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**Research Article**

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# Processing Small GNSS Networks using GNSS Systems

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**Abstract** For decades, positioning accuracy via satellite technology was mainly based on the Global Positioning System of the USA and a little support from GLONASS. Due to the development of new GNSS systems and the new brand of GNSS receivers, users have much more options in GNSS data processing. This paper is an experimental study on GNSS data processing using different systems. In the research, GNSS data were obtained from a set of Trimble R8s devices including three multi-frequency and multi-channel receivers. GNSS data were calculated with three small networks using Trimble Business Center 5.0 with the same input parameters for each GNSS system. At the same time, the paper has various combinations among systems. The results showed the advantages and disadvantages of the combination and ability of every single system either in horizontal position or elevation accuracy.

**Keywords** Static GNSS, Network Processing, Beidou 3 system, PDOP

## 1. Introduction

Completion of the existing and the introduction of new GNSS systems are an invaluable addition for the geodesy community in performing geodesy tasks. An overview of GNSS systems and their applications is in [1]. Each system has different architecture but has the same principle "*the more observations we do, the higher accuracy we gain"* as formulas mentioned in [2],[3]. The introduction of Beidou 3 is a meaningful addition. Its specifications, various services, and the first assessment of the BDS-3 system are in [4]. Comparing to the two previous phases BDS-1 and BDS-2, BDS-3 has a huge improvement in terms of accuracy. A more detailed assessment of the Beidou system (both BDS-3 and previous BDS) was shown in [5]–[8]. Due to the difference in orbit design, the number of satellites and time of observation in each system isdifferent. The work [9] showed that the observation time of the BDS satellites at Geostationary Earth Orbit (GEO) is the longest**.** For instance, satellites C01 and C04 can acquire data all day, and satellites at MEO have the lowest time of observation about 6-10 hours per day. Regarding the PDOP of each system, for GPS, these values vary from 1.5 to 3.5; 1.2÷3 for Glonass; 1.8÷4.5 for Beidou. Combining four systems, PDOP is smaller and stable. It should be noted that this work was declared in 2013 when the BDS system is BDS-2.

In terms of research, there are two directions. The first one is producing software for GNSS receivers with multi-frequency, multi-channel functions. It aims to increase the number of observations and reduce the time in the field [10]. The finishing of this work is the software for the dual-frequency receivers [11]. The second one is how to process GNSS data using the multi-GNSS system in large-scale networks. For demonstration, in the work [12], [13], software Bernese 5.0 was used for processing a very large network (Baselines are from 934Km to 4500Km, the year of 2010). Base on output data, the result from the GPS has higher accuracy. When processing combining GPS and GLONASS data, the results are equivalent compare to using a single GPS. The same study but the static method is replaced by the single point positioning (spp) method under the different conditions of tracking satellite. The addition of the BDS satellites in difficult conditions makes a huge improvement in accuracy. Detailed information is in [14], in the open-air location, the average number of GPS satellites at that time is about 8.9, and the accuracy is not much better when adding seven BDS satellites. Surprisingly, under the tree and adding six BDS satellites, PDOP reduce from 6.1 to 3.0. The similar results with multi-path error and so on under the different level of difficulty. This is one of the advantages of the BDS system. Due to the operation of the ionosphere and troposphere, elevation in the GNSS technique is still a struggle. However, this problem seems to have a solution with BDS satellites [15].

**2. Data, software, and procedure**

**Data:** To survey the influence of GNSS systems on the accuracy of the networks, three small networks are installed using three Trimble R8s receivers,and all use the static method.

For static mode

+ Horizontal accuracy: ±3mm + 0.1 ppm.

+ Altitude accuracy: ±3.5mm + 0.4ppm.

Session time ranges from 40 minutes to 60 minutes depends on each network

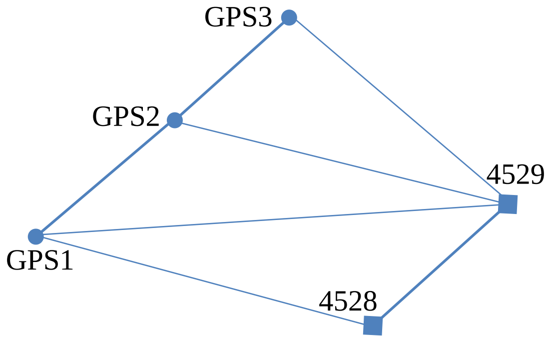


*Figure 1a: Network 1*

**Table 1:** Session time of NET1

| S/N<br>Sessions | 198 | 260 | 438 |
|---|---|---|---|
| SS1<br>(08h15-09h15) | 104528<br>(1686) | GPS1<br>1554) | 104529<br>(1870) |
| SS2<br>(09h40-10h40) | GPS2<br>(1461) | GPS1<br>(1554) | 104529<br>(1870) |
| SS3<br>(11h00-12h00) | GPS2<br>(1461) | GPS3<br>(1367) | 104529<br>(1870) |

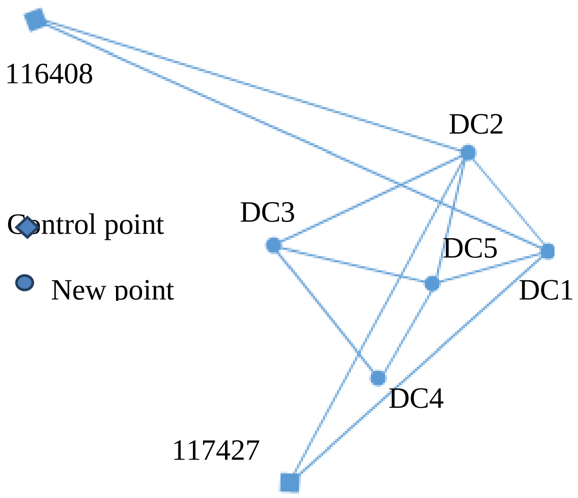


*Figure 1b: Network 2*

Table 2. Session time of NET2

| S/N<br>Session | 198 | 438 | 260 |
|---|---|---|---|
| SS 1<br>(15h15-15h50) | DC4<br>(1275) | DC5<br>(1585) | DC3<br>(1494) |
| SS 2<br>(16h15-16h55) | DC2<br>(1082) | DC5<br>(1585) | DC3<br>(1494) |
| SS3<br>(17h15-17h55) | DC2<br>(1082) | DC5<br>(1585) | DC1<br>(1413) |
| SS 4<br>(18h40 -19h20) | DC2<br>(1082) | 117427<br>(2006) | DC1<br>(1413) |
| SS 5<br>(19h35-20h15) | DC2<br>(1082) | 116408<br>(1946) | DC1<br>(1413) |

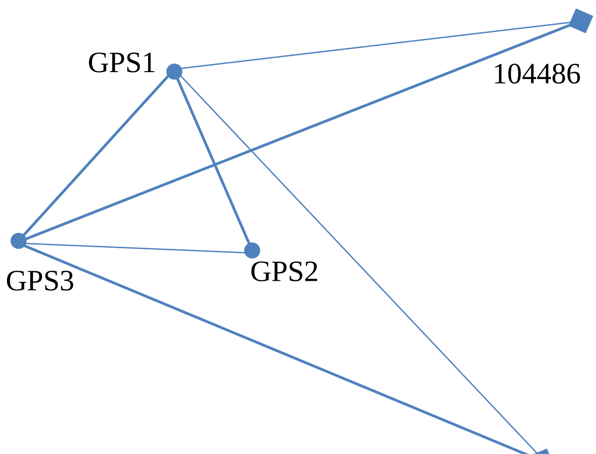


*Figure 1c: Network 3*

| **Table 3:** Session time of NET3 | | | |
|---|---|---|---|
| S/N / Session | 438 | 260 | 198 |
| SS1 (11h00-12h00) | GPS1 (1064) | GPS2 (1473) | GPS3 (1002) |
| SS2 (12h54-13h55) | GPS1 (1064) | 104486 (1737) | GPS3 (1002) |
| SS3 (15h40-16h40) | GPS1 (1064) | 116437 (1526) | GPS3 (1002) |

**Software:** Trimble Business Center version 5.00 was used to process date for all GNSS networks.

**Procedure:** For an objective assessment about the effect of GNSS systems on the accuracy, three networks are processed using the same input data (*elevation mark, sample interval..*) and default processing mode at four issues including GPS only; Glonass only, Galileo only, Beidou only. Baseline RMS, horizontal, and elevation accuracy will be taken for all issues.

### 3. Results and Discussion

To begin with, RMS of processed baselines of three networks are taken first. Take a look at below figures, RMSs of Glonass system are the biggest values for almost baselines in three networks, and RMSs of Beidou system are recorded for the smallest values*(note that baselines are processed with the same input parameters and processing mode)*.

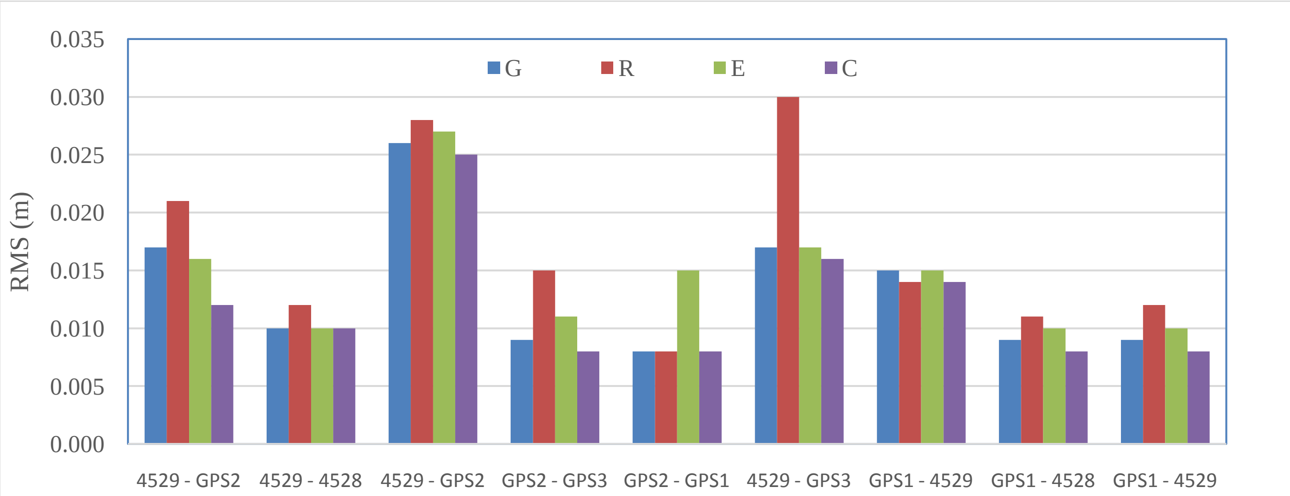


*Figure 2a: RMS fowr network 1*

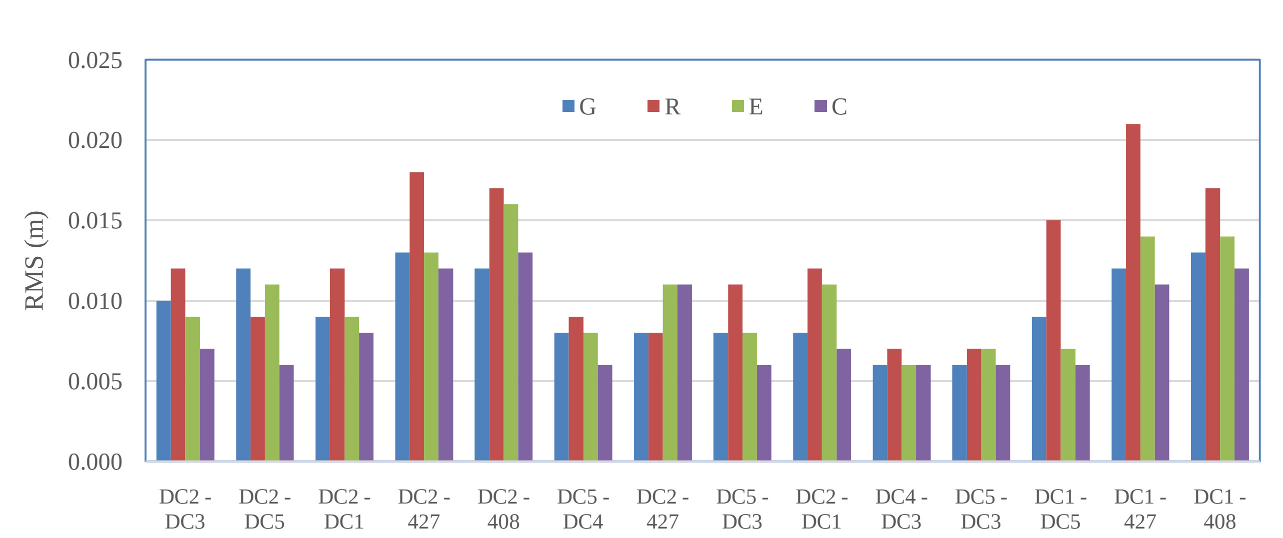


*Figure 2b: RMS for network 2*

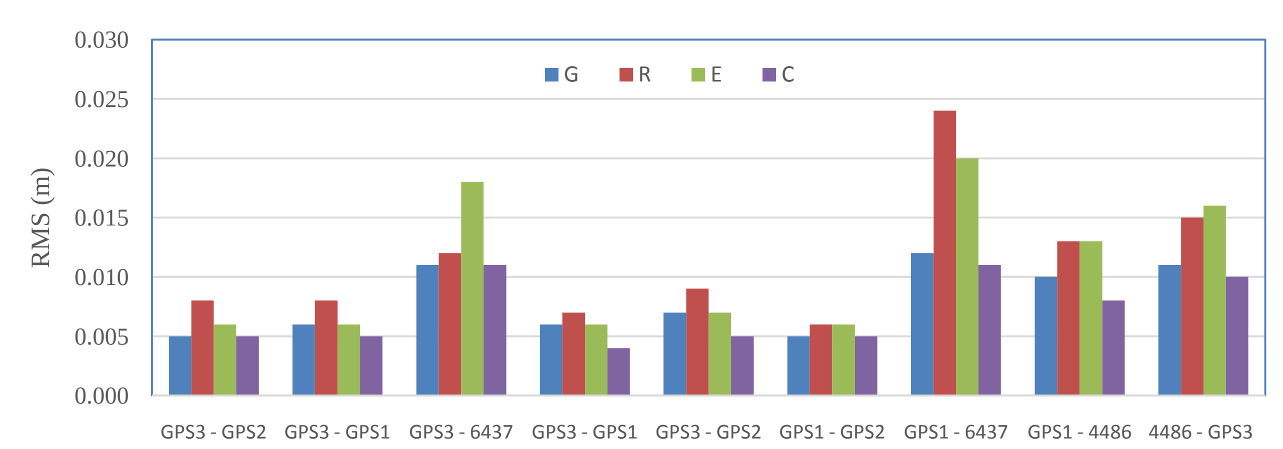


*Figure 2c: RMS for network 3*

For further assessment, horizontal and vertical position errors will be considered after network adjustment.

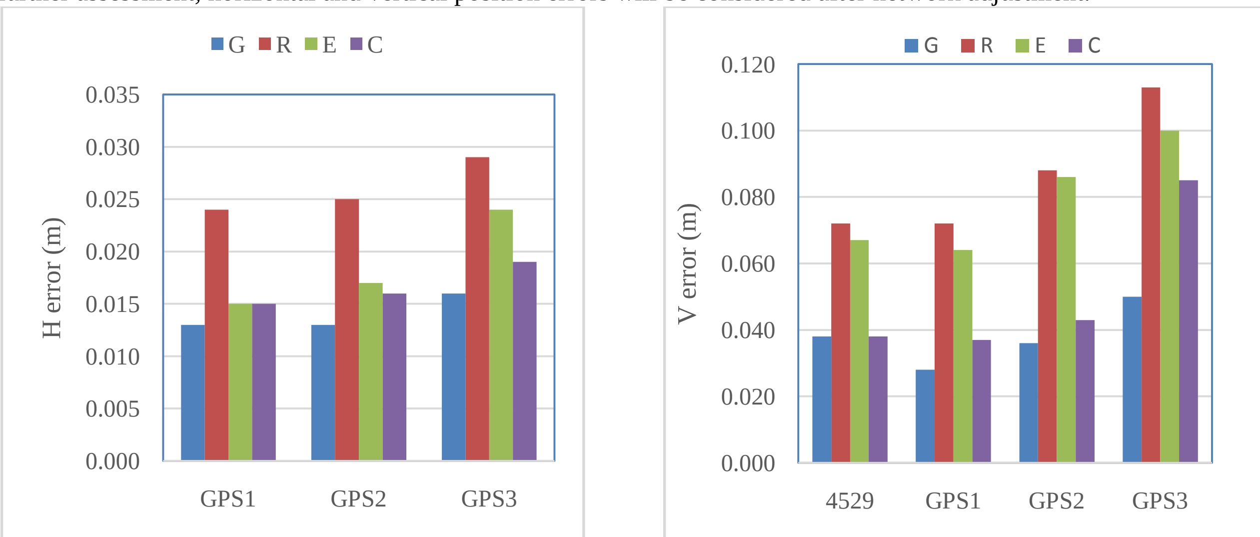


*Figure 3a: Horizontal and vertical position errors for network 1*

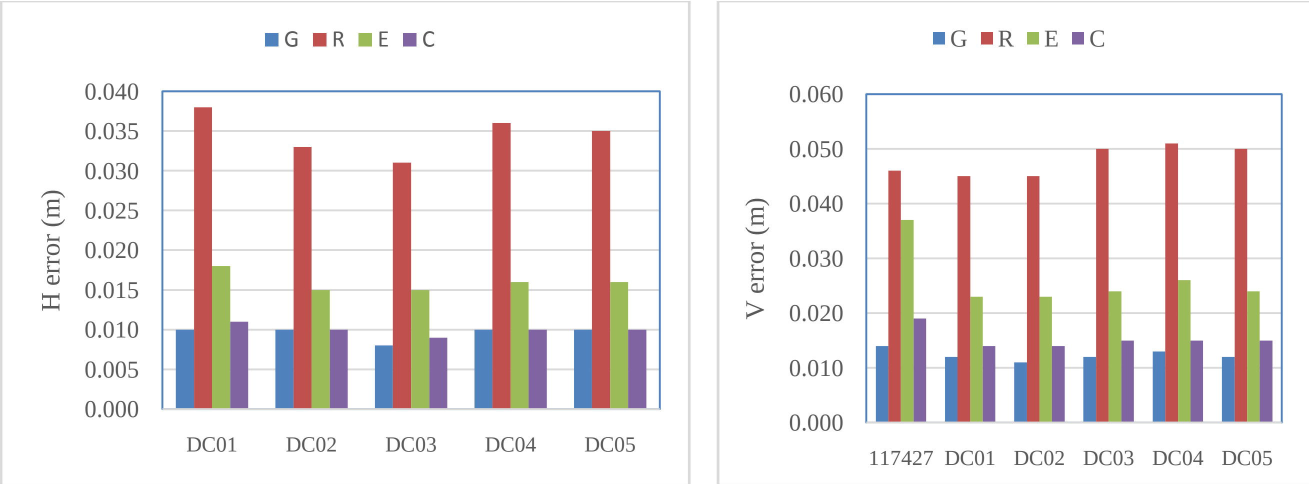


*Figure 3b: Horizontal and vertical position errors for network 2*

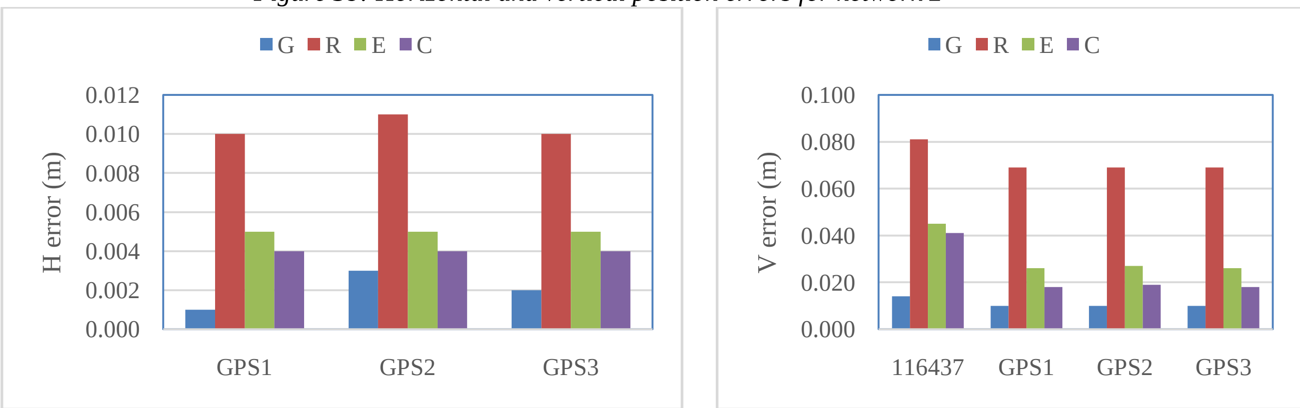


*Figure 3c: Horizontal and vertical position errors for network 3*

GPS system has the best accuracy for both horizontal and vertical position after adjustment, and Glonass system has the worst accuracy for both. Accuracy of Beidou system is lower than GPS but higher than Galileo system. For the combinations among systems, network 2 was choosen to process. Results of the combination can be seen in the below figures.

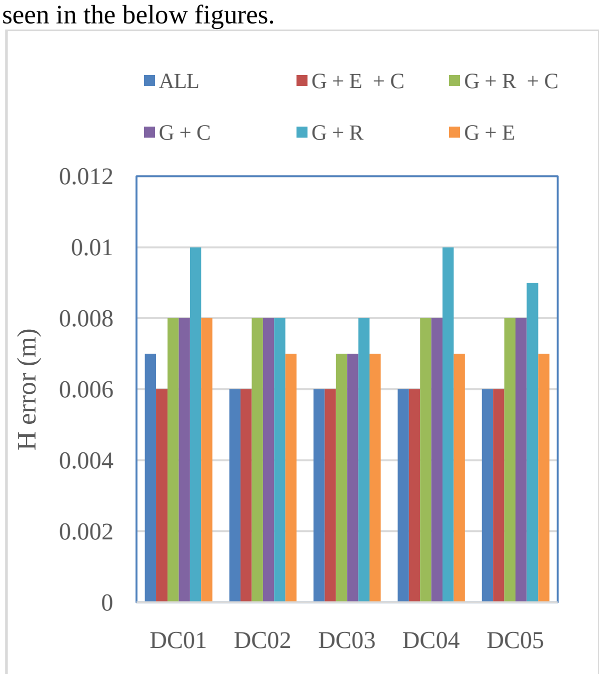


*Fig.4a. H error (m)*

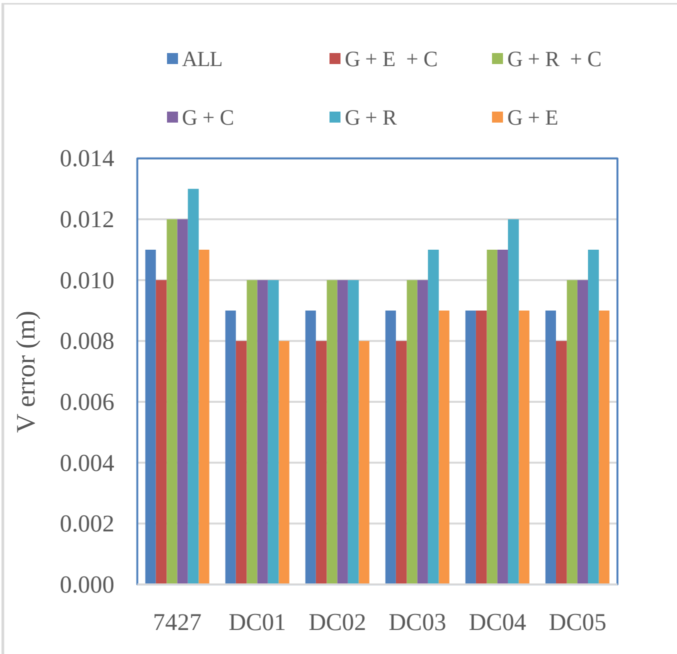


*Fig.4b. V error (m)*

Take a look at fig. 4, the occurrence of glonass satellites reduces the accuracy for both horizontal and vertical position errors. However, presence of beidousatelites have a good accuracy compare to combining all. Especially for vertical position. These results is similar to previous studies about elevation element [15]

## 4. Conclusions

This is an experiment for small scale networks, and will not be concluded for all issues. However, via this study, users have various options for static GNSS processing.

The perfection of BD-3 system at the end of 2020 is a meaningful addition, especially for elevation element when new standard allows users using GNSS technology to establish elevation network *(currently apply for technical order)*.

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