P5: 009

Application of IGS Real-Time Products in Time Service: Performance and Challenge

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1. Introduction

The International GNSS Service (IGS) Real-Time Service (RTS) offers a suite of products essential for various applications, such as real-time precise positioning, navigation and atmospheric monitoring. These products mainly encompass GNSS satellite orbit and clock corrections, along with code bias information. Precise time, a foundational element of modern society, is integral to sectors such as communication, finance, transportation, and aerospace, where the demand for accurate time is substantial. Despite the wide and successful application of RTS products, research focusing on time services derived from these products remains limited. This study evaluates the performance of time service based on RTS products, specifically within the realms of time transfer and time synchronization based on Precise Point Positioning (PPP) and Precise Common-View (PCV), as well as PPP single station time dissemination.

2. Real-Time Products

The available RTCM SSR APC product streams of GFZ gnss ntrip caster were saved by BNC Client and analyzed, covering the time period of May 2024.

Table 1 RTS products information from source table of GFZ ntrip caster

Mountpoint	Format-details							System	Country	Generator
	System	ORB	CLK	COD-BIA	ORB-CLK-COM	ION	PHA-BIA			
SSRA00APM0	G				1060(3)			GPS+GLO+GAL+BDS(BD2(NO-GEO)+BD3)	CHN	MGP-RT
	R				1066(3)					
	E				1243(3)					
	C				1261(4)					
SSRA00BKG0	G			1059(5)	1060(5)		1265(5)	GPS+GLO+GAL	DEU	RETICLE
	R			1065(5)	1066(5)		1266(5)			
	E			1242(5)	1243(5)		1267(5)			
	C									
SSRA00CAS0	G	1057(5)	1058(5)			1264(90)		GPS+GLO+GAL+BDS(BD2+BD3)	CHN	GPSNet
	R	1063(5)	1064(5)							
	E	1240(5)	1241(5)							
	C	1258(5)	1259(5)							
SSRA00CNE0	G			1059(5)	1060(5)	1264(60)	1265(5)	GPS+GLO+GAL+BDS(BD2(NO-GEO)+BD3)	FRA	PPP-WIZARD
	R			1065(5)	1066(5)		1266(5)			
	E			1242(5)	1243(5)		1267(5)			
	C			1260(5)	1261(5)		1270(5)			
SSRA00GFZ0	G	1057(5)	1058(5)	1059(5)			1265(5)	GPS+GLO+GAL+BDS(BD2+BD3)	DEU	EPOS-RT
	R	1063(5)	1064(5)	1065(5)			1266(5)			
	E	1240(5)	1241(5)	1242(5)			1267(5)			
	C	1258(5)	1259(5)	1260(5)			1270(5)			
SSRA00GMV0	G			1059(5)	1060(5)			GPS+GLO+GAL+BDS(BD2+BD3)	ESP	magicGNSS
	R			1065(5)	1066(5)					
	E			1242(5)	1243(5)					
	C			1260(5)	1261(5)					
SSRA00WHU0	G				1060(5)			GPS+GLO+GAL+BDS(BD2+BD3)	CHN	PANDA
	R				1066(5)					
	E				1243(5)					
	C				1261(5)					
SSRA02IGS0	G	1057(10)	1058(10)	1059(10)				GPS+GLO+GAL	DEU	BNC
	R	1063(10)	1064(10)	1065(10)						
	E	1240(10)	1241(10)	1242(10)						
	C									
SSRA03IGS0	G	1057(10)	1058(10)	1059(10)				GPS+GLO+GAL+BDS(BD2+BD3)	DEU	BNC
	R	1063(10)	1064(10)	1065(10)						
	E	1240(10)	1241(10)	1242(10)						
	C	1258(10)	1259(10)	1260(10)						

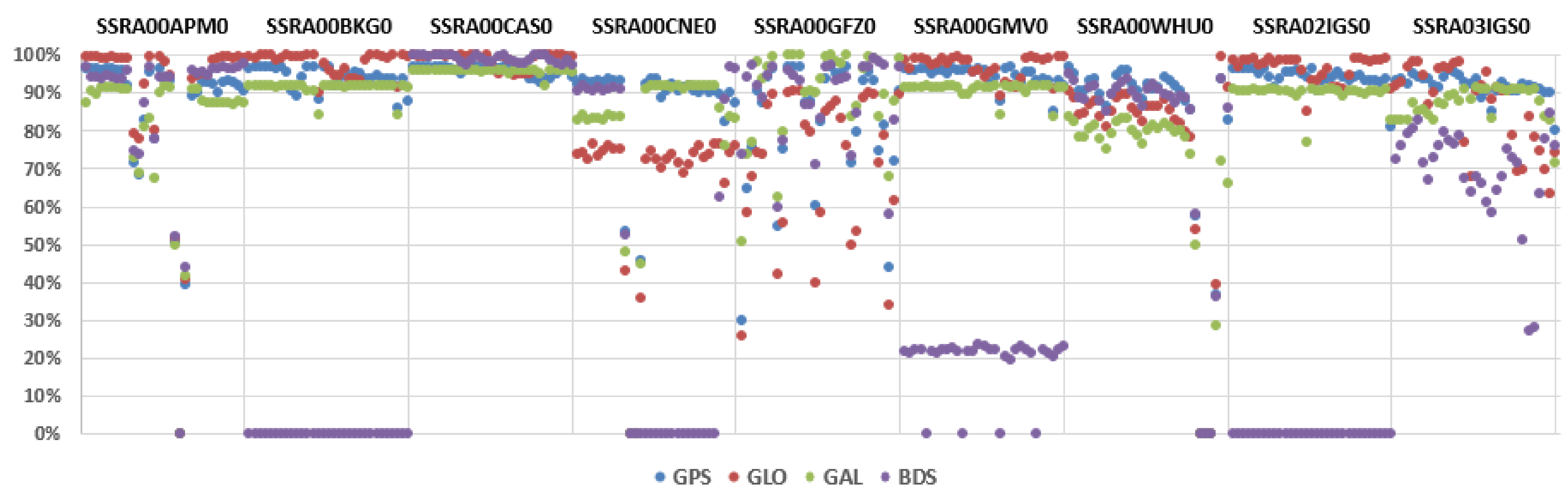

Figure 1 RTS products completeness percentage of each product from May 1st to May 31st

3. Data and Method

For PPP time transfer, typically, the ionosphere-free (IF) combinations of dual-frequency pseudo-range and carrier phase are used. And for PCV time transfer, single differencing was further performed between two stations a and b which have common visible satellites.

PPP

$$P_r^s = \rho_r^s + c(dt_r - dt^s) + T_r^s + e_r^s$$
$$L_r^s = \rho_r^s + c(dt_r - dt^s) + T_r^s + \lambda N_r^s + \varepsilon_r^s$$

PCV

$$\Delta P_{a,b}^s = \Delta\rho_{a,b}^s + c\Delta dt_{a,b} + \Delta T_{a,b}^s + \Delta e_{a,b}^s$$
$$\Delta L_{a,b}^s = \Delta\rho_{a,b}^s + c\Delta dt_{a,b} + \Delta T_{a,b}^s + \lambda\Delta N_{a,b}^s + \Delta\varepsilon_{a,b}^s$$

Table 2 Station information

Station	Time Lab	Receiver Type	Clock	Data Period	Distance
PTBB	PTB(Braunschweig, Gemany)	SEPT POLARX5TR	UTC(PTBB)	2024.5.1-5.31	7170.6km
NTSC	NTSC(Xi'an, China)	SEPT POLARX5TR	UTC(NTSC)	2024.5.1-5.31	

To assess the performance of real-time products in terms of time service applications, the following analyses of stations from two high quality time laboratories were conducted: single-station PPP clock offset estimation, two-station PPP and PCV time transfer. BIPM Circular T provided the difference between UTC and UTC(k). The table below shows the UTC-UTC(NTSC) and UTC-UTC(PTBB). The derived UTC(PTB)-UTC(NTSC) results indicate that the time difference between the two time labs were stable around -2ns during May, 2024. So the time application performance of the RTS products could be evaluated by the standard deviation (STD).

Table 3 [UTC-UTC(k)] ns, from BIPM Circular T

Laboratory k	APR 29	MAY 4	MAY 9	MAY 14	MAY19	MAY 24	MAY 29
PTB(Braunschweig)	-1.8	-1.3	-1.1	-0.8	-0.6	-0.5	-0.4
NTSC(Lintong)	0.2	0.9	0.5	1.3	1.3	1.4	1.3
PTB-NTSC	-2.0	-2.2	-1.6	-2.1	-1.9	-1.9	-1.7

4. Performance

The results of PPP single station receiver clock offsets, PPP and PCV time transfer between NTSC and PTBB, are shown in the table and figures below. To facilitate analysis, the data points that deviated more than 3σ were removed. The results shows:

(1) For PPP single station time dissemination, the differences between the four navigation systems are relatively significant. The time reference trends of different RTS products are consistent. As for the stability, the GMV and WHU products perform better.

(2) For the PPP and PCV time transfer results, the time transfer performance can achieve better than 1ns. And the results from BKG, WHU and GMV of different systems are better than 0.7ns.

Table 4 STD values of PPP and PCV from different RTS products

RTS PRO	PPP(PTBB) clock offset STD(ns)				PCV(PTBB-NTSC) clock offset STD(ns)				PPP-link(PTBB-NTSC) clock offset STD(ns)			
	GPS	GLO	GAL	BDS	GPS	GLO	GAL	BDS	GPS	GLO	GAL	BDS
APM	1.44	3.91	1.14	1.66	1.35	1.96	1.43	1.63	0.75	2.09	0.38	0.88
BKG	1.27	5.29	0.99	-	0.46	0.60	0.55	-	0.62	0.43	0.32	-
CAS	1.31	-	1.38	1.27	0.92	-	1.04	0.70	0.33	-	0.32	0.37
CNE	1.37	3.93	0.94	-	0.82	1.17	0.64	-	0.52	0.99	0.29	-
GFZ	1.59	3.47	28.29	26.00	1.09	1.32	1.05	1.34	0.47	0.90	0.27	0.51
GMV	1.24	1.28	1.25	-	0.28	0.50	0.41	-	0.33	0.51	0.25	-
WHU	1.24	2.63	0.61	1.70	0.27	0.55	0.41	0.44	0.44	0.46	0.23	0.69
IG2	1.41	3.79	0.97	-	0.48	1.06	0.79	-	0.90	1.95	0.36	-
IG3	1.30	3.78	1.06	-	1.95	2.16	2.06	-	0.65	1.86	0.26	-

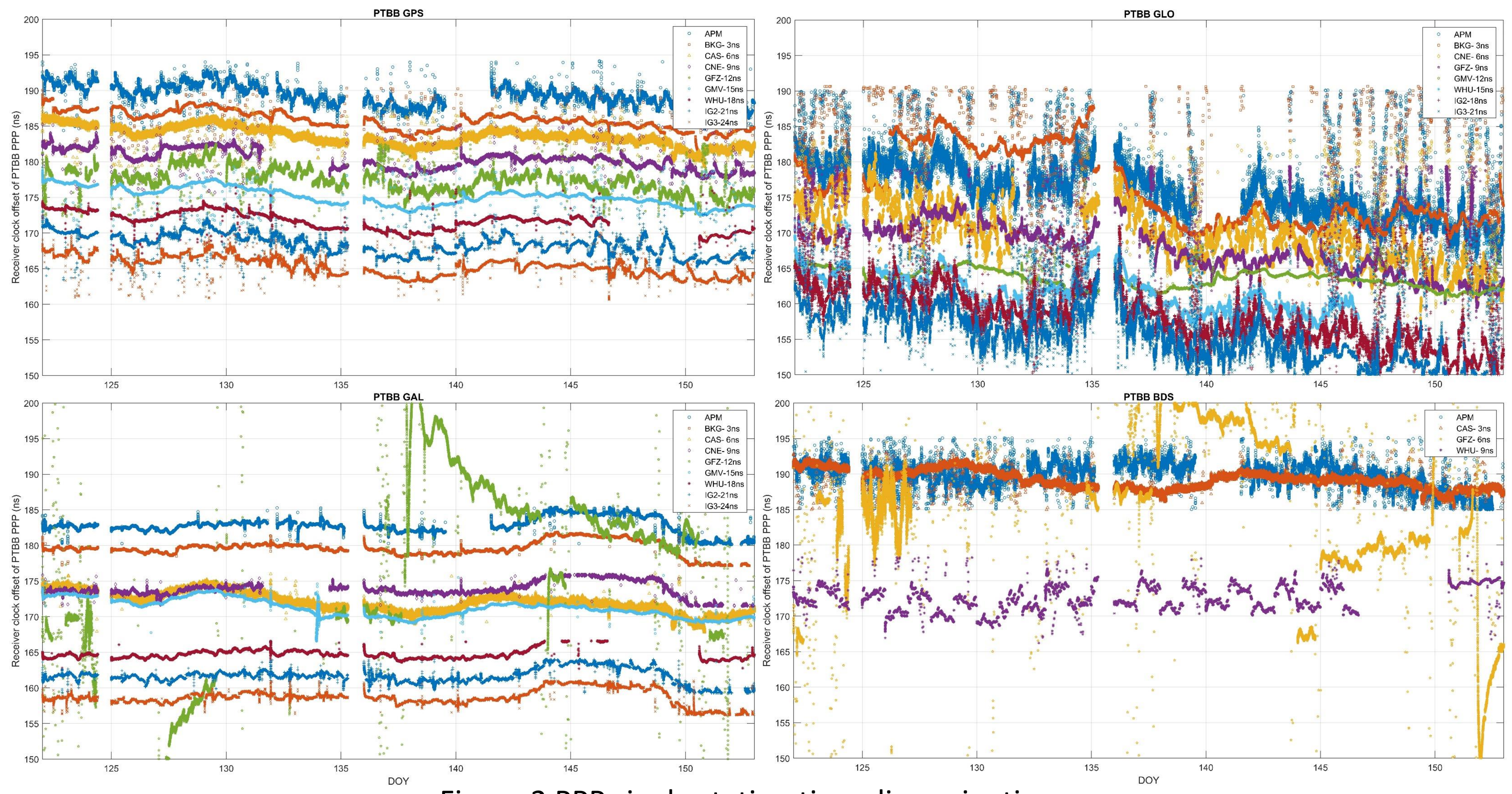

Figure 2 PPP single station time dissemination

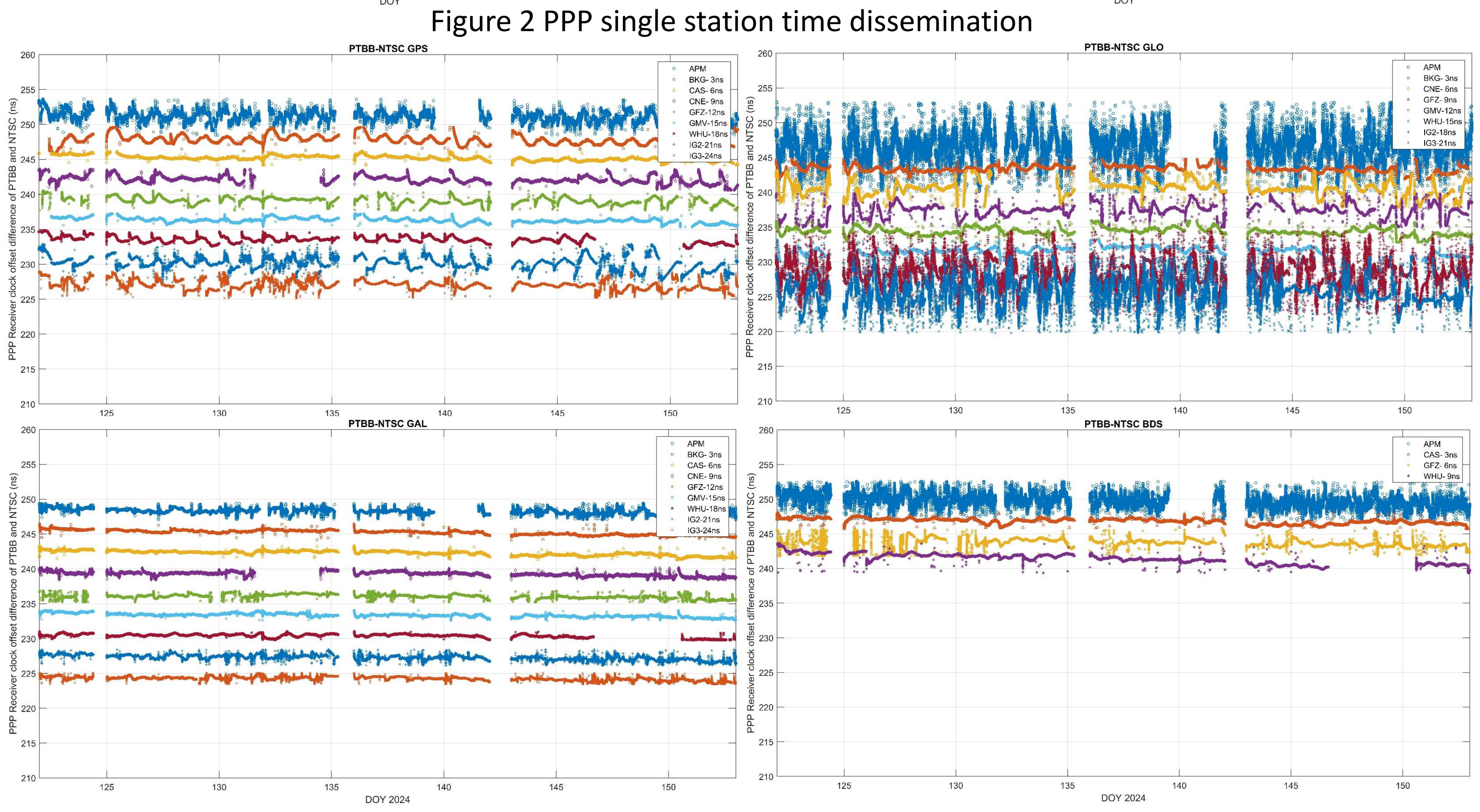

Figure 3 PPP time transfer between NTSC and PTBB

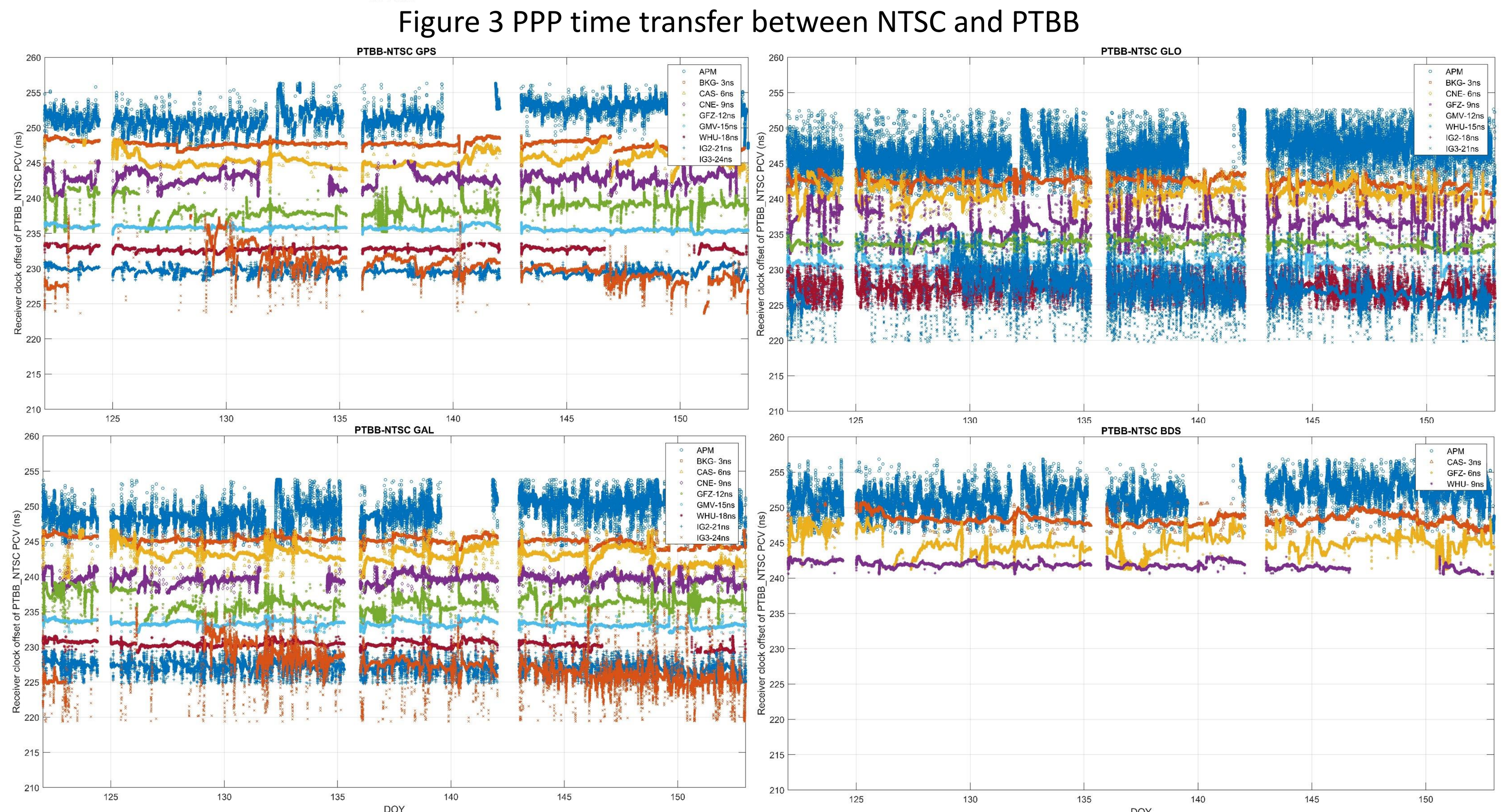

Figure 4 Precise Common-View time transfer between NTSC and PTBB

5. Challenge

(1)There are significant differences between four systems in RTS products. For example, although most centers' products include BDS system, only a few BDS products are available.

(2)PCV has unique advantages, as it does not rely on RTS clock products. Some analysis centers' long-baseline PCV time transfer performance is affected by the insufficient satellite numbers or corrections in their products.

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References:

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