Assessment of BeiDou-3 PPP-B2b signal-in-space and positioning performance

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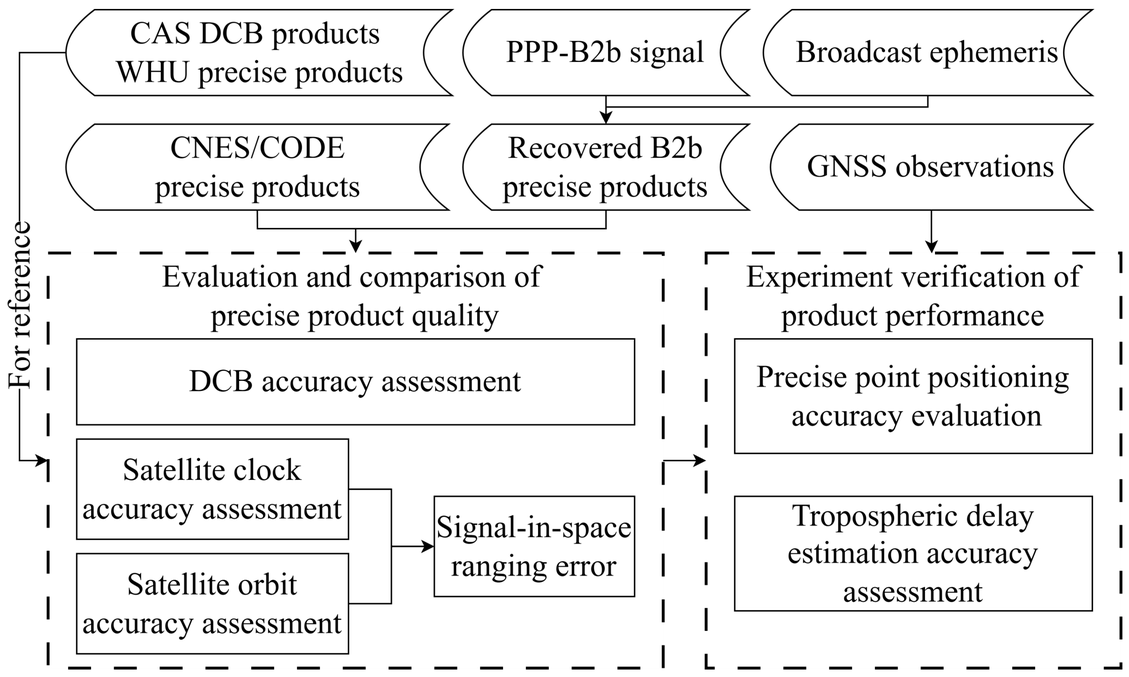
Introduction

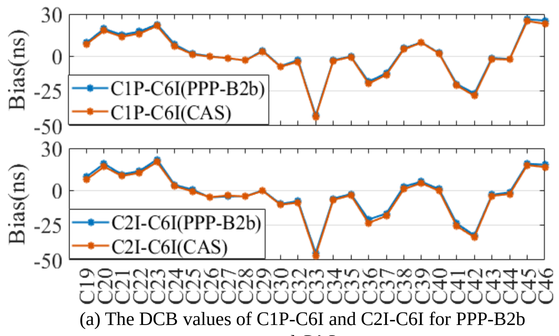
- The third generation of the BeiDou Navigation Satellite System (BDS-3) was officially launched in July 2020, providing open, free and high-precision PPP-B2b service to users in China and surrounding regions
- Studying the accuracy and statistical characteristics of BDS-3 PPP-B2b signals is of significant importance for enhancing system service performance, improving positioning accuracy, and achieving high-precision positioning in adverse communication environments

Experimental Steps

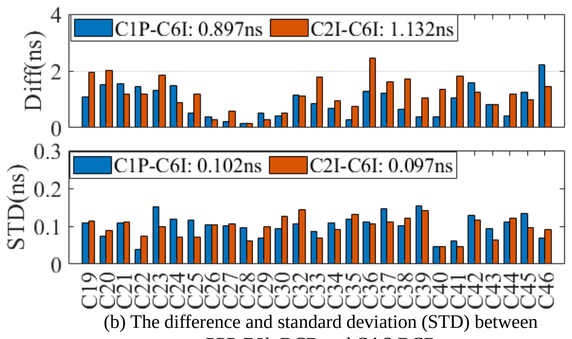


- The data used in this study was collected from August 20 to August 26, 2023
- The DCB accuracy of PPP-B2b product was evaluated with CAS DCB product as a reference
- Final products by WHU was taken as a reference to evaluate the SISRE of PPP-B2b products, CNES real-time products, and CODE final products
- Performances of positioning and ZTD estimation were assessed through PPP experiments

DCB and Clock

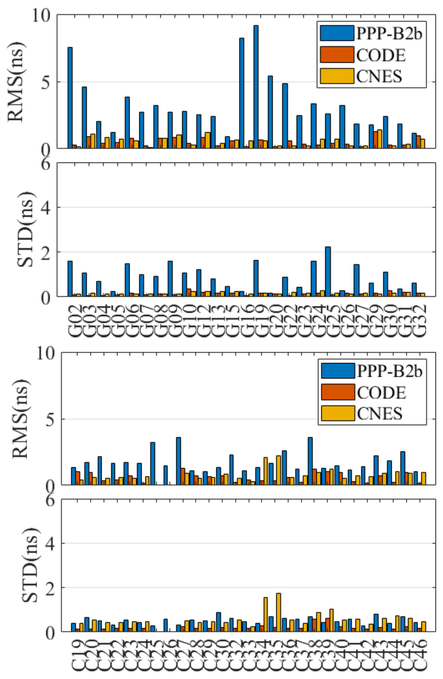


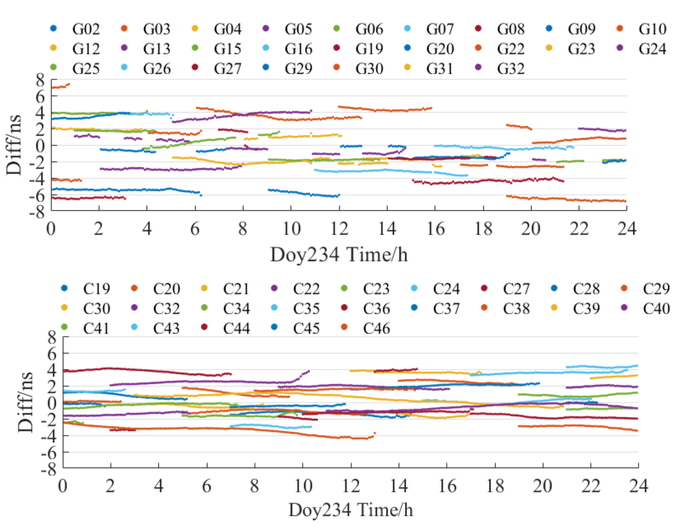
(a) The DCB values of C1P-C6I and C2I-C6I for PPP-B2b and CAS



(b) The difference and standard deviation (STD) between PPP-B2b DCB and CAS DCB

- PPP-B2b product is highly compatible with CAS DCB product



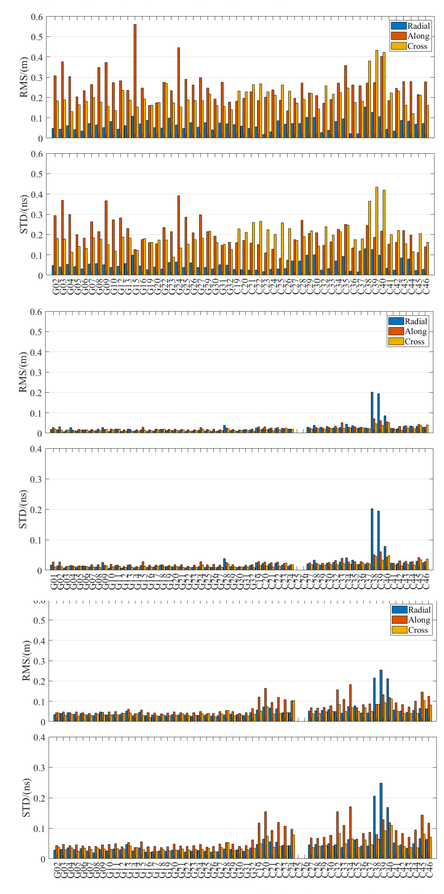


(c) Clock accuracies of PPP-B2b, CODE, and CNES products (top: GPS, bottom: BDS-3)

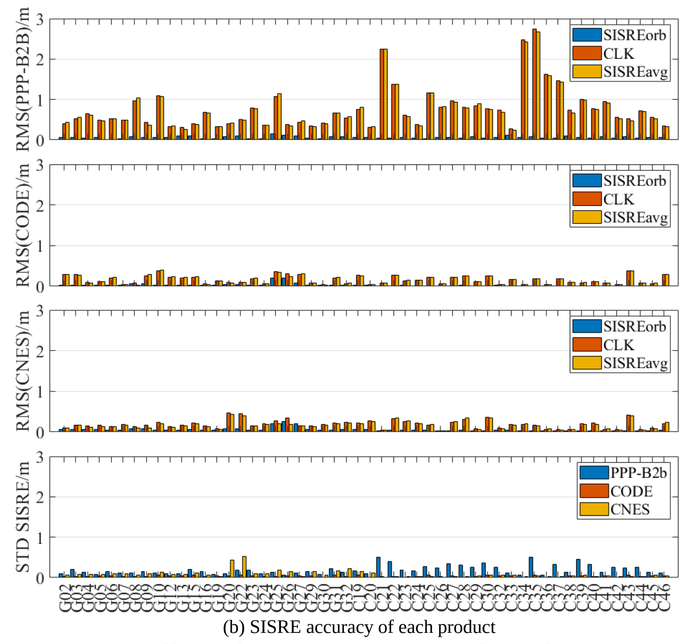
(d) Time series of PPP-B2b clock errors on DOY 234, 2023

- The satellite clock accuracy for the PPP-B2b products: BDS-3 outperforms GPS
- Clock stability of the BDS-3 satellites: PPP-B2b products (0.52 ns) outperform CNES products (0.62 ns)

Orbit and SISRE



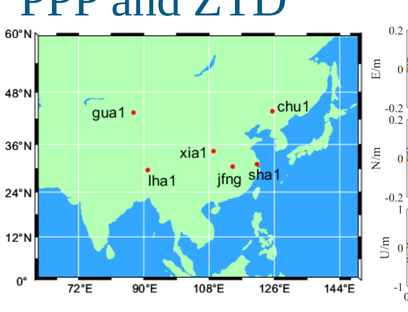
(a) Orbit accuracies in radial, along-track, and cross-track directions (top: PPP-B2b, middle: CODE, bottom: CNES)



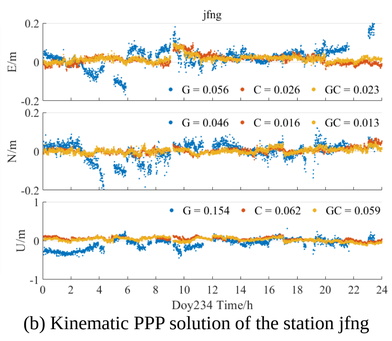
(b) SISRE accuracy of each product

- BDS-3 satellite orbit accuracy: PPP-B2b products are 11% more accurate than CNES products in radial direction
- Radial accuracy of the IGSO satellites: PPP-B2b products outperform both CODE and CNES products
- The stability of SISRE can reflect the accuracy of PPP. In PPP-B2B products, the GPS satellites SISRE performance is relatively poorer compared to other products, but its BDS-3 satellites SISRE std (0.130 m) is slightly better than that of the BDS-3 satellites in CNES products (0.131 m)

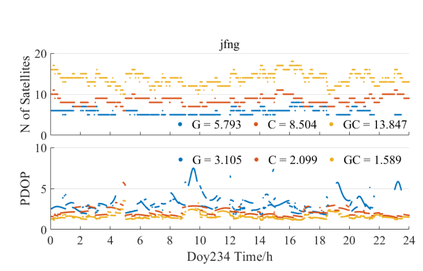
PPP and ZTD



(a) Distribution of the 6 stations

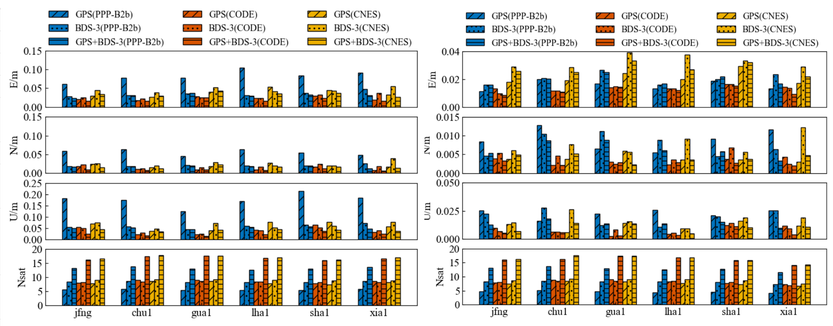


(b) Kinematic PPP solution of the station jfng



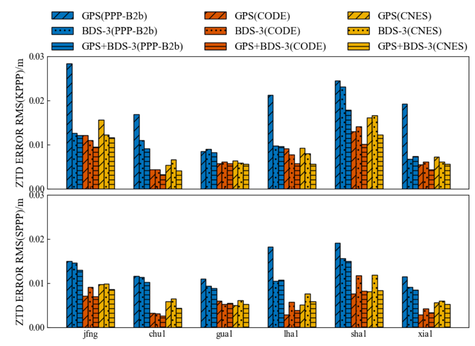
(c) Number of available satellites and PDOP of the station jfng

Processing strategies	
Observation type	IF: B1/B3, L1/L2
Interval	30s
Cut-off elevation	5°
Satellite orbit and clock	PPP-B2b /CODE/CNES
PCO and PCV	IGS14.atx
Solid tide, ocean tide	IERS Conventions 2010
ZTD parameters	Saastamoinen model and random walk
Noise levels of code and phase	0.3m/0.01cycle
Ambiguity	Float



(d) Weekly average results for kinematic (left) and static (right) PPP solutions

- The number of available satellites and PDOP values of BDS-3 satellites in the PPP-B2b products are much more stable than those of GPS satellites
- PPP-B2b product performs better than CNES product in kinematic PPP with BDS-3 satellites
- When GPS and BDS-3 are combined, accuracies with PPP-B2b product are comparable to those with CNES product for both kinematic and static PPP
- The ZTD accuracies with PPP-B2b products are slightly outperformed by CODE and CNES products
- The static solutions are more accurate than the kinematic solutions



(e) Weekly accuracies of ZTDs with GPS, BDS-3 and both

Conclusion

- The radial components of BDS-3 orbits are slightly more accurate than those of GPS orbits, which might be attributed to the ISL payloads upon the BDS-3 satellites
- The GPS satellite clock with PPP-B2b are not as accurate, since the initial clock offset could not be fully separated from the ambiguities by utilizing a regional network. This significant satellite-specific bias cannot be ignored due to its impact on the stability of SISRE
- When both GPS and BDS-3 are used, centimeter-level accuracy can be achieved for kinematic PPP with PPP-B2b product, comparable to the kinematic PPP solution with the CNES RTS product.
- The ZTD parameters with PPP-B2b products are not as accurate as those with CODE and CNES products
- The performance of PPP-B2b service at the selected six stations is comparable to CNES RTS, and is expected to be further enhanced by properly addressing the satellite-specific biases

Main references:

1. CSNO (2020) BeiDou Navigation Satellite System signal in space interface control document precise point positioning service signal PPP-B2b (Version 1.0).
2. Kazmierski K, Zajdel R, Sośnica K (2020) Evolution of orbit and clock quality for real-time multi-GNSS solutions. GPS Solutions, 24(4), 1-12. https://doi.org/10.1007/s10291-020-01026-6
3. Tao J, Liu J, Hu Z, Zhao Q, Chen G, Ju B (2021) Initial assessment of the BDS-3 PPP-B2b RTS compared with the CNES RTS. GPS Solutions, 25(4):131. https://doi.org/10.1007/s10291-021-01168-1
4. Xie X, Geng T, Zhao Q, Lv Y, Cai H, Liu J (2020) Orbit and clock analysis of BDS-3 satellites using inter-satellite link 94observations. Journal of Geodesy (7):64. https://doi.org/10.1007/s00190-020-01394-4
5. Yang Y X, Ding Q, Gao W G, Li J L, Xu Y Y, Sun B J (2022) Principle and performance of BDSBAS and PPP-B2b of BDS-3. Satellite Navigation, 3(1), 5. https://doi.org/ 10.1117/12.953958