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

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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.

Over the past years, the Satellite Precise Orbit and Clock Combination (SPOCC) software tool has been developed at GFZ. It provides a fully consistent multi-GNSS orbit and clock combination that covers all available and possible future constellations and is based on a well-defined unified least-squares framework. The resulting combined orbit and clock products are a weighted average of the individual AC solutions with weights determined through least-squares variance component estimation (VCE). A main objective is to support multi-GNSS precise point positioning (PPP) users.

We will introduce the combination workflow, which essentially consists of alignments harmonizing the AC products followed by the VCE and the weighted averaging, and is complemented by quality checks such as outlier detection. For the orbit combination, the alignment consists of Helmert transformations applied to the AC orbits, which is iterated with the VCE-based weighted averaging until convergence. The clock alignments consist of a radial correction from the orbit differences between the AC solutions, a removal of the impact of different reference clocks in the AC solutions, as well as an adjustment of all non-GPS satellite clocks for different inter-system bias (ISB) references at the ACs. The combination can be configured for different weighting schemes, including AC specific weights, AC+constellation specific weights, up to satellite type or even satellite specific weights, and the Helmert transformations can be based on different sets of satellite orbits.

The SPOCC software has been extensively tested with the operational IGS products, the IGS Multi-GNSS Experiment (MGEX) products, and the IGS repro3 products. Performance evaluations by means of a comparison of the combination with the input products and the official IGS combination, through a satellite laser ranging (SLR) validation, and with PPP results will be used to show that the software achieves reliable results that are suitable for the users' high precision

GNSS applications.

SPOCC is implemented in Python and will be provided as open source software.