FY-3D and FY-3C Onboard Observations for DCB Estimation: BDS and GPS DCBs

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Introduction

With the development of Low Earth Orbit (LEO) satellites, differential code biases (DCBs) estimation based on onboard observations have been widely studied. In this study, BDS and GPS onboard observations from Chinese Fengyun-3D (FY-3D) and Fengyun-3C (FY-3C) are applied to estimate BDS and GPS DCBs. DCB estimation results based on FY-3D onboard observations are firstly analyzed and compared with the DCB estimation results based on FY-3C onboard observations. When jointly processing BDS+GPS onboard observations, the stability of satellite and receiver DCBs for both BDS and GPS can be improved. Compared with the FY-3C solution, the FY-3D solution can achieve a more stable satellite and receiver DCBs. Furthermore, both FY-3D and FY-3C onboard observations are processed together to estimate BDS and GPS DCBs. Compared with FY-3D solution, most of the stability of satellite DCB can be improved.

DCB Estimation Strategy

BDS and GPS onboard observations in 30-second interval from FY-3D and FY-3C during the period from DOY 356 in 2017 to DOY 019 in 2018 are used to estimate BDS and GPS DCBs. The cut-off elevation mask of 30° is set to reduce the mapping function errors. In addition, carrier-phase smoothed pseudorange is adopted to improve the precision of DCB estimation. As indicated in some studies, the F&K geometric mapping function can be used for the LEO-based methods when the assumption of spherical symmetry is adopted. A centroid method based on $F_{10.7}$ (Solar Radio Flux at 10.7 cm) is used to calculate plasma-sphere effective height. Besides, a zero-mean constrain condition for all satellite DCB is imposed.

Results and Analysis

☐DCB Estimation with FY-3D Onboard Observations

For GPS and BDS solutions, their monthly mean differences with DLR and CAS products are within ±1 ns for GPS, ±1.5 ns for BDS (Fig. 1). In Fig. 2, the mean STDs of GPS satellite DCBs for GPS-only, BDS+GPS, DLR and CAS solutions are 0.101, 0.096, 0.050 and 0.044 ns respectively. Compared with GPS-only solution, the monthly stability of satellite DCBs for BDS+GPS solution can be improved with an overall improvement of 5%. Compared with BDS-only solution, the mean STDs of BDS satellites for BDS+GPS solution can be improved by 11%, 26% and 26% for BDS GEO, IGSO and MEO satellites respectively. The monthly mean and STD of FY-3D receiver DCB for GPS-only, BDS+GPS (GPS result), BDS-only and BDS+GPS(BDS result) solutions are -17.658±0.163, -17.582±0.125, 9.416±0.147 and 8.873±0.118 ns respectively. The receiver DCB for BDS+GPS solutions are more stable than that for single-system solutions.

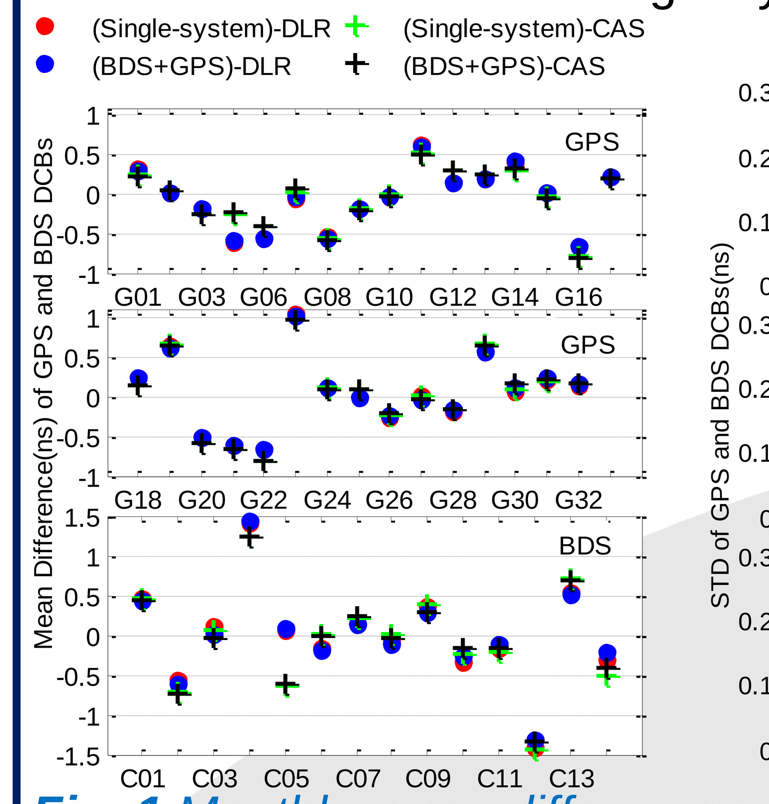

Fig. 1 Monthly mean differences of satellite DCBs between FY-3D solution and DCB products

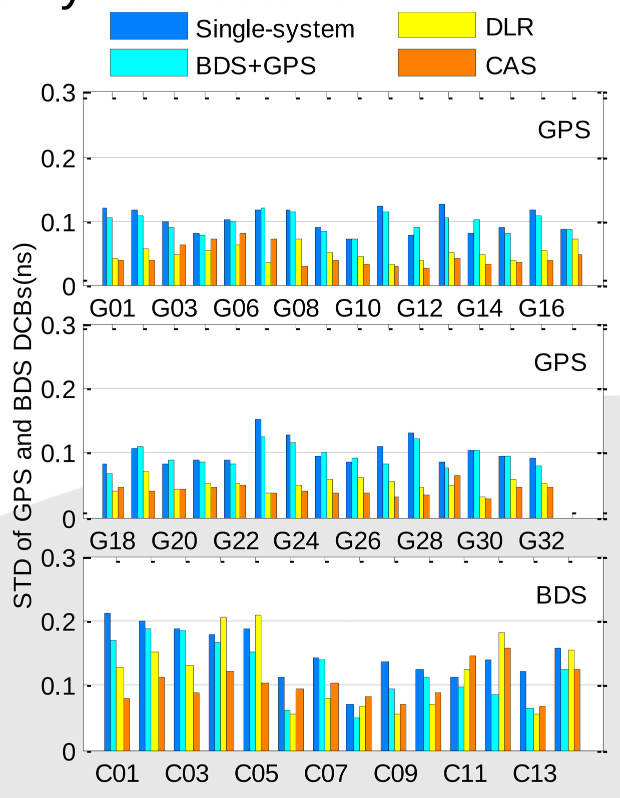

Fig. 2 Monthly STDs of satellite DCBs

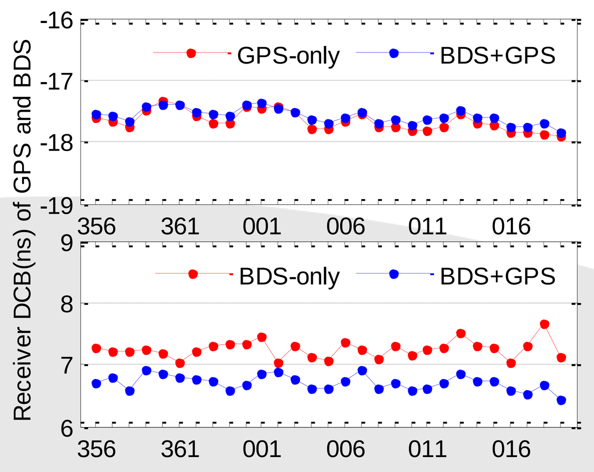

Fig. 3 Time series of FY-3D receiver DCB

☐Comparison with DCB Estimation between FY-3D and FY-3C

Compared with FY-3C solutions, the stability for GPS satellite DCBs can be improved by 30% for both GPS-only and BDS+GPS solutions, and the stability for BDS GEO, IGSO and MEO satellites can be improved by (46%, 62%, 54%) for FY-3D BDS-only solution and (51%, 61%, 47%) for FY-3D BDS+GPS solution respectively (Table 1). Compared with FY-3C receiver DCB, the stability of FY-3D receiver DCB is 60%, 50%, 21% and 39% higher for BDS-only, BDS+GPS (BDS result), GPS-only and BDS+GPS (GPS result) solutions respectively (Table 2).

	Solution	LEO Satellite	Mean of Monthly STD			
			GPS	GEO	IGSO	MEO
BDS	BDS-only	FY-3D	—	0.190	0.109	0.150
		FY-3C	—	0.349	0.289	0.329
	BDS+GPS	FY-3D	—	0.168	0.093	0.112
		FY-3C	—	0.340	0.238	0.212
GPS	GPS-only	FY-3D	0.101	—	—	—
		FY-3C	0.143	—	—	—
	BDS+GPS	FY-3D	0.096	—	—	—
		FY-3C	0.138	—	—	—
—	DLR	—	0.050	0.164	0.061	0.159
	CAS	—	0.044	0.104	0.086	0.144

Table 1 The statistics of mean values of monthly STD for BDS and GPS satellite DCBs

	Solution	LEO Satellite	Mean	STD
BDS	BDS-only	FY-3D	9.442	0.137
		FY-3C	12.076	0.343
	BDS+GPS	FY-3D	8.865	0.121
		FY-3C	11.526	0.241
GPS	GPS-only	FY-3D	-17.658	0.163
		FY-3C	-50.087	0.206
	BDS+GPS	FY-3D	-17.582	0.125
		FY-3C	-49.990	0.206

Table 2 The statistics of monthly mean and STD of receiver DCBs

☐DCB Estimation with FY-3D and FY-3C Onboard Observations

Compared with FY-3D-only solution, the stability of GPS satellites DCBs for FY-3D+FY-3C solution can be improved by 19%, and the stability of BDS IGSO and MEO satellites DCBs for FY-3D+FY-3C solution can be slightly improved by 2% and 4% respectively, but the stability of BDS GEO satellites DCBs for FY-3D+FY-3C solution is at the same level with that for FY-3D-only solution. Besides, the FY-3D+FY-3C solution can improve the stability of 4% and 5% for receiver DCBs of GPS and BDS respectively.

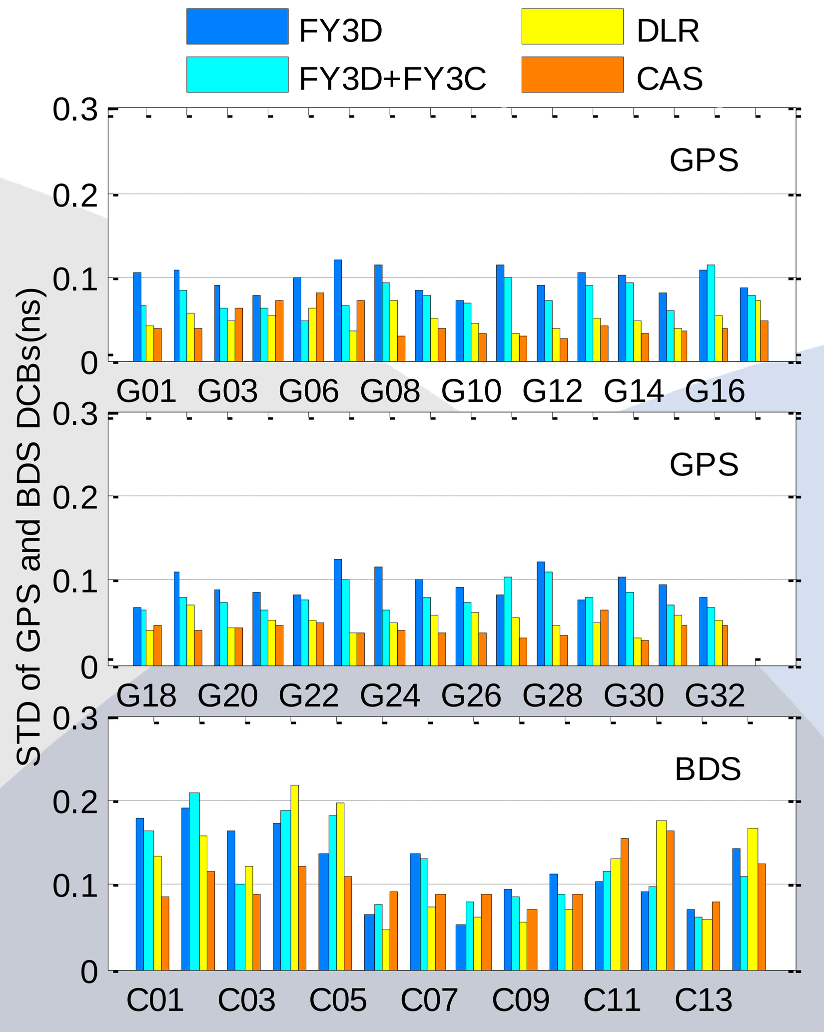

Fig. 4 Monthly STDs of satellite DCBs

	FY-3D-only	FY-3D+FY-3C	DLR	CAS
GPS	0.096	0.078	0.050	0.044
GEO	0.168	0.168	0.165	0.104
IGSO	0.093	0.092	0.061	0.086
MEO	0.101	0.096	0.133	0.131

Table 3 The statistics of mean values of monthly STD for GPS and BDS satellites

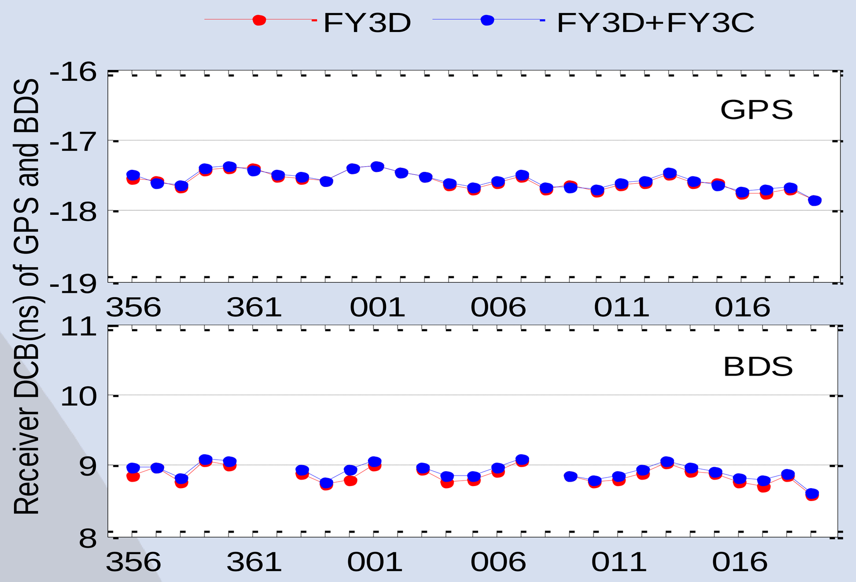

Fig. 5 Time series of FY-3D receiver DCB

Conclusions

- When jointly processing BDS+GPS onboard observations, the stability of satellite and receiver DCBs for both BDS and GPS has better consistency with the DCB products of DLR and CAS than that for the single-system solutions (BDS-only solution and GPS-only solution).
- Compared with FY-3C, FY-3D presents better results of DCB estimation, which can be owing to the enhancement of FY-3D GNSS Occultation Sounder (GNOS) instrument, which can provide more observations with higher quality.
- when both FY-3D and FY-3C onboard observations are jointly processed, the improvement of DCB results for GPS is more significant than that for BDS. This could be due to the relatively few onboard BDS observations of FY-3C, which makes a small contribution in the BDS DCB estimation.

References

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