On the interoperability of open Satellite-based Precise Point Positioning services

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SUMMARY

Global Navigation Satellite System (GNSS) Real-time Precise Point Positioning (RT-PPP) technology enables high-precision positioning globally using a single receiver. This capability is extensively utilized in terrestrial and aeronautical applications, as well as for precise orbit determination. However, RT-PPP's effectiveness is heavily reliant on real-time precise orbit and clock corrections delivered through network streams, making it vulnerable to interruptions that can significantly affect users. To mitigate this issue, various GNSS systems are developing or implementing satellite-based high-accuracy correction services. These services transmit precise corrections via satellite communication links, referred to as satellite-based PPP services, providing a more robust and reliable means to enhance positioning accuracy. In the future, users will be able to decode multiple GNSS corrections embedded in satellite signals from various service providers. These services are tailored for specific coverage areas and support distinct GNSS system augmentations. By integrating these services, users can extend their coverage, increase satellite availability, and improve the reliability and stability of their positioning solutions. However, careful consideration must be given to the systematic biases that may exist between different satellite-based services, as these can hinder their seamless integration. This study examines the interoperability of various satellite-based services, specifically focusing on the operational services: BeiDou Navigation Satellite System (BDS-3) PPP-B2b, Europe's Galileo High Accuracy Service (HAS), and the Quasi-Zenith Satellite System (QZSS) Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis (MADOCA). We analyzed the correction availability, orbit, and clock quality of these individual services using data collected in Hong Kong from day of year (DOY) 153 to 336 in 2024. Based on the evaluation of signal-in-space range errors (SISREs), we determined the appropriate weights for combining the different satellite-based services. For uncommon constellations, the average accuracy improvement achieved through combination is 50.2% greater than that obtained using the services independently. For common constellations, we propose and

compare two combination strategies: the first involves switching to the second-best stream (HAS) during an outage of the best stream (MADOCA), while the second strategy employs a full combination of services. The first strategy yields superior overall positioning performance, as MADOCA demonstrates exceptional performance when available. Conversely, incorporating HAS in the second strategy may diminish overall accuracy. However, this dynamic may evolve as the total number of services increases and the variability of services decreases, potentially making a standard full combination the optimal approach in the future.