Influence of the Multi-frequency Phase Center Offset Differences on the Characteristics of GNSS Inter-Frequency Clock Bias

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1 Introduction

- GNSS has entered the era of multi-system and multi-frequency availability. However, due to the existence of Inter-Frequency Clock Bias (IFCB), the traditional IGS precision satellite clock products cannot be directly applied to the multi-frequency precision point positioning (PPP).
- Recognizing the contribution of the phase center offset (PCO) to the ITRF scale and PPP, however, their corrections are usually ignored when forming the geometry- and ionosphere-free (GIF) epoch-differenced observations to estimate the IFCB. Employing inappropriate PCO processing strategies may compromise the time-varying characteristics of IFCB.

2 Methods

a) Conventional IFCB estimation

- If true PCO values at each frequency are known, forming the GFIF observations and correcting PCO values to estimate the IFCB θ.

$$L^s_{r,GFIF} - \boldsymbol{\mu}^s_r * \boldsymbol{M}^e_s * \left(\boldsymbol{O}^s_{IF12} - \boldsymbol{O}^s_{IF13}\right) = N^s_{r,GFIF} + \theta^s_{r,IF} \quad (1)$$

where ***O*** and ***N*** represent the PCO and constant part of GFIF. Unit vector ***u*** and matrix ***M*** denote the satellite line-of-sight direction and the rotation matrix from satellite body-fixed frame to ECEF.

b) IFCB estimation considering PCO

- However, the PCO values of newly launched satellites or new types of satellite, for instance, newest GPS IIIA or GLONASS-K satellites, are usually unknown. The epoch-differenced IFCB and the PCO of third-frequency are estimated simultaneously as follows:

$$\boldsymbol{x} = \left[\Delta\theta^s_{r,IF}(t_1,t_0), \Delta\theta^s_{r,IF}(t_2,t_1), ..., \Delta\theta^s_{r,IF}(t_n,t_{n-1}), \boldsymbol{O}^s_3\right]^{\mathrm{T}} \quad (2)$$

3 Data and Processing strategy

a) IFCB estimation

- Observations: over 90 MGEX stations;
- Third frequency of PCO:

  s1) use L2 PCO values from igs20.atx as the approximate value;

  s2) estimate as white noise with loose constraint.

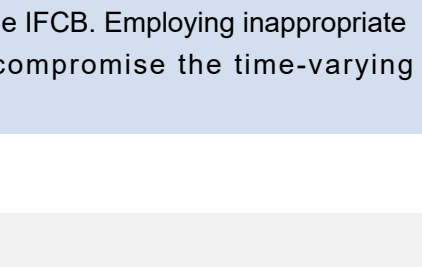

Fig. 1 Stations used for IFCB estimation and PPP

b) GLONASS triple-frequency PPP

- Estimate code IFB on the third frequency pseudorange for each GLONASS M+/K satellites (no code DCB/OSB available);
- Two schemes:

  s1) use L2 PCO values as the approximate value for the third-frequency;

  s2) use the estimated L3 PCO without IFCB corrections.

4 Results and Discussion

a) IFCB comparison and estimated PCO values

The IFCB of GLONASS M+ satellites is disappeared when the third-frequency PCO were estimated simutaneously, and the PCO-*x* is several decimeters deviated from the nominal value of L2 in igs20.atx.

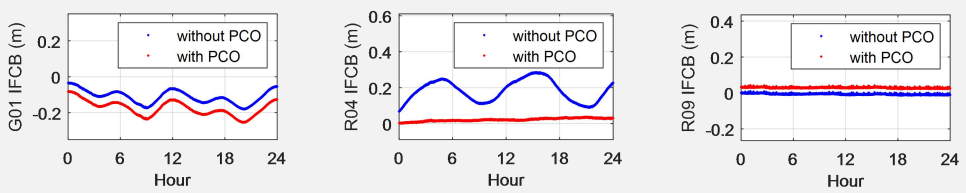

Fig. 2 Estimated IFCB for GPS IIF/GLONASS M+/GLONASS K satellites (on doy 071)

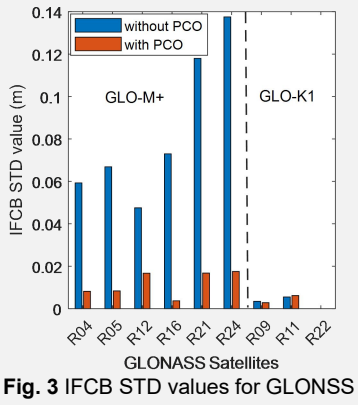

Fig. 3 IFCB STD values for GLONSS

Table 1 L3 PCO estimates of GLONASS (unit: mm)

Satellite		x-offset	y-offset	z-offset
M+	R04	-1097.82	-5.82	2706.27
	R05	-1093.49	-8.61	2402.94
	R12	-1113.76	-8.20	2495.81
	R16	-1113.28	1.46	2716.13
	R21	-1035.95	8.11	2558.81
	R24	-1042.36	13.34	2728.78
	Mean	-1082.77	0.05	2601.46
K1	R09	-4.06	0.81	2235.39
	R11	-8.14	2.00	2016.35
	R22	-	-	-
	Mean	-6.10	1.41	2125.87

b) GLONASS triple-frequency PPP

When the estimated M+/K satellite L3 PCO is used, the convergence time of GLONASS PPP is significantly shortened. Besides, the phase observation residuals conform to a normal distribution with its noise level as expected.

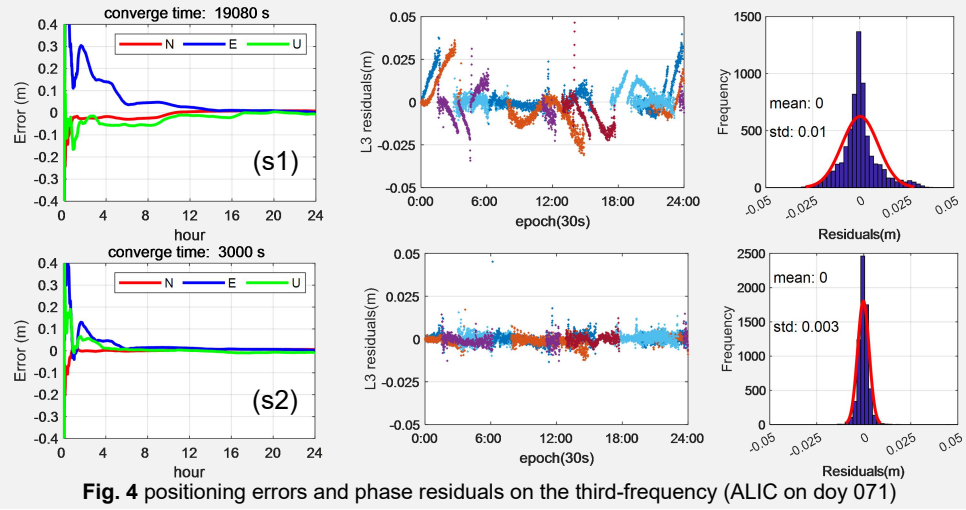

Fig. 4 positioning errors and phase residuals on the third-frequency (ALIC on doy 071)

5 Conclusion

- Multi-frequency PCO errors can significantly affect the time-varying characteristics of IFCB. For GLONASS M+ satellites, in particular, PCO-*x* errors of several decimeters will lead to incorrect conclusions.
- When the consistent multi-frequency PCO values are applied to multi-frequency PPP, the convergence time can be significantly improved and the phase residuals can be greatly reduced from centimeter-level to the accuracy level of phase observation.

References

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