



Assessment and Application of BeiDou Real-Time Orbit and Clock Products

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Introduction

In recent years, Real-Time Precise Point Positioning (RTPPP) using BeiDou Navigation Satellite System (BDS) is facing new developments thanks to the dissemination of BDS real-time State Space Representation (SSR) corrections provided by some institutions. In this contribution, the quality of BDS real-time products provided by CNES, as well as the performance of BDS standalone RTPPP and BDS/GPS combined RTPPP, are assessed and validated.

Assessment of BDS Real-Time Products

1. Availability

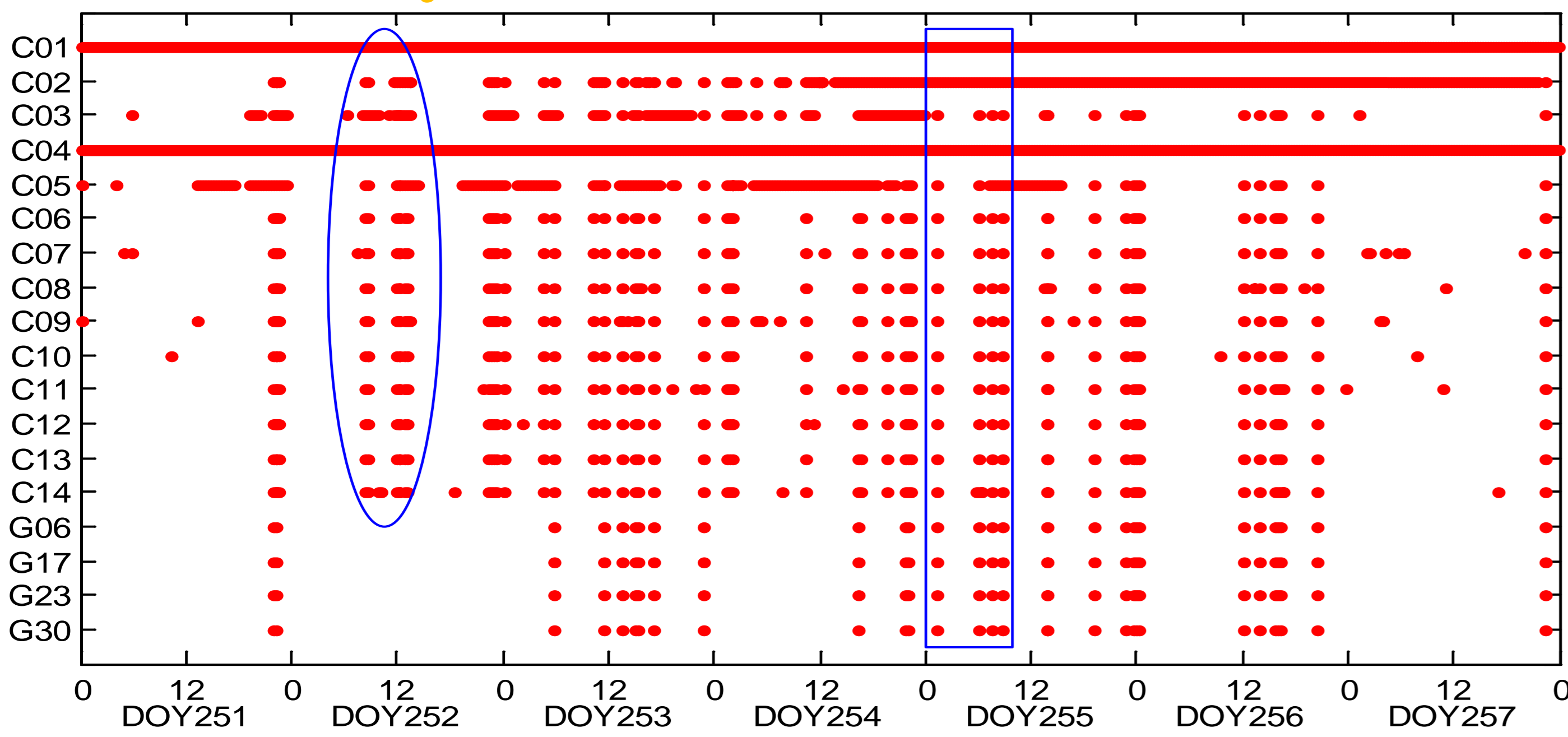


Figure: Unavailability of real-time corrections during DOY 251-257 in 2017

Four types of unavailability:

- (1) all satellites unavailable at some epochs (e.g. the rectangle area)
--mainly originates from network outages on the user or caster side
- (2) all BDS satellites unavailable at some epochs (e.g. the oval area)
--may refer to the outage of BDS priori orbits
- (3) temporarily unavailable for some certain satellites
--may refer to the failure of processing chain or lack of tracking stations on the ground
- (4) long-term unavailable for some certain satellites (mainly BDS-GEO)
--directly refer to the outage of GEO priori orbits in the BDS ultra-rapid products
--intrinsicly refer to the inherent difficulties for predicting the GEO orbits and the scheduled maneuvers

2. Continuity

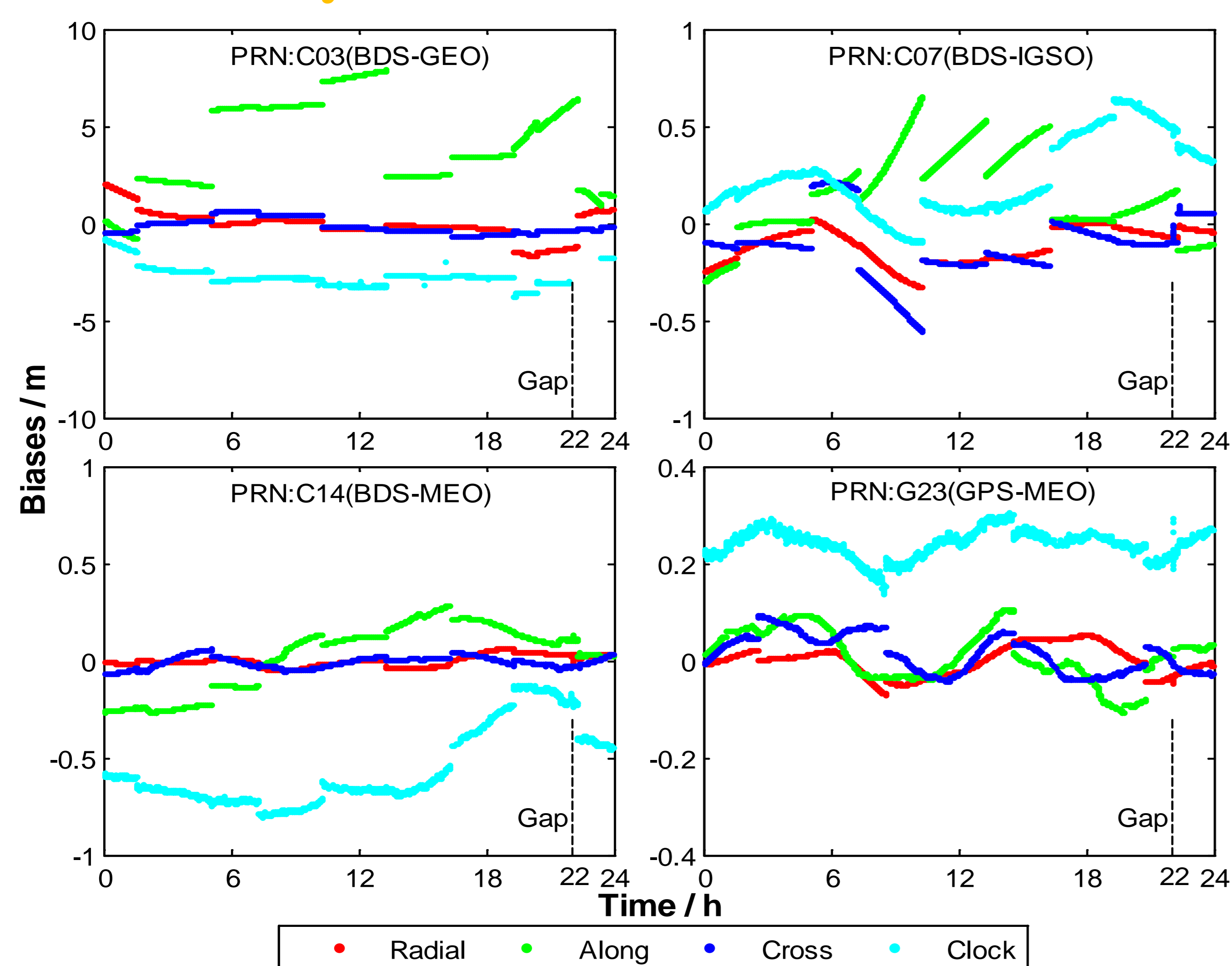


Figure: Real-time orbit and clock biases referring to GBM product on DOY 251

- Originates from the updates of priori orbits (i.e. the ultra-rapid products):
 - IGU products (providing priori orbits for GPS satellites) are updated every 6 hours
 - GBU products (providing priori orbits for BDS satellites) are updated every 3 hours
- may bring about some jumps and re-convergences to BDS standalone kinematic positioning results

3. Accuracy

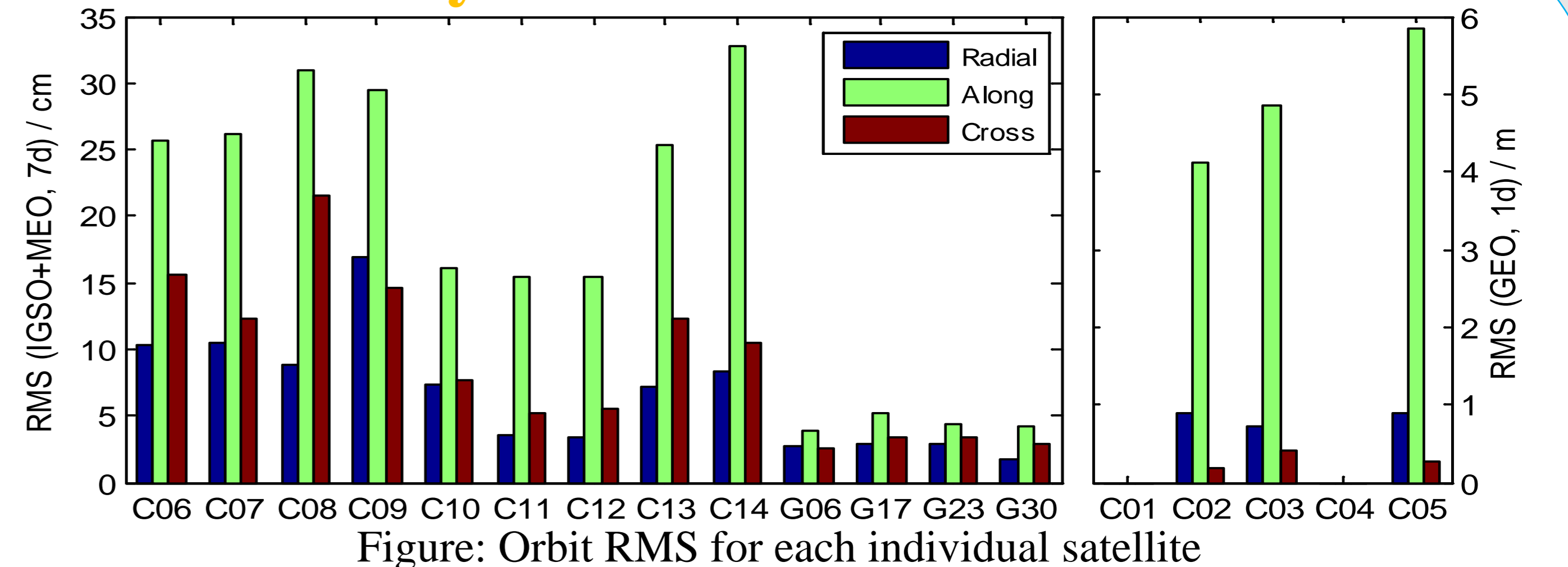


Figure: Orbit RMS for each individual satellite

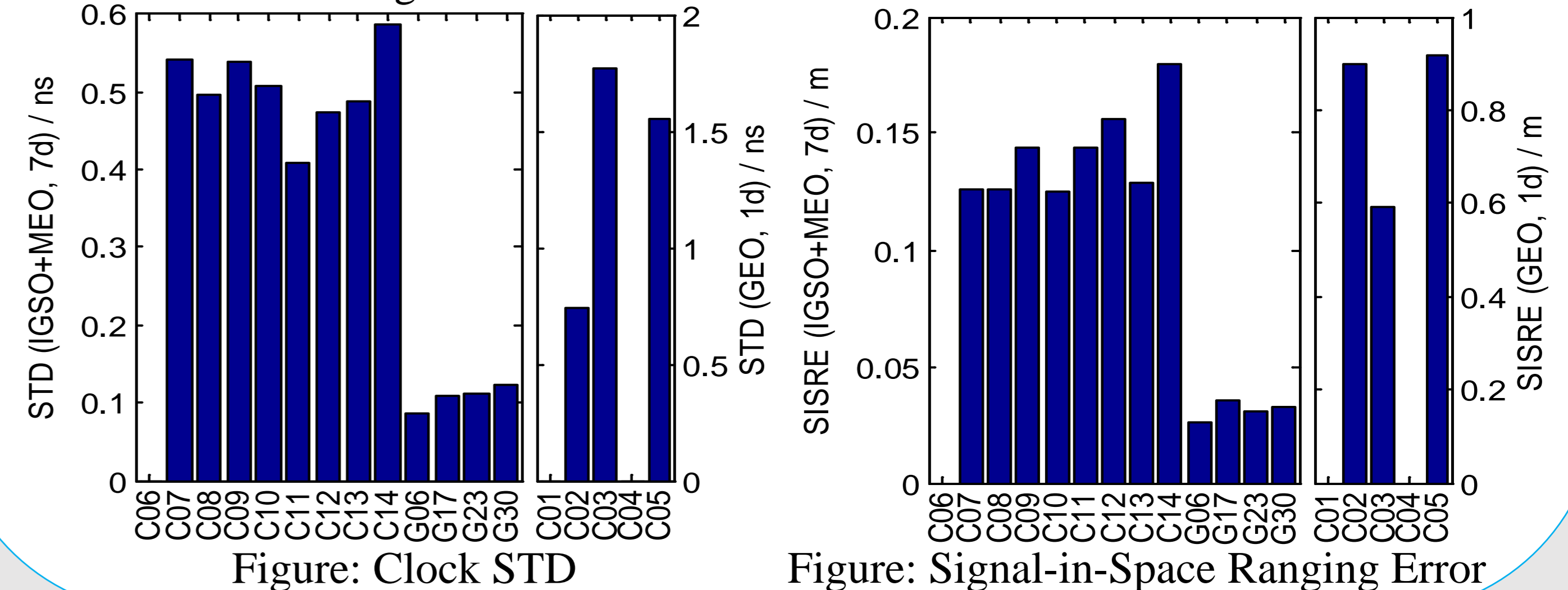


Figure: Clock STD

Figure: Signal-in-Space Ranging Error

RTPPP Tests and Analyses

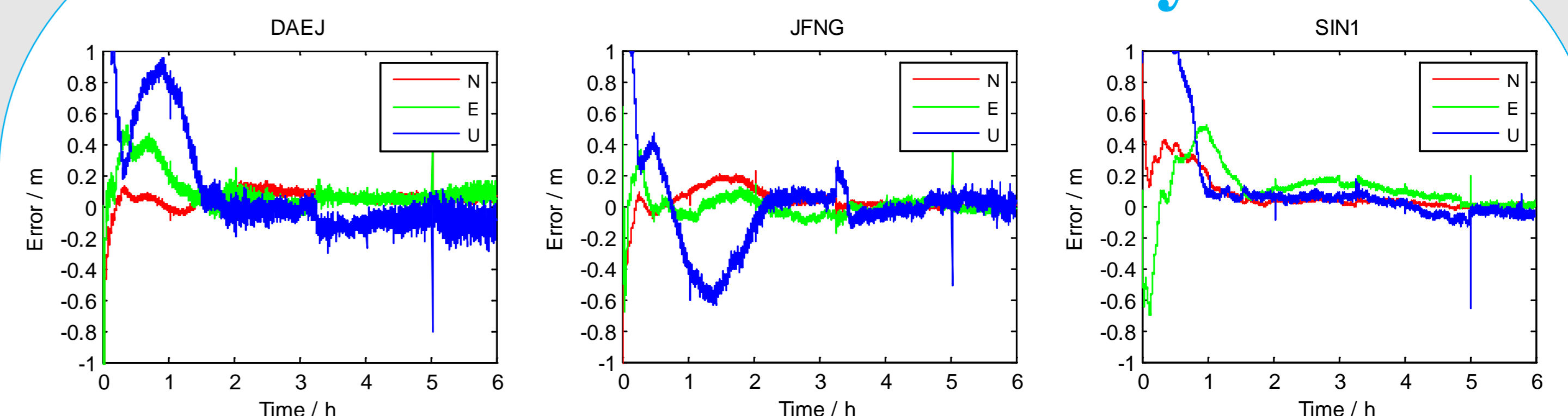


Figure: BDS standalone RTPPP on DOY 251

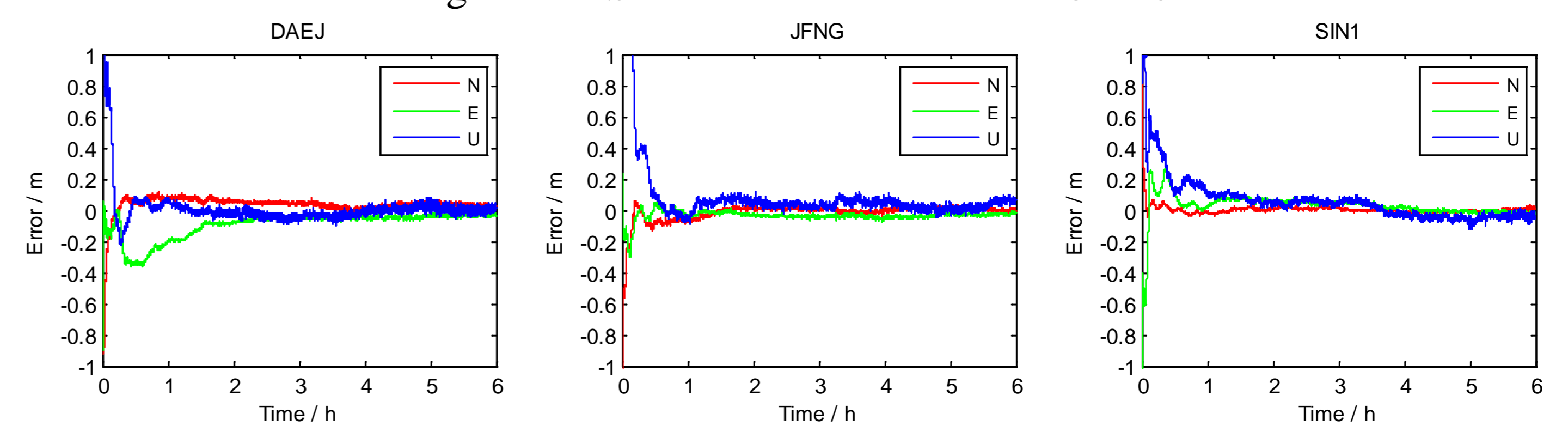


Figure: BDS/GPS combined RTPPP on DOY 251

Station	BDS standalone				BDS/GPS combined			
	Convergence time (min)	N (cm)	E (cm)	U (cm)	Convergence time (min)	N (cm)	E (cm)	U (cm)
DAEJ	87.3	5.85	6.83	8.99	59.5	2.25	3.45	2.91
JFNG	117.2	2.08	1.33	2.72	25.3	0.47	1.78	6.46
SINI	82.0	1.14	1.57	4.51	26.4	1.97	1.94	3.42
Mean	95.6	3.02	3.24	5.41	37.1	1.56	2.39	4.26

BDS standalone RTPPP in kinematic mode:

- the positioning errors in the north, east and up components can all remain within 0.2 m after a period of convergence
- there exist high-frequency noises and some jumps in the positioning errors, which are related to the unstable quality of BDS real-time products

BDS/GPS combined RTPPP in kinematic mode:

- accelerate the convergence
- improve the accuracy
- remove the outliers and smooth the curve of positioning errors

Conclusions

- (1) BDS standalone RTPPP can provide an accuracy of decimeter- to centimeter-level after convergence, but suffers from the issues of unavailability and discontinuity at some time.
- (2) BDS/GPS combined RTPPP can improve the convergence speed, accuracy and stability.