Investigation of the Kinematic PPP-AR Positioning Performance with Online CSRS-PPP Service

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SUMMARY

The Global Navigation Satellite System (GNSS) has been widely used for many years as it provides precise positioning. In general, relative or absolute positioning methods are used for GNSS. The precise point positioning (PPP), which is an absolute positioning technique has become more practical with online data processing services. The main drawback of PPP technique is that it needs a long convergence time to achieve millimeter level accuracy. With the recently popular PPP with ambiguity resolution (PPP-AR), the positioning accuracy can be improved. However, the ambiguity resolution in PPP can only be possible with additional hardware biases which are previously computed from a network. Among the online GNSS data processing services, CSRS-PPP (The Canadian Spatial Reference System-PPP) provides reliable and robust solutions. At the end of 2020, CSRS-PPP updated its software, and it has begun to give ambiguity-fixed solutions. In this study, the kinematic positioning performance of CSRS-PPP was examined. Thus, the improvements of the CSRS-PPP-AR solutions were analyzed comparing to the previous version (CSRS-PPP-FLOAT).

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1. INTRODUCTION

The Global Navigation Satellite System (GNSS) has been used in precise positioning for decades. Besides, the precise point positioning (PPP) method has been used in many scientific studies to determine plate or structural movements (Hefty and Gerhatova 2012; Tang et al. 2017). The PPP technique can provide millimeter level accuracy by using the precise satellite orbit and clock products after a convergence time (Zumberge et al. 1997; Kouba and Héroux 2001). Traditionally, the PPP method offers an ambiguity-float solution due to the complexity of PPP ambiguity fixing. The ambiguity fixing for PPP requires additional phase-clock bias products calculated from the network. These products are generated by International GNSS Service (IGS) analysis centers such as CODE (Center for Orbit Determination in Europe), NRCan (Natural Resources Canada), and Wuhan University. Different analysis centers of IGS perform different strategies for obtaining PPP-AR (PPP with Ambiguity Resolution) products and some of them are not publicly available. Furthermore, the PPP processing software should be consistent with the PPP-AR products since they differ in obtaining approaches (Banville et al. 2020). However, for online GNSS data processing services such as CSRS-PPP (Canadian Spatial Reference System-PPP) only observation data need to be submitted (URL-1). CSRS-PPP is an online PPP processing service managed by NRCan since 2003 (Tétreault et al. 2005). Many studies have been conducted referring to CSRS-PPP, including kinematic positioning and tropospheric delay estimation (Alkan et al. 2015; Krasuski et al. 2018; Mendez Astudillo et al. 2018). Accordingly, the robustness of the CSRS-PPP has been proven. Moreover, with upgrading CSRS-PPP to PPP-AR at the end of 2020, estimating coordinates via the PPP-AR method has become easier. The new implementation of the software utilizes the ambiguity resolution on the GNSS data collected after 1 January 2018. For the data before 2018, CSRS-PPP uses traditional IGS final precise products. In this study, the kinematic positioning performance of the recently upgraded CSRS-PPP service was investigated. For this purpose, three daily data of the KNY1 station in 2017 and 2018 were processed. The results were analyzed in terms of positioning accuracy.

2. METHOD

For examining the kinematic positioning performance of the upgraded CSRS-PPP service, the data of KNY1 station of the Turkish CORS-TR network was used. The observation data belong to the DOY 1, 2, and 3 in 2018 were processed since the CSRS-PPP utilizes the ambiguity resolution after 1 January 2018. In order to compare the ambiguity-fixed solutions with ambiguity-float solutions, DOY 363, 364, and 365 in 2017 were used as they are nearest days to PPP-AR processing days. The location of KNY1 station is shown in Figure 1. The observation data interval was used as 30 seconds. While the IGS Final clock and orbit products were used for CSRS-PPP-FLOAT solutions, NRCan/IGS Final products were used in CSRS-PPP-AR processes.

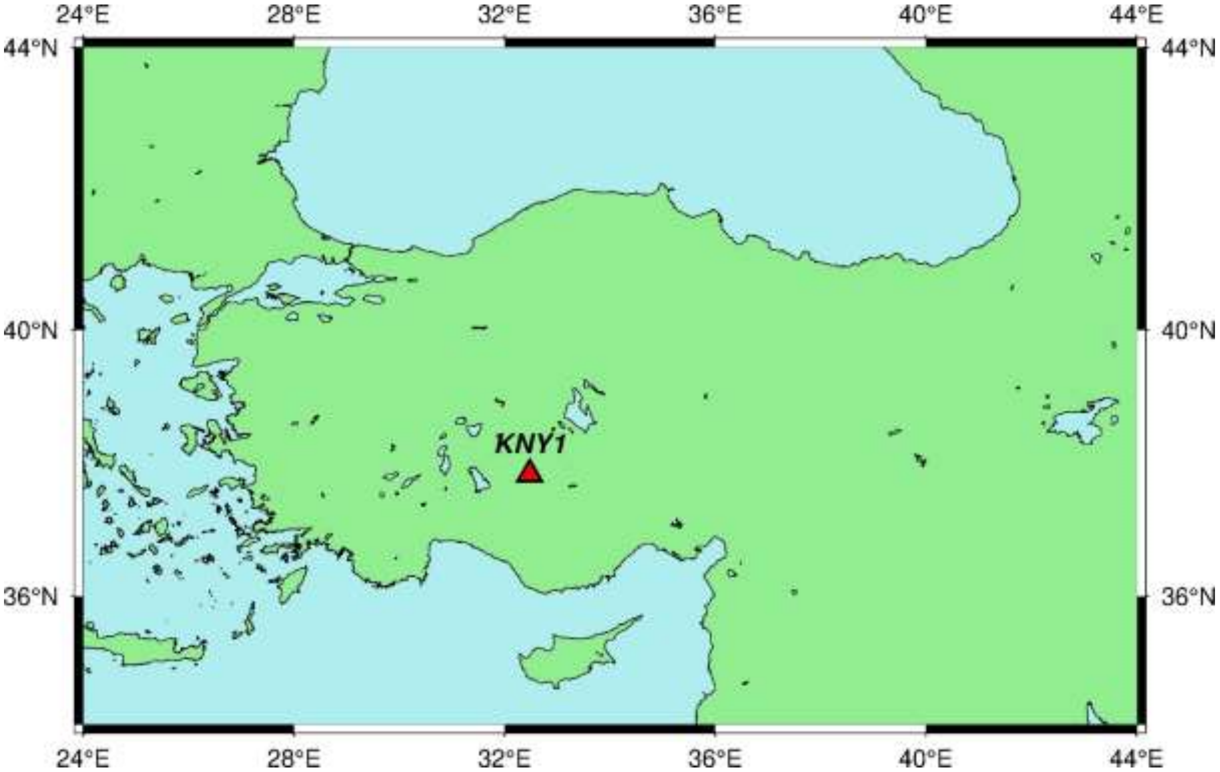

Figure 1. The location of KNY1 station

For ambiguity resolution in the PPP, it is necessary to estimate the uncalibrated hardware delay (UHD) biases originating from both receivers and satellites. The IGS analysis centers perform different strategies for estimating phase/clock biases such as “integer clock” (Laurichesse et al. 2009), “uncalibrated phase delays” (Ge et al. 2008), and “decoupled clock model” (Collins et al. 2010). The AR implementation of the CSRS-PPP service is based on undifferenced measurements as described to “decoupled clock model” in the work of Collins et al. 2010. Moreover, the NRCan produces and uses phase/clock bias products consistent with CSRS-PPP.

Although CSRS-PPP only performs AR for GPS satellites, GLONASS satellites - as ambiguity-float- can be used for estimating rover coordinates. Hence, GLONASS was included in the processes to take advantage of additional satellites. Besides the kinematic processes, each observation data was processed in the static mode in the same way. The kinematic results were compared according to the static results as ground truth.

3. RESULTS

The kinematic results belong to six days at total, converted to the topocentric coordinate system (north, east, and up). The static results were used as the ground truth. The coordinate time series of CSRS-PPP-FLOAT solutions for each coordinate component is shown in Figure 2.

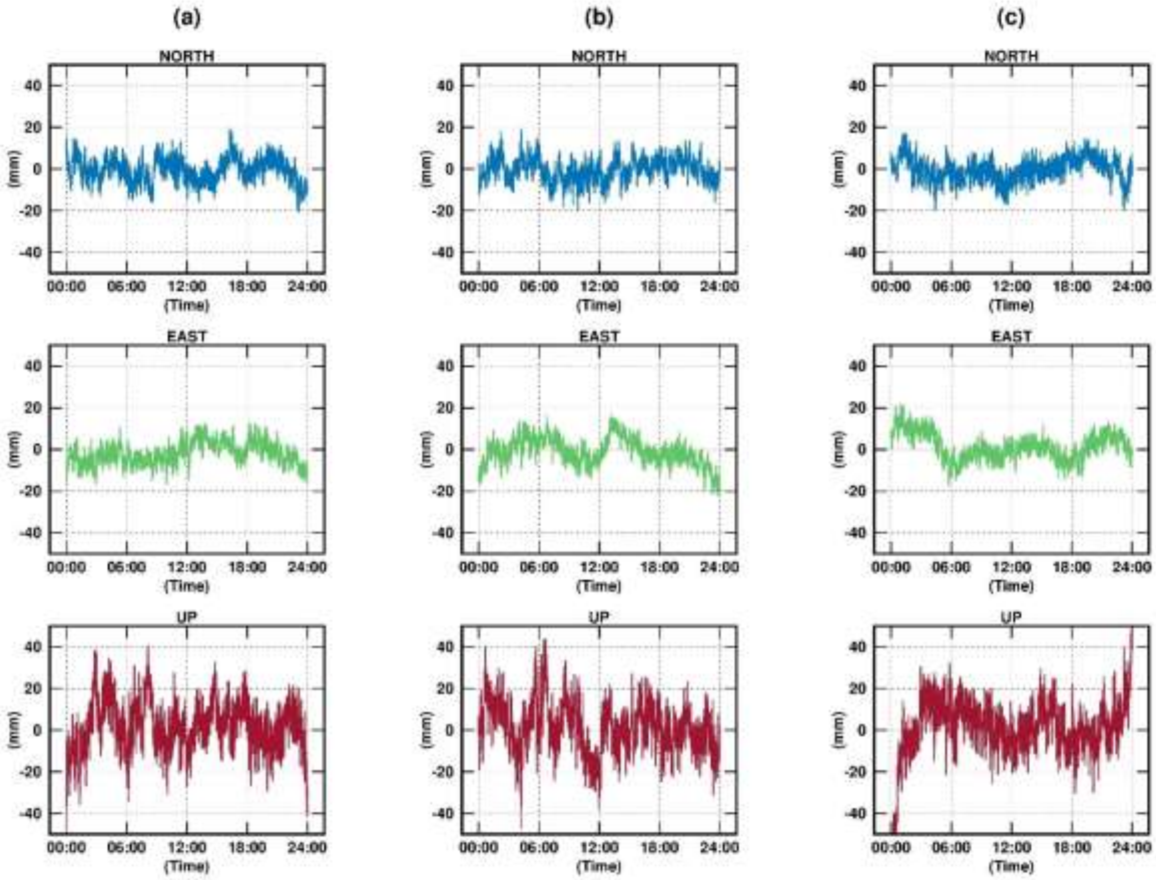

Figure 2. The coordinate time series of ambiguity-float solutions DOY 363 (a), DOY 364 (b), and DOY 365 (c) in 2017

According to Figure 2, ambiguity-float solutions in the north and east components in the range of -20.0/+20.0 mm. However, the up component is worse as expected. In a similar way, the ambiguity-fixed solutions were obtained. The percentages of fixed ambiguities are provided in Table 1.

Table 1. The percentages of fixed ambiguities

DOY (2018)	Static	Kinematic
1	% 99.24	% 99.32
2	% 99.94	% 99.94
3	% 99.46	% 99.93

As seen in Table 1, almost all phase ambiguities were fixed in both static and kinematic processes. The coordinate time series of CSRS-PPP-AR solutions for each coordinate component is shown in Figure 3.

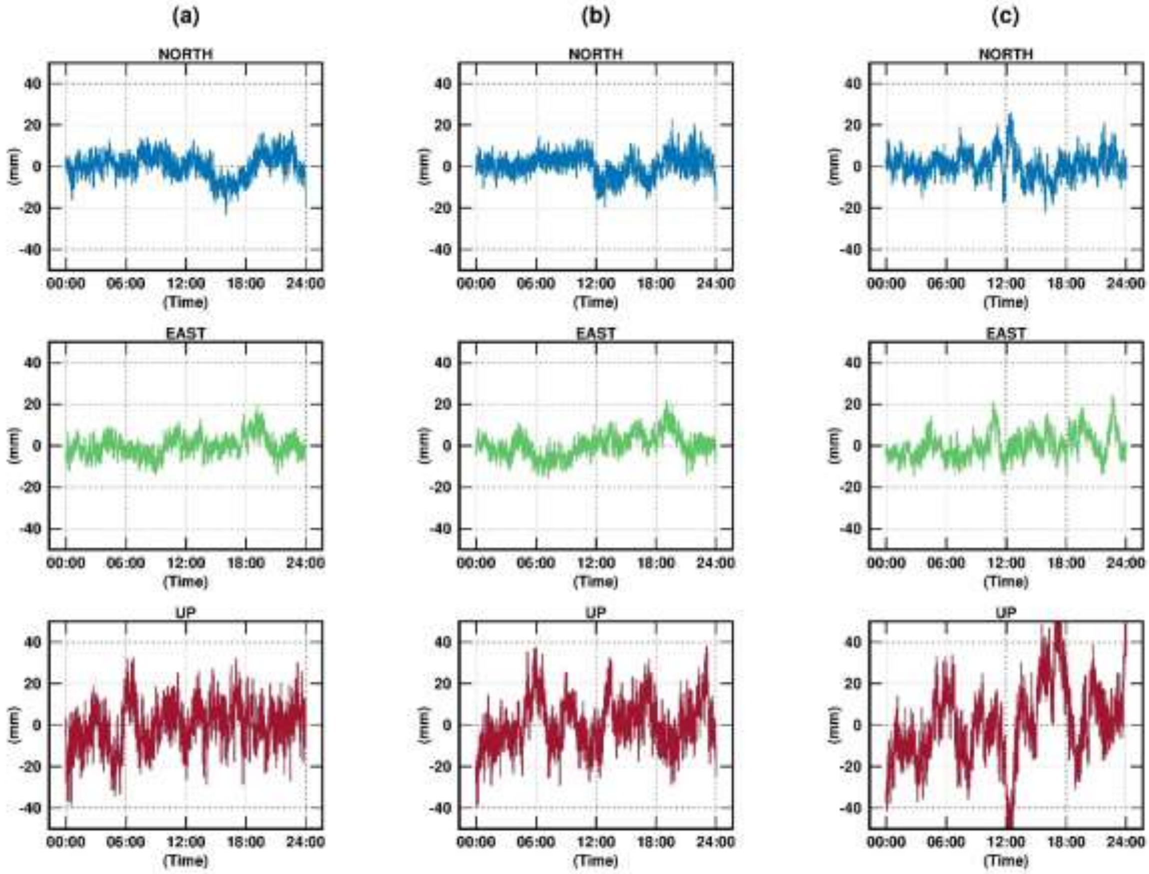

Figure 3. The coordinate time series of ambiguity fixed solutions DOY 1 (a), DOY 2 (b), and DOY 3 (c) in 2018

As shown in Figure 3, the time series are more smoothed in all components. Particularly, the improvement in the east component is slightly better. For a better understanding of the results, some statistical parameters were examined. The absolute maximum, mean, standard deviation (std), and root mean square error (RMSE) values were computed and provided in Tables 2-3.

Table 2. The statistical parameters for ambiguity-float solutions

DOY (2017)	Parameter	N (mm)	E (mm)	U (mm)
363	Abs. max	20.90	16.80	50.20
	Mean	-0.67	-1.86	1.84
	Std	5.90	5.44	12.24
	RMSE	5.94	5.75	12.38
364	Abs. max	19.80	22.30	47.20
	Mean	-0.54	-1.09	1.19
	Std	5.67	6.61	12.15
	RMSE	5.70	6.70	12.21
365	Abs. max	19.90	21.70	88.70
	Mean	-0.39	1.25	0.92
	Std	5.68	6.41	14.40
	RMSE	5.69	6.53	14.43

According to the Table 2, the RMSE values of the north and east components are between 5.69/ 5.94 mm and 5.75/ 6.70 mm, respectively. In addition, the RMSE values of the up component are in the range of 12.21/ 14.43 mm. The same statistical parameters were calculated for the ambiguity-fixed results. The statistical parameters for PPP-AR solutions are given in Table 3.

Table 3. The statistical parameters for PPP-AR solutions

DOY (2018)	Parameter	N (mm)	E (mm)	U (mm)
1	Abs. max	23.30	19.50	39.30
	Mean	0.30	0.13	-0.05
	Std	5.88	5.88	10.89
	RMSE	5.89	4.91	10.88
2	Abs. max	22.90	22.10	39.70
	Mean	0.61	0.25	0.68
	Std	5.41	5.72	12.09
	RMSE	5.44	5.73	12.11
3	Abs. max	26.00	24.40	63.20
	Mean	0.59	0.08	0.62
	Std	6.27	6.28	18.70
	RMSE	6.29	6.28	18.71

According to Table 3, the RMSE values of the north and east components are in the range of 5.44/ 6.29 mm and 4.91/ 6.28 mm, respectively. However, the maximum RMSE is 18.71 mm in the up component of DOY 3. When the mean values are analyzed, both options of CSRS-PPP showed similar results in the north component, while the PPP-AR significantly improved the results in the east and up components.

4. CONCLUSION

In this study, the kinematic positioning performance of the latest version of CSRS-PPP was analyzed. The results of this study showed that the implementation of ambiguity resolution to CSRS-PPP improved the results. In terms of mean values, the ambiguity resolution significantly contributed to the east and up components. Consequently, the new CSRS-PPP online service can easily be used for PPP-AR kinematic positioning requirements.

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