for the SISRE assessment.
Multi-GNSS SISRE Assessment

Monthly SISRE in 2017 of GPS and GLONASS (note scales!). Upper boundaries of
- Magenta bar: orbit-only RMS SISRE
- Gold bar: RMS SISRE (orbit+clocks+biases)
- Blue bar: 95th percentile SISRE
Multi-GNSS SISRE Assessment

Monthly SISRE in 2017 of Beidou-2 System (note scales!; B1 single frequency, B1/B2 dual freq.).

Upper boundaries of
- Magenta bar: orbit-only RMS SISRE
- Gold bar: RMS SISRE (orbit+clocks+biases)
- Blue bar: 95th percentile SISRE

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Monthly SISRE in 2017 of **Galileo** (scale as for GPS!).

**Upper boundaries of**
- Magenta bar: orbit-only RMS SISRE
- Gold bar: RMS SISRE (orbit+clocks+biases)
- Blue bar: 95th percentile SISRE
Multi-GNSS SISRE Assessment

Based on data from January to December 2017

Global monthly average RMS SISRE of

- 0.2 m, 0.6 m, 1 m, and 2 m were obtained for
- Galileo, GPS, Beidou-2, and GLONASS, respectively.

- For GPS and GLONASS orbit errors contribute only a moderate part to SISRE; the SISRE budget is dominated by clock errors.
- For Galileo and BeiDou, the RMS SISRE for orbits and clocks is only slightly larger than orbit-only contribution.
- Galileo benefits from the use of highly stable satellite clocks and short ephemeris update intervals (typically < 100 minutes).
- Beidou minimizes the overall range error in the broadcast generation rather than fitting orbits and clocks individually.
- GLONASS provides the largest SISRE values, due to the FDMA (Frequency Division Multiple Access) modulation.
- The outlier of the Galileo SISRE in May was due to problems in the ephemerides update.
81 (soon 84) GNSS & RNSS satellites are currently analyzed at CODE. The satellites have different characteristics (s-m 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 ($e\approx0.075$, $e\approx0.16$, respectively)

There are 31 satellites in the GPS constellation, 24 in GLONASS, 14 in Galileo, 15 in Beidou-2, 4 in QZSS.

Galileo approaches full constellation beginning of 2019.

[Private communication, Lars Prange (CODE AC), and Oliver Montenbruck, DLR]
GRACE-FO Launch, May 19 (?)

GRACE-FO is the successor of the US/German GRACE mission, 2002 – 2017 (October, end of GRACE science mission). The GRACE-FO twin satellites measure the Earth’s variable gravity field using GPS, microwave & laser inter-satellite link, and accelerometers.
In April 2018 Ruth Neilan stepped down as Director of the IGS Central Bureau and as member of the PNT Board.
1993 – 2018 she was the director of the IGS Central Bureau – and its soul.

The international representatives and the members of the science subcommittee of PNTAB are most grateful to Ruth for a very long, very fruitful cooperation, for her vision, and for her friendship.

We wish Ruth a exciting next phase of her life!
Summary

The article (Montenbruck et al, 2018) illustrates the value of permanent IGS-MGEX monitoring and data analysis for the “normal” users (hikers, bikers, astronauts in Low Earth Orbits) and for providers of GNSSs.

- The SISRE is an excellent key performance indicator for individual GNSS, which does, however, not account for constellation differences (# of satellites, inclination, # of orbital planes).
- The analysis performed by Montenbruck et al. (2018) is “slightly more complex” than our summary suggests → read the informative article.

The era of 3+ fully deployed GNSS is about to begin, rendering the MGEX indispensable.

Ruth Neilan was the soul of the IGS for a quarter of a century!