Potentiality of Multi-GNSS precise point positioning (PPP) with ambiguity resolution (AR) in determining gravity potential

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Brief introduction of Multi-GNSS

Fig. 1 Composition of multi - Global Navigation Satellite System (GNSS).

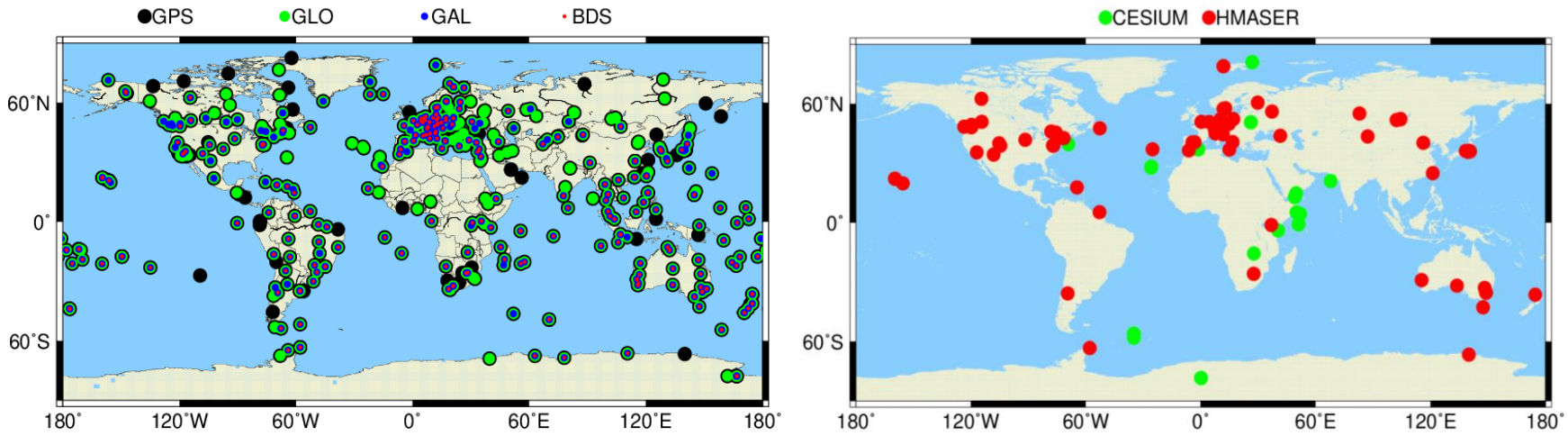
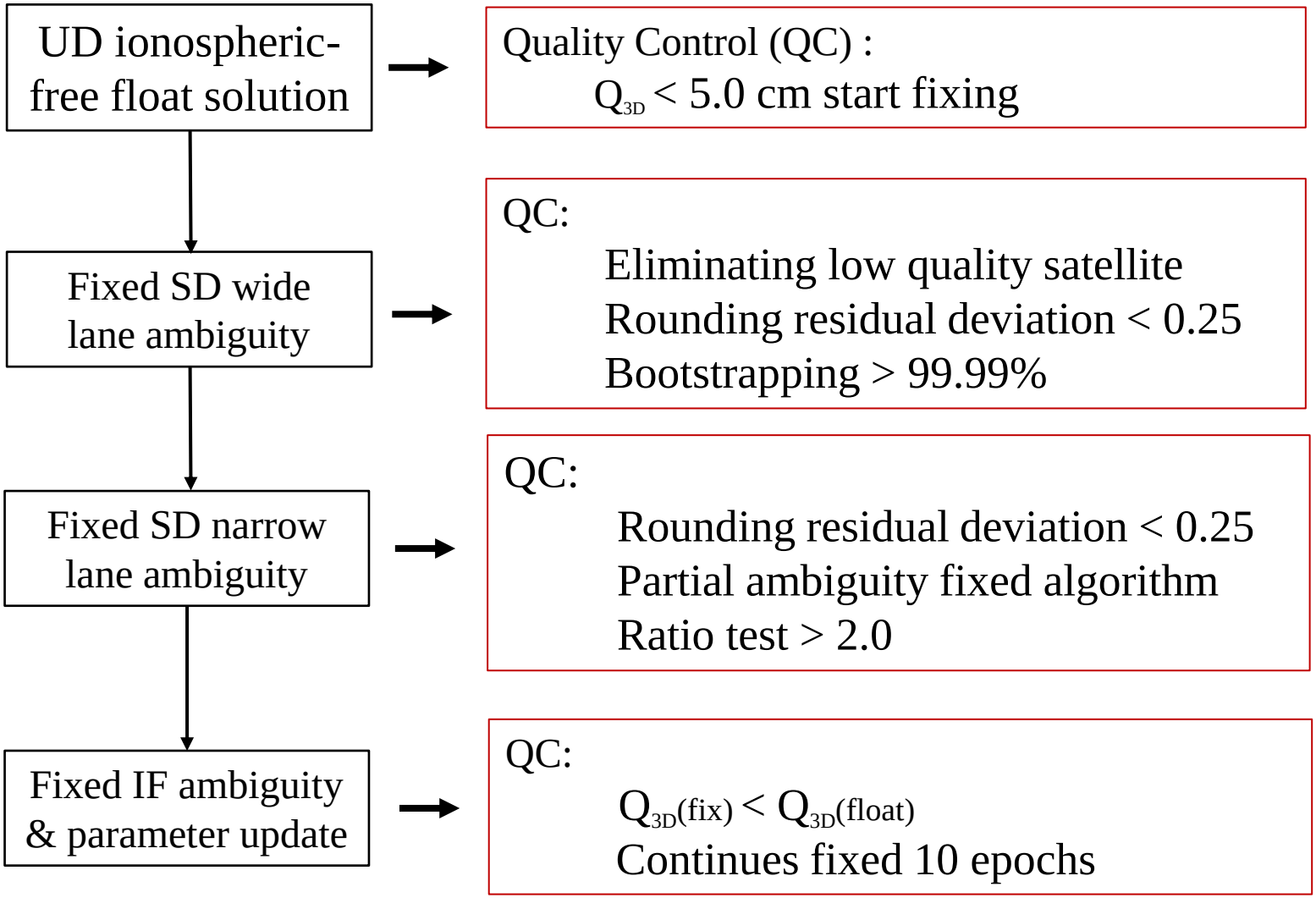


Fig. 2 Geographical distribution of multi-system and external high precision atomic clock stations.

- A large number of stations equipped with Hydrogen and Cesium atomic clocks.
- Multi-GNSS will bring more opportunities for gravity potential determination using PPP time transfer technology.

Multi-GNSS PPP ambiguity resolution method



Multi-GNSS PPP AR time transfer experiment

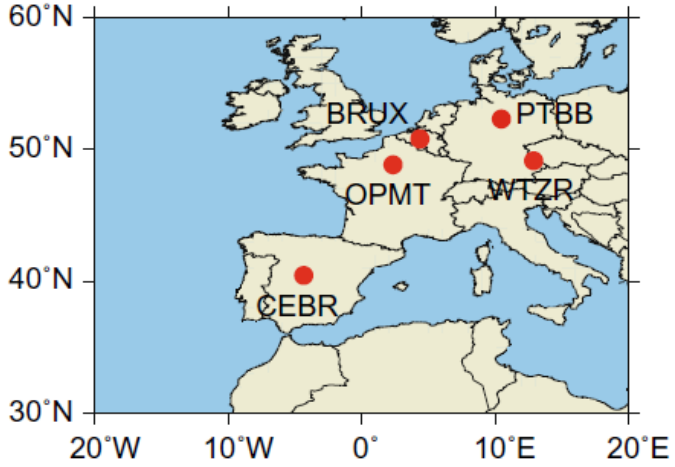


Fig. 3 Geographical distribution of the stations.

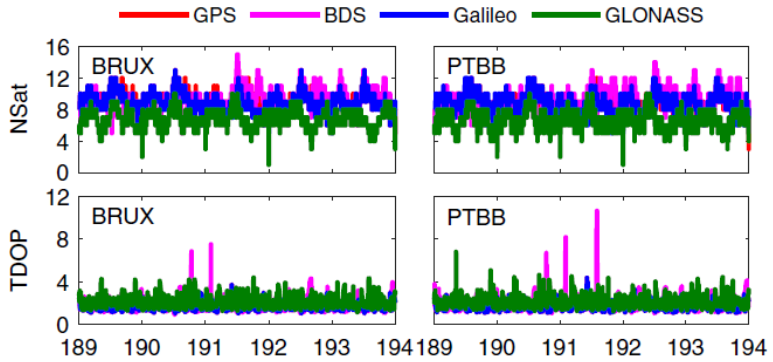


Fig. 4 Number of satellites (NSats) (top) and time dilution of precision (TDOP) (bottom)

Table 1 List of selected stations

Station	Receiver type	Antenna type	Location
BRUX	SEPT POLARX5TR	JAVRINGANT_DM	Belgium
OPMT	ASHTECH Z-XII3T	3S-02-TSADM	France
PTBB	SEPT POLARX5TR	LEIAR25.R4	Germany
WTZR	LEICA GR50	LEIAR25.R3	Germany
CEBR	SEPT POLARX5TR	SEPCHOKE_B3E6	Spain

Table 2 Details of processing strategies

Items	Strategies
Solutions	PPP and IPPP
Observations	GPS: L1/L2; Galileo: E1/E5a; BDS-2/BDS-3: B1I/B3I; GLONASS: G1/G2
Elevation cutoff	7°
Satellite orbit and clock	CNES GRG precise products
Satellite DCB	CAS BSX products (Zhang et al. 2018)
Earth rotation	Corrected (Petit et al. 2010)
Relativistic effect	Corrected (Kouba 2009)
Phase windup effect	Corrected (Wu et al. 1992)
Tide effect	Solid Earth, pole, and ocean tide (Petit and Luzum 2010)
Satellite and receiver antenna	IGS14.atx
Station coordinates	Estimated as constants
Receiver clock	Estimated as white noise
Tropospheric delay	Dry component: GPT add Saastamoinen model (Böhm et al. 2007; Saastamoinen 1973); Wet component: estimated as random part, Global mapping function (Böhm et al. 2006)
Ambiguities	Estimated as constant

Multi-GNSS PPP AR time transfer results analysis

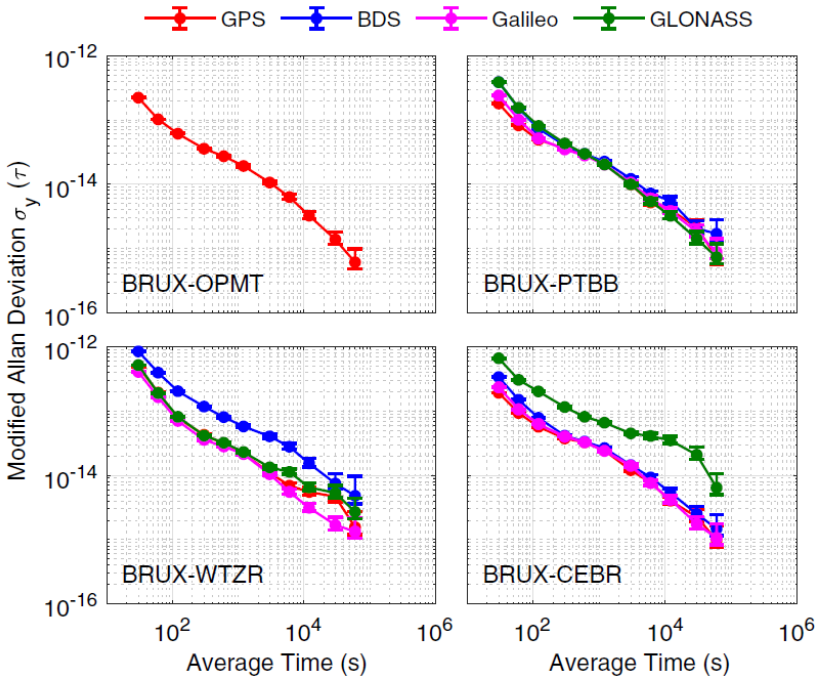


Fig. 5 Time transfer instabilities for GPS, BDS, Galileo, and GLONASS by PPP solutions.

- The stabilities of GPS and Galileo are generally better than those of BDS and GLONASS, which are shown in BRUX–WTZR and BRUX–CEBR

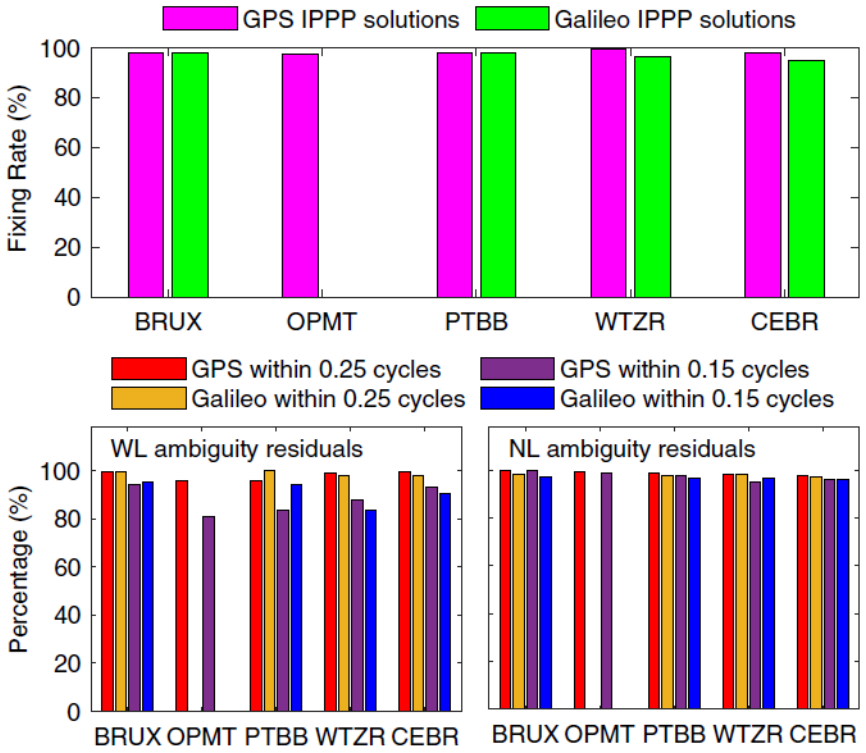


Fig. 6 Fixing rates of narrow-lane (NL) ambiguity (top), wide-lane (WL) ambiguity residuals (bottom left) and NL ambiguity residuals (bottom right)

- The fixing rates are better than 95%, and the NL ambiguity residuals within $\pm$0.15 cycles was better than 96%.

Multi-GNSS PPP AR time transfer results analysis

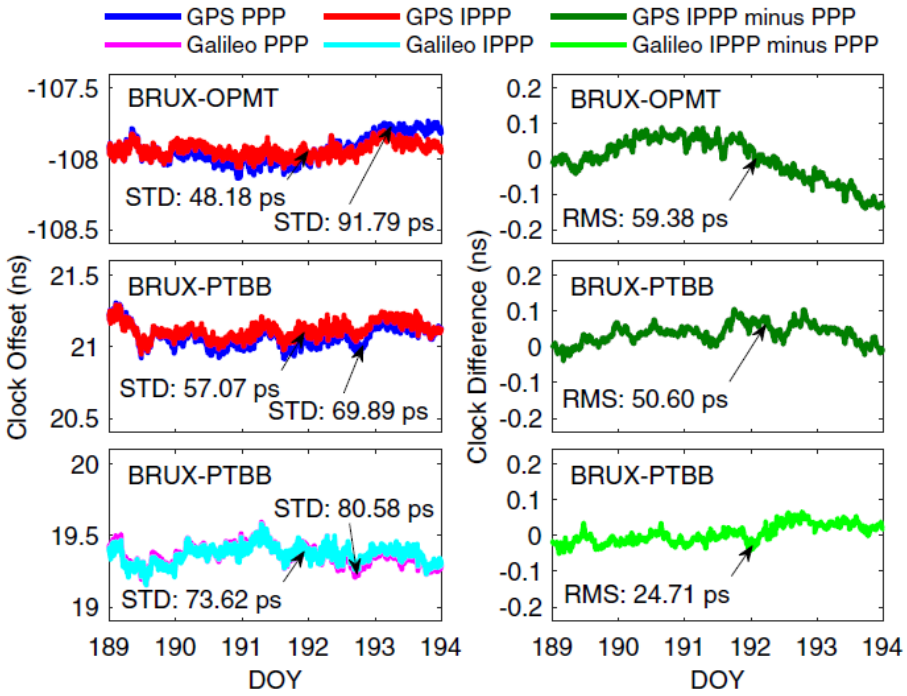


Fig. 7 Clock offsets for PPP and IPPP (left) and clock differences between PPP and IPPP (right)

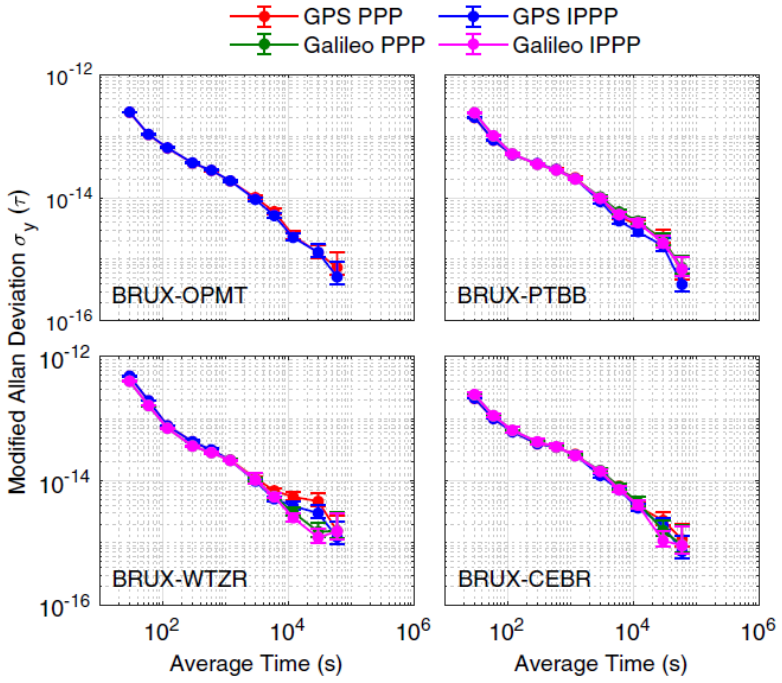


Fig. 8 Time transfer instability for IPPP and PPP

- The fluctuation of IPPP (mean STD is 59.72 ps) is smaller than that of PPP (mean STD is 90.42 ps) indicating that IPPP is more stable than PPP.

- The short-term stability of the IPPP is not significantly improved.
- For intervals larger than 3,000 s, the average of the stability improvement rate for the four links is about 15%.

Conclusions and Discussions

- The time transfer stabilities of GPS and Galileo are generally better than those of BDS and GLONASS.
- Compared with the float PPP solutions, the long-term frequency stability of fixed PPP is improved by above 15% on average.
- High-precision GNSS time transfer methods, especially the fixed PPP time transfer techniques with their advantages in long-term stability, will provide prospective applications for determining the gravity potential.

Thanks for your attention !