

# Multi-GNSS IPPP based on the Atomium software

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The current best performance of GNSS frequency transfer is obtained through Integer Precise Point Positioning with ambiguities (IPPP), i.e. resolving integer ambiguities of carrier phases. This technique allows to compare clocks with a stability of sub  $10^{-16}$  for averaging times longer than a few days<sup>1</sup>. Atomium is a GNSS data processing software developed at the Royal Observatory of Belgium, mainly for time and frequency transfer. This presentation will outline its latest developments providing an improved IPPP solution.

In IPPP, the integer ambiguities are determined based on the criterion that the recovered unambiguous should be consistent with pseudorange observations, which leaves integer-cycles day boundaries to both satellite and receiver clocks with the varying of pseudorange scales. Different techniques have been proposed in the past years to retrieve the continuity at the day boundaries. However, none of them provides a 100% efficiency. Since January 1 of 2024, Wuhan International GNSS Service (IGS) Analysis Center has been releasing continuous satellite phase clocks/bias products to the public. These products will enable short latency multi-day IPPP processing, producing continuous time links.

In parallel, Atomium has been upgraded to offer the possibility to compute IPPP clock solutions from either single-constellation or multi-GNSS, including GPS, Galileo and BDS. The combination provides better satellite geometry and more redundant observations. In this study, we initially assess the contribution of multiple constellations on both short- and long-term frequency stability of time links using GPS, Galileo and BDS. We then propose a strategy to mitigate the time-link discontinuities related to troposphere and multipath errors, which will benefit the alignment method of day boundaries for classic single-day IPPP. We then compare these solutions with the multi-day solutions based on the aligned satellite clock products newly released by the Wuhan Analysis Center.

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<sup>1</sup> G Petit et al 2022, Continuous IPPP links for UTC, Metrologia 59 045007