SPOCC – a GFZ Software Tool for a Multi-GNSS Orbit and Clock Combination

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Motivation

Among the core products of the International GNSS Service (IGS) are precise satellite orbits and clocks, which are generated by the Analysis Center Coordinator (ACC) as a combination of the solutions provided by different Analysis Centers (AC). A strategic goal of the IGS is to facilitate multi-GNSS solutions, implying that the currently operational system-wise GPS and GLONASS combinations should be replaced by a *consistent set of multi-GNSS products*, eventually containing at least GPS, GLONASS, Galileo, BeiDou, and QZSS.

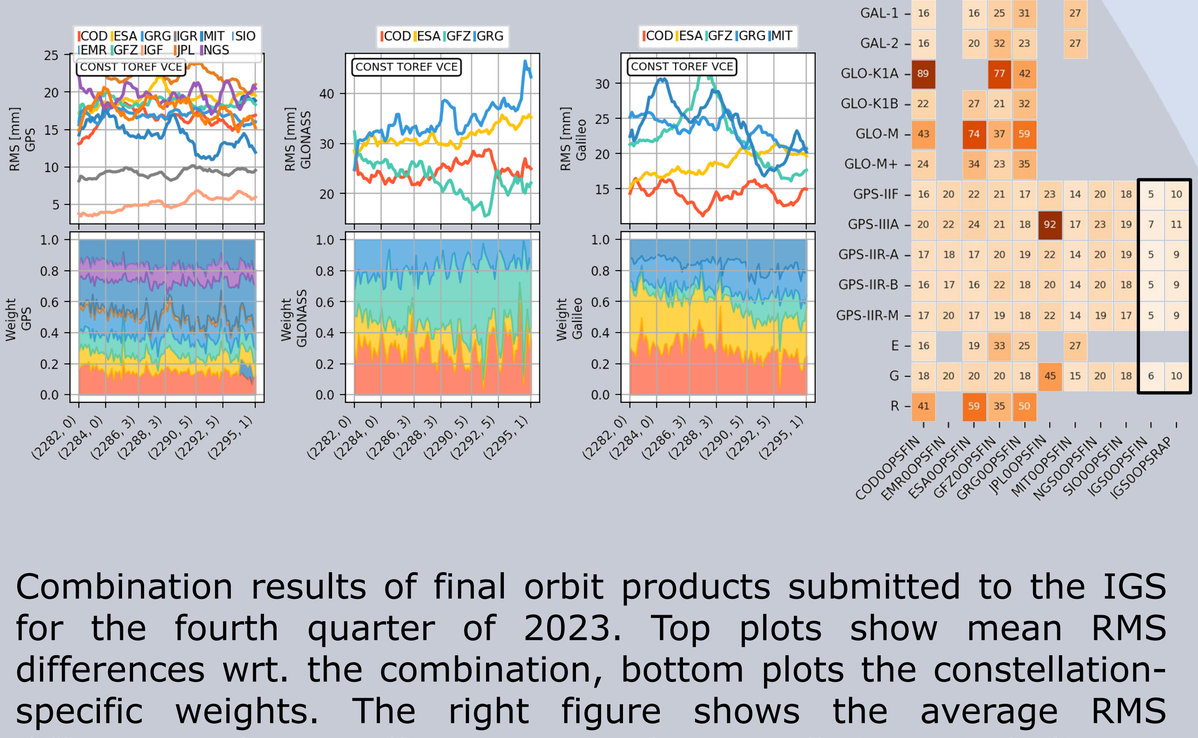
GFZ Software for Precise Orbit and Clock Combination (SPOCC)

General	Developed at GFZ in Python, YAML configuration file
Input/Output	Orbits in SP3 format, clocks in RINEX clock format
Systems	GPS, GLONASS, Galileo, BeiDou, QZSS, LEO satellite missions
Combination Strategy	- *Weighted average* of *aligned AC products* with weights from *variance component estimation* (VCE) - Least-squares VCE[1] or Förstner's VCE[2] - AC+constellation, AC+satellite-type or AC+satellite specific weighting
Processing	- VCE day-by-day or sequential in filter-mode - A-priori weights can be included, e.g. from SLR analyses
Alignment	- Orbits: could be aligned to terrestrial reference frame - Clocks: could be aligned to GPS time using broadcast clocks

Orbit Combination

Pre-check → Helmert transform. → Definition of core satellites → Variance component estimation → Orbit combination

Screening, est. of mean orbit | Alignment of AC orbits | Satellites to be used in VCE | Iterative est. of weights | Weighted average



Combination results of final orbit products submitted to the IGS for the fourth quarter of 2023. Top plots show mean RMS differences wrt. the combination, bottom plots the constellation-specific weights. The right figure shows the average RMS differences by satellite type and constellation, including a comparison to the operational GPS-only IGS combination in the last two columns. For more information, see [3].

Clock Combination

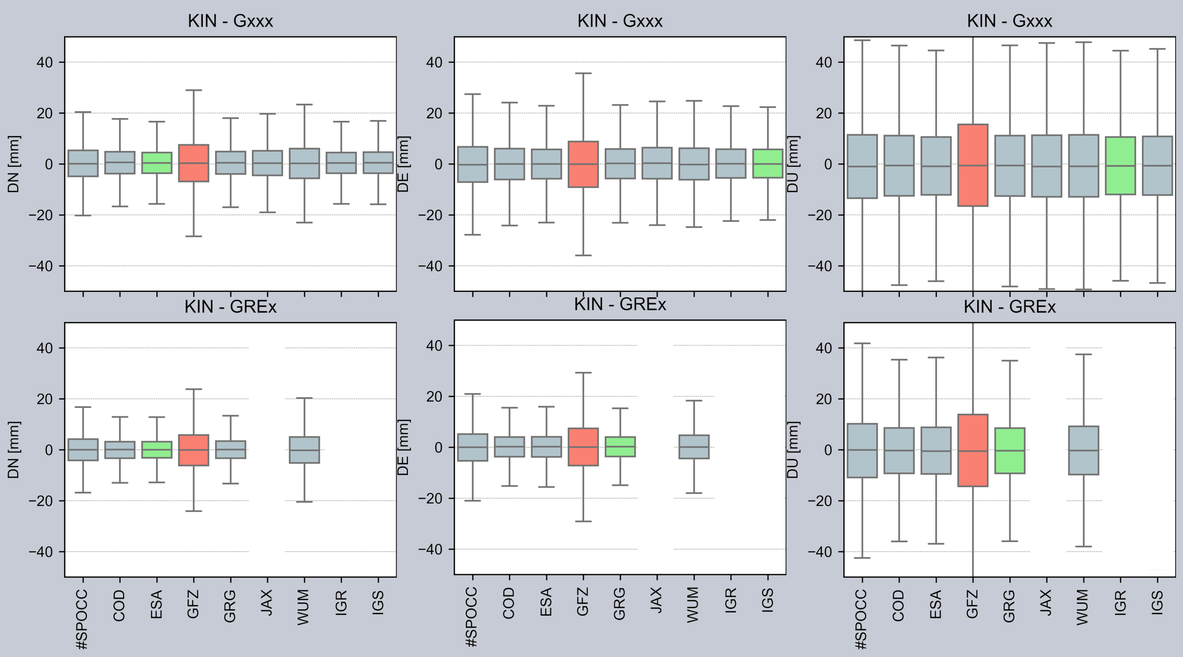
Radial correction → Pre-check → Offset and trend to reference → ISB alignment → Variance component estimation → Clock combination

From orbit differences | Standardize AC products, detect clock jumps | Alignment of AC reference clocks | Alignment of AC reference ISBs | Iterative est. of weights | Weighted average

Combination results of final clock products submitted to the IGS for the fourth quarter of 2023 (see description in Orbit Combination on the left). For more information, see [4].

PPP Using Combined Orbit and Clock Products

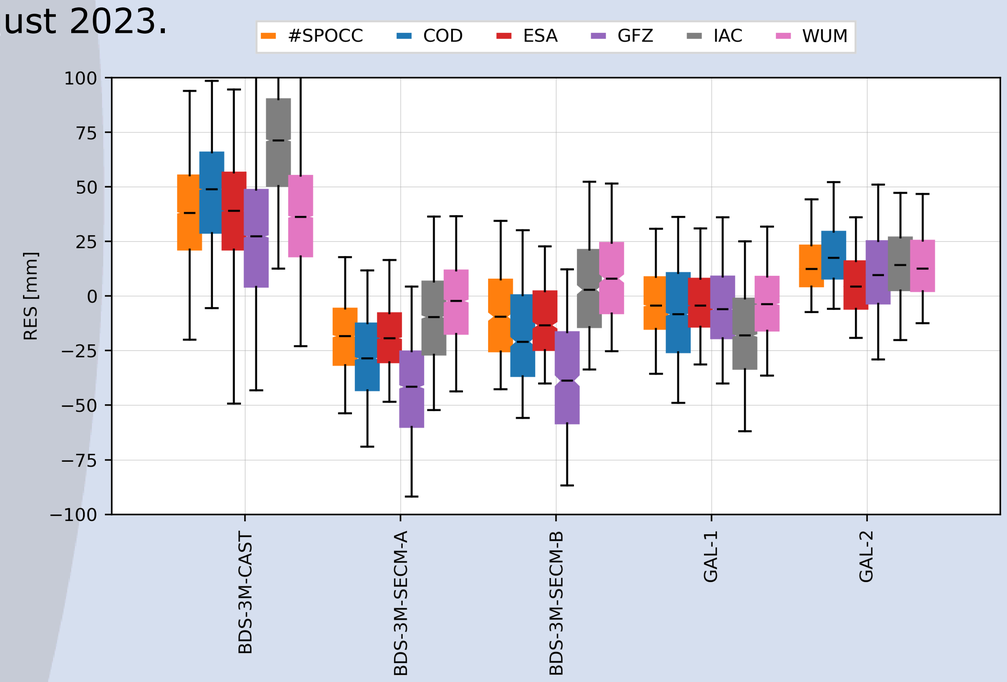
A main objective of this work is to support multi-GNSS precise point positioning (PPP) users with a consistent set of orbit and clock products, for which constant ISBs can be assumed.



North, East and Up coordinate repeatability of kinematic GPS (G), and GPS+GLONASS+Galileo (GRE) ambiguity-float PPP for 25 IGS stations during February to March 2023 using IGS MGEX orbit and clock products and the G-Nut processing software.

SLR Validation of Combined Orbit

Satellite laser ranging (SLR) measurements to GNSS satellites serve as an external validation of the satellite orbits. The figure shows the SLR residuals of the IGS MGEX orbits for February to August 2023.



References

[1] Teunissen PJG, Amiri-Simkooei AR (2008) Least-squares variance component estimation. Journal of Geodesy 82(2):65—82

[2] Förstner W (1979) Ein Verfahren zur Schätzung von Varianz- und Kovarianzkomponenten. AVN 86(11-12):446—453

[3] Mansur G, Sakic P, Brack A, Männel B, Schuh H (2022) Combination of GNSS orbits using least-squares variance component estimation. Journal of Geodesy 96:92

[4] Mansur G, Brack A, Sakic P, Männel B, Schuh H (2024) Utilizing least squares variance component estimation to combine multi-GNSS clock offsets. GPS Solutions 28:70