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Assessment of GPS, GLONASS and GPS+GLONASS processing solutions at different baseline lengths

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Abstract: Nowadays, using GNSS constellations in many applications is clear. The increasing of the satellites availability at any place of the world from different GNSS constellations is compared against using GPS only for improving the positioning accuracy. In this research, the availability of complete GNSS constellations (GPS and GLONASS) at some of IGS stations are illustrated. Performance with different baseline lengths are assessed using observations from GPS only, GLONASS only and (GPS+GLONASS) using different duration times. The processed data are collected at the same day in two different years. The results indicate that using GLONASS only does not give the best accuracy compared to (GPS only and (GPS and GLONASS). Finally, the results obtained by the GPS only are close to a large extent with the (GPS and GLONASS) results.

Keywords: Trimble Business Centre (TBC) software, International Terrestrial Reference Frame (ITRF), Vector Length Errors (VLE) and International GNSS Service (IGS)

1. Introduction

The four global satellite navigation systems, Global Positioning System (GPS), Global Navigation Satellite System (GLONASS), Galileo Satellite Navigation System (Galileo), and Beidou Satellite Navigation System (BDS) have enabled a wide range of applications for positioning, navigation and timing (Zhang et al., 2018). Two new global systems, Beidou in China and Galileo in Europe, are currently under development (Januszewski, 2018). The principle of GPS in position determination has not changed in GNSS but an expectation of achieving greater accuracy and precision with GNSS is envisaged. Baseline processing, the fundamental principle of satellite based positioning is still applicable with the GNSS system both in PPP and differential positioning. The baselines spans from short to long ranges with various error compensations and corrections applied to longer baseline to achieve desired precision and accuracy with the use of various commercial GNSS data processing softwares (Okorocha and Olajugba, 2014). The performed research on GPS-only, GLONASS-only and combined (GPS and GLONASS) daily static observations with usage of PPP technique in different sky visibility level shows that currently existing software does not improve results significantly comparing GPS-only solutions with multi-GNSS. Adding GLONASS signals to GPS does not affect noticeable improvement of coordinates' accuracy and in some cases even caused accuracy's deterioration (Maciuk, 2018).

2. Study area and data collection

One same day of data collected by IGS stations in two different years 2014 and 2018 are used in this research. Firstly, five IGS stations (NZRT, ELAT, ISBA, NICO and RAMO) on 18-04-2014. Secondly eight IGS stations (NZRT, ARUC, ELAT, ISBA, MATE, MERS, NICO and RAMO) on 18-04-2018 (Figure 1). The different baseline lengths are processed by fixing NZRT as a base station. Choosing of these stations depended on the same criteria. At each receiver, the signals from GPS and GLONASS are collected for 24 Hours session.

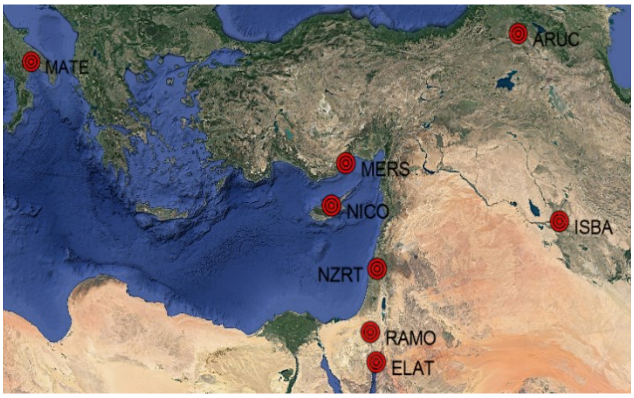

Figure 1: IGS stations used in this study

The baselines with different lengths are processed by using Trimble Business Center version 3.5 (TBC) commercial software. RINEX observation files of IGS stations downloaded from (CDDIS Daily 30-seconds data, 2019) and the broadcast and precise satellite ephemeris for GPS and GLONASS observations on these days obtained from (CDDIS Daily 30-second data, 2019) and (CDDIS GNSS Orbit Products, 2019).

3. Precise Point Positioning (PPP) and differential GPS positioning

Precise point positioning to achieve high positioning accuracy involves removal of all potential errors in the space segment, signal propagation, ground environment and receiver segment. In the differential GPS positioning, the reason that millimeter-level accuracy can be achieved is because some common errors can be fully or partially removed by differencing observations between two stations. However, this differential technique can't be used in PPP due to the fact that only observations from a single receiver are available. Therefore, all errors must be handled in PPP in order to achieve centimeter-level accuracy. The others include the special error sources that need to be mitigated specifically to PPP, such as the satellites and receiver antenna phase center offsets, phase wind up, relativistic effect, Earth tide, ocean tide loading, and atmosphere loading. Most of these errors can be mitigated to some extent through modeling (Cai, 2009). The AUSPOS provides accuracies of several millimeters in the horizontal component and a couple of centimeters in the vertical component. In addition, this capability can also support high precision applications and research into crustal deformation monitoring. Typical examples of crustal deformation monitoring and establishment of a local control networks using AUSPOS for multiple days' data sets collected from multiple sites (Jia et al., 2014) and the relative GPS solution software (TBC) are observed to give better result at all observation times (Abdel Aziz, 2018). The maximum vector length errors obtained by using TBC, Trimble RTX, AUSPOS and CSRS-PPP at 1 hour are 0.015 m, 0.093 m 0.235 m and 0.075 m respectively, at 2 hours are 0.009 m, 0.066 m, 0.033 m and 0.061 m respectively, at 3 hours are 0.008 m, 0.017 m, 0.033 m and 0.016 m respectively and at 4 hours are 0.005 m, 0.019 m, 0.014 m and 0.021 m respectively, by using the different baseline lengths 17.52 km, 48.793 km, 91.279 km and 102.777 km.

The following steps illustrate how to use the AUSPOS - Online GPS Processing Service:

i) Selection of RINEX file (s), one wishes to submit,
ii) Second step, enter the RINEX information - repeat for each of the RINEX files,
iii) Third step is to provide Email address and
iv) Fourth step is submission of the RINEX files.

Finally, the results are sent to the e-mail that was recorded on the site (AUSPOS - Step by Step Guide, 2019).

4. Reference Systems and ITRF

The international civil coordinate reference standard is the International Reference Frame (ITRF), each GNSS has its own reference frame, which depends on the control stations coordinates hence guaranteeing independence among systems. The reference frame for GPS system is World Geodetic system 1984 (WGS84), its present version is almost identical with the latest version ITRF. The coordinates in GLONASS system are based on the parameter of the Earth 1990 (PZ-90) frame, since 2014 in version 90.11, also known Parametry Zemli 1990 (PZ-90). The new system is already coordinated with the ITRF at the centimeter level (Mikulski, 2014).

5. Methodology

In this research, GPS, GLONASS and combined GPS and GLONASS dual carrier phase observations are used to assess all satellites constellations with different baseline lengths and duration times on two different years. The following illustrates the work steps: -

- Processing the RINEX observation file of NZRT IGS station by AUSPOS Online GPS Processing Service (version: AUSPOS 2.3) on ITRF 2014 from (AUSPOS - Online GPS Processing, 2019), on two days 18-04-2014 and 18-04-2018.
- Firstly, processing the different baseline lengths by using Trimble Business Center (TBC) for five IGS stations in 18-04-2014 at three different solutions using (GPS only, GLONASS only and combined GPS + GLONASS) by fixing the NZRT station and processing the four IGS stations (ELAT, ISBA, NICO and RAMO) to the NZRT station at 24 Hrs. duration time of observations on ITFR 2014.
- Processing the different baseline lengths at different duration times of observations (4, 8, 12, 16, 20 Hrs.) for the three above mentioned solutions.
- Determining the Vector Length Errors (VLEs) for the different baseline lengths by computing the difference between the positioning of IGS station obtained by 24 Hrs. duration time of observations and the positions of these IGS stations at different processing period times by using three different solutions.

$$VLE = \sqrt{(x - x_r)^2 + (y - y_r)^2 + (z - z_r)^2}$$

where: x, y and z: the position of IGS station at different processing period times. x_r, y_r and z_r: the position of the same IGS station obtained by 24 Hrs. duration time of observations.

- Repeating the same last steps on the 18-04-2018 to determine the VLE.

6. Results and analysis

The aim of this research is to assess the contribution of the modernization of GNSS signals and study the complete GNSS systems (GPS and GLONASS) in processing different baseline lengths on the same day at two different years. The VLE generally is depending on the baseline length but there are some factors that affect VLE for examples (DOP and the common time between base and rover).

The baseline lengths are NZRT-RAMO is 248.181 km, NZRT-NICO is 316.879 km, NZRT-ELAT is 365.015 km and NZRT-ISBA is 852.461 km.

The VLE of different baseline lengths obtained from the two solutions of GPS and combined (GPS and GLONASS) gave the best results shown in figure 2, but the results derived from GPS are the best at all baseline lengths except the baseline NZRT-NICO because the maximum PDOP was 2.205 in combined (GPS+GLONASS) and it was 5.026 in the case of GPS only.

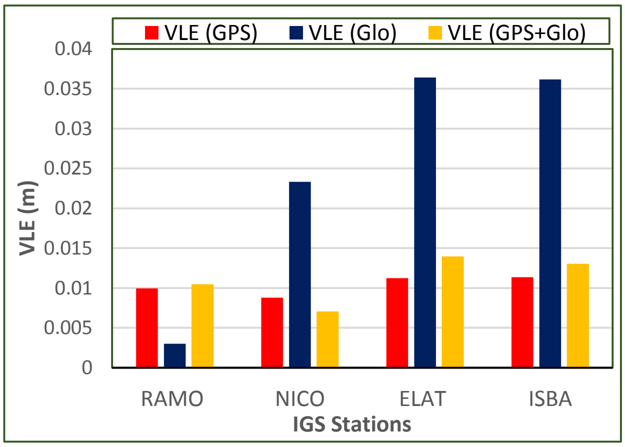

Figure 2: Vector Length Errors (VLE) for different baseline lengths by using the three solutions (4 hrs) in 2014

Figures 3 and 4 shows the duration of processing time of 8 and 12 hours respectively. Figure 3 shows the accuracy of 8 hours session compared to 4 hours session. Figure 4 also shows the accuracy of 12 hours' session compared to 8 hours' session. Still in both figures, GPS is the best than GPS+GLONASS and finally GLONASS with noticeable difference. The accuracy of GLONASS in using 12 hours' session is better than GPS and GPS+GLONASS and became more close to them. The baseline NZRT-NICO has not improved with increasing the session time in the cases of GPS and GPS+GLONASS and has improved in the case of GLONASS.

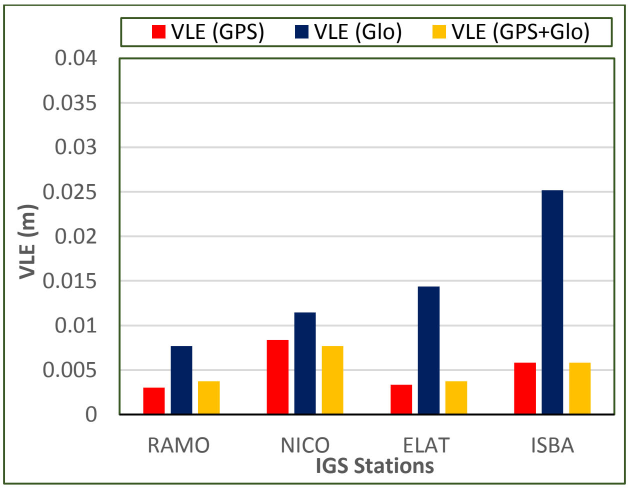

Figure 3: Vector Length Errors (VLE) for different baseline lengths by using the three solutions (8 hrs) in 2014

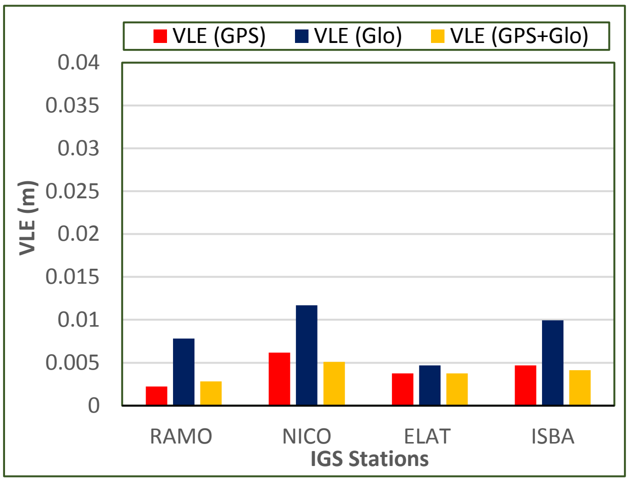

Figure 4: Vector Length Errors (VLE) for different baseline lengths by using the three solutions (12 hrs) in 2014

Figures 5 and 6 illustrated the results obtained by two period processing times 16 and 20 Hrs. The accuracies in both cases are equal. In both cases the accuracies much improved compared to the case of 12 hours. The three cases of GPS, GONASS and GPS+GLONASS became very close to each other. The results showed that achieving the accuracy of GPS by using GLONASS only requires 16 hours session.

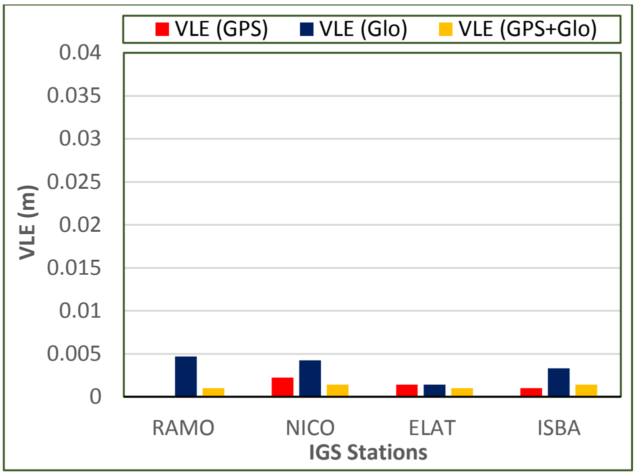

Figure 5: Vector Length Errors (VLE) for different baseline lengths by using the three solutions (16 hrs) in 2014

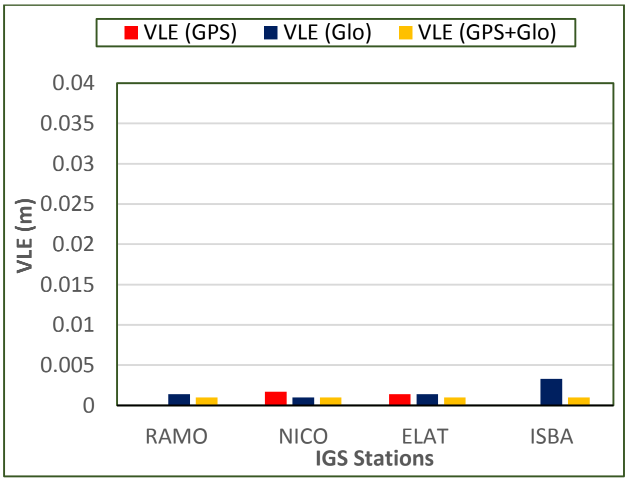

Figure 6: Vector Length Errors (VLE) for different baseline lengths by using the three solutions (20 hrs) in 2014

The following graphs illustrate the results obtained by processing the different baselines lengths at 2018 on same day used of 2014, but in 2018 was added a set of different baseline lengths to clarify the extent to take advantage of the development that occurred in these systems, either combined or individually.

In year 2018, three lines were added to previous baselines, NZRT-MATE is 1873.805 Km, NZRT-ARUC is 1142.405 Km and NZRT-MERS is 431.174 Km.

In Figure 7 it was detected that in most lines, when using GLONASS in processing, the solution is float. This is represented in the figure by the blue dashed line, which represents the VLE. When the duration time of processing was 4 hours in case of GLONASS, there were not enough available satellites. The VLE of baseline NZRT-RAMO is 0.738 m, because the processing duration time is less than one hour.

It is clear, in 4 hours session, that the VLE of different baseline lengths in 2018 is less than their corresponding values of 2014. The improvement was about 1 cm in both cases of GPS and GPS+GLONASS.

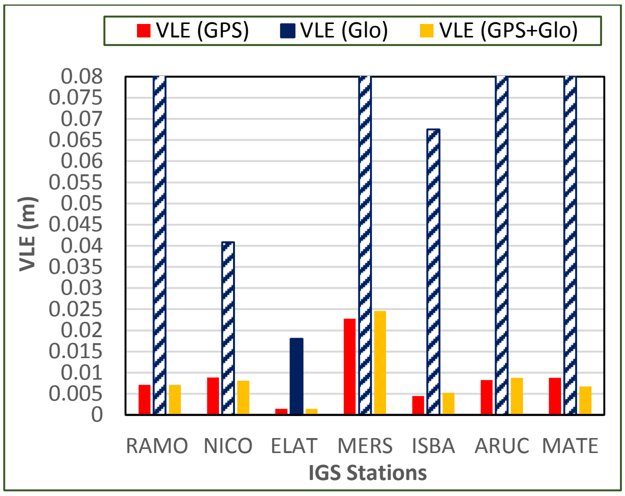

Figure 7: Vector Length Errors (VLE) for different baseline lengths by using the three solutions (4 hrs) in 2018

In figure 8, it is noted that when using GLONASS solution some baselines gave a float solution. Some other baselines gave a fixed solution with improved accuracy and sometimes not compared to the corresponding results from 2014.

In the case of using GPS and (GPS+GLONASS) solutions for 8 hours, there was an improvement in the values of VLE within 5 mm compared to the corresponding values of 2014.

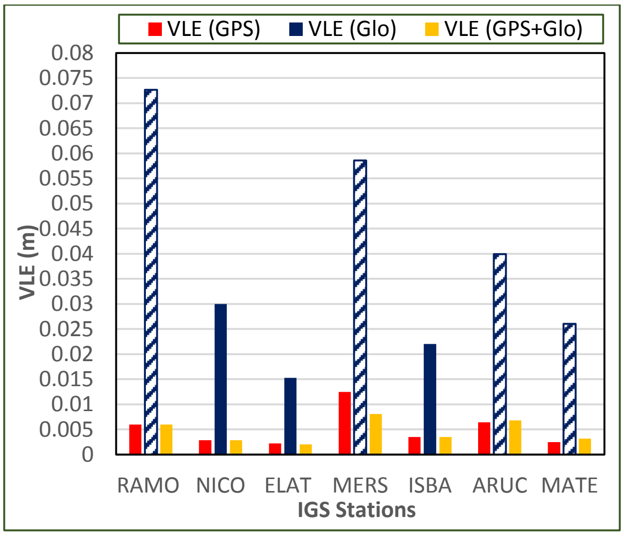

Figure 8: Vector Length Errors (VLE) for different baseline lengths by using the three solutions (8 hrs) in 2018

Figure 9 shows that GLONASS from 12 hours' session got fixed solutions but still have VLE larger than the other two cases. Also the VLE of GLONASS baselines in 2018 is larger than their corresponding values of 2014 in most baselines.

The differences between results obtained by processing the different baselines using GPS and (GPS+GLONASS) at 2014 and 2018 are within 2 mm.

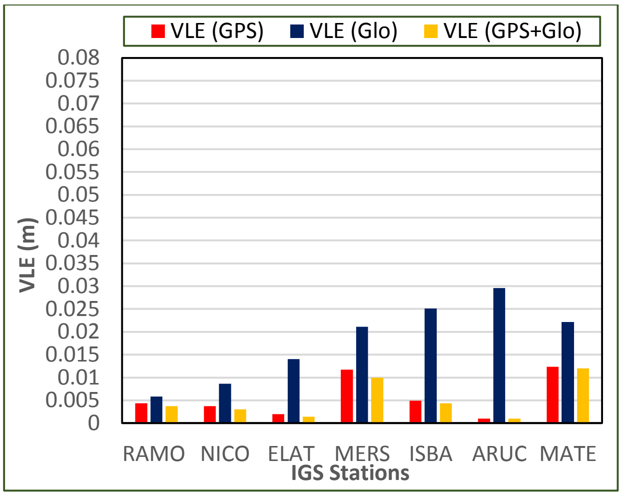

Figure 9: Vector Length Errors (VLE) for different baseline lengths by using the three solutions (12 hrs) in 2018

Figure 10 illustrates that VLE obtained by GLONASS solution is still larger compared to other two solutions except for one baselines. The results of GLONASS also showed that the VLE obtained in 2018 is larger than those of 2014.

The results obtained by processing the different baselines using GPS and (GPS+GLONASS) of 2018 have larger values of VLE compared to the corresponding values of 2014.

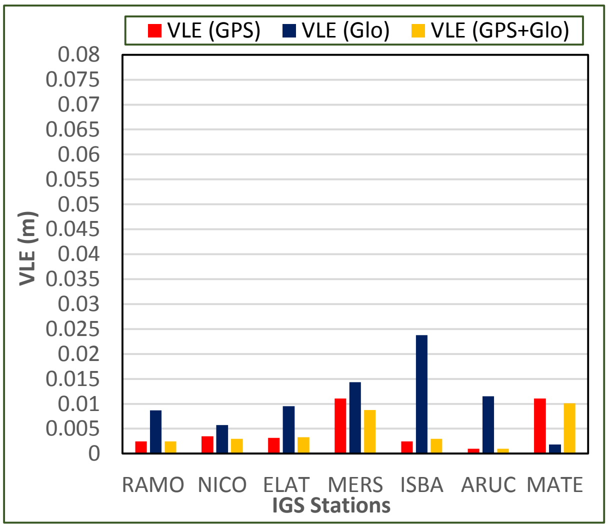

Figure 10: Vector Length Errors (VLE) for different baselines lengths by using the three solutions (16 hrs) in 2018

In figure 11, after 20 hrs duration time of processing, GLONASS solution became close or better in VLE than the other two solutions. The processing of different baselines using (GPS and GPS+GLONASS) gave VLE less than 5 mm for most baselines.

Results obtained are closely correlated with results obtained in 2014.

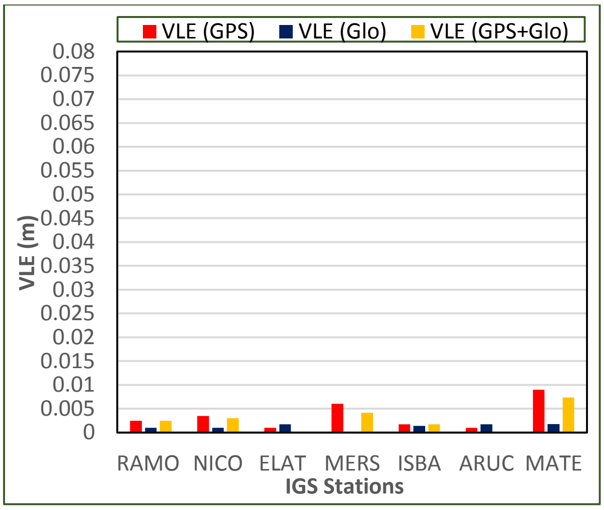

Figure 11: Vector Length Errors (VLE) for different baseline lengths by using the three solutions (20 hrs) in 2018

The tables 1-7 given below illustrates the Vector Length Errors (VLEs) for different base line lengths at different times of processing in two years 2014 and 2018.

Table 1: Vector Length Errors (VLE) of baseline NZRT- RAMO by using the three solutions at different processing times in 2014 and 2018

Base Line	Year / Times	2014 VLE (m)			2018 VLE (m)		
		GPS	GLO	GPS+GLO	GPS	GLO	GPS+GLO
NZRT-RAMO	4 Hrs.	0.01	0.003	0.01	0.007	0.738	0.007
	8 Hrs.	0.003	0.008	0.004	0.006	0.073	0.006
	12 Hrs.	0.002	0.008	0.003	0.004	0.006	0.004
	16 Hrs.	0	0.005	0.001	0.002	0.009	0.002
	20 Hrs.	0	0.001	0.001	0.002	0.001	0.002

Table 2: Vector Length Errors (VLE) of baseline NZRT- NICO by using the three solutions at different processing times in 2014 and 2018

Base Line	Year / Times	2014 VLE (m)			2018 VLE (m)		
		GPS	GLO	GPS+GLO	GPS	GLO	GPS+GLO
NZRT-NICO	4 Hrs.	0.009	0.023	0.007	0.009	0.041	0.008
	8 Hrs.	0.008	0.011	0.008	0.003	0.03	0.003
	12 Hrs.	0.006	0.012	0.005	0.004	0.009	0.003
	16 Hrs.	0.002	0.004	0.001	0.003	0.006	0.003
	20 Hrs.	0.002	0.001	0.001	0.003	1E-03	0.003

Table 3: Vector Length Errors (VLE) of baseline NZRT- ELAT by using the three solutions at different processing times in 2014 and 2018

Base Line	Year / Times	2014 VLE (m)			2018 VLE (m)		
		GPS	GLO	GPS+GLO	GPS	GLO	GPS+GLO
NZRT-ELAT	4 Hrs.	0.011	0.036	0.014	0.001	0.018	0.001
	8 Hrs.	0.003	0.014	0.004	0.002	0.015	0.002
	12 Hrs.	0.004	0.005	0.004	0.002	0.014	0.001
	16 Hrs.	0.001	0.001	1E-03	0.003	0.01	0.003
	20 Hrs.	0.001	0.001	0.001	0.001	0.002	0

Table 4: Vector Length Errors (VLE) of baseline NZRT- ISBA by using the three solutions at different processing times in 2014 and 2018

Base Line	Year / Times	2014 VLE (m)			2018 VLE (m)		
		GPS	GLO	GPS+GLO	GPS	GLO	GPS+GLO
NZRT-ISBA	4 Hrs.	0.011	0.036	0.013	0.004	0.067	0.005
	8 Hrs.	0.006	0.025	0.006	0.003	0.022	0.003
	12 Hrs.	0.005	0.01	0.004	0.005	0.025	0.004
	16 Hrs.	1E-03	0.003	0.001	0.002	0.024	0.003
	20 Hrs.	0	0.003	0.001	0.002	0.001	0.002

Table 5: Vector Length Errors (VLE) of baseline NZRT- MERS by using the three solutions at different processing times in 2018

Base Line	Year / Times	2018 VLE (m)		
		GPS	GLO	GPS+GLO
NZRT-MERS	4 Hrs.	0.023	0.092	0.025
	8 Hrs.	0.012	0.059	0.008
	12 Hrs.	0.012	0.021	0.01
	16 Hrs.	0.011	0.014	0.009
	20 Hrs.	0.006	0	0.004

Table 6: Vector Length Errors (VLE) of baseline NZRT- ARUC by using the three solutions at different processing times in 2018

Base Line	Year / Times	2018 VLE (m)		
		GPS	GLO	GPS+GLO
NZRT-ARUC	4 Hrs.	0.008	0.155	0.009
	8 Hrs.	0.006	0.04	0.007
	12 Hrs.	0.001	0.03	1E-03
	16 Hrs.	0.001	0.012	0.001
	20 Hrs.	0.001	0.002	0

Table 7: Vector Length Errors (VLE) of baseline NZRT- MATE by using the three solutions at different processing times in 2018

Base Line	Year / Times	2018 VLE (m)		
		GPS	GLO	GPS+GLO
NZRT-MATE	4 Hrs.	0.009	0.104	0.007
	8 Hrs.	0.002	0.026	0.003
	12 Hrs.	0.012	0.022	0.012
	16 Hrs.	0.011	0.002	0.01
	20 Hrs.	0.009	0.002	0.007

Due to the float solutions which obtained by processing the different baselines at processing duration (4H and 8H) by using the GLONASS system in 2018 compared to the same baselines in 2014 which obtained the fixed solutions. The table 8 -11 given the maximum PDOP and the actual processing duration for different baseline lengths at (4H and 8H) in two years 2014 and 2018 by using the GLONASS solution. When using the time of processing (4H) at 2014 that gives the largest maximum PDOP for baselines NZRT – ISBA and NZRT – ELAT compared to the remaining baselines, but the solutions are fixed. At (8H) the maximum PDOP is large at all baselines, but due to increasing the times of processing we obtained the fixed solution for all baselines.

In 2018 when processing duration are (4H and 8H) the maximum PDOP is large for most baselines and given a float solution which appear on the form of large VLE. The accuracy of these baselines is improved when increasing the processing time into 12H.

Table 8: The maximum PDOP and the actual processing duration by using the GLONASS solution (4 hrs) in 2014

Baseline observation	Maximum PDOP	Processing Duration (H:M:S)
NZRT - RAMO	05.545	03:59:30
NZRT - NICO	05.545	03:59:30
NZRT - ISBA	19.260	03:59:30
NZRT - ELAT	19.767	03:59:30

Table 9: The maximum PDOP and the actual processing duration by using the GLONASS solution (8 hrs) in 2014

Baseline observation	Maximum PDOP	Processing Duration (H:M:S)
NZRT - RAMO	18.905	07:59:30
NZRT - NICO	13.425	07:59:30
NZRT - ISBA	19.26	07:59:30
NZRT - ELAT	19.767	07:59:30

Table 10: The maximum PDOP and the actual processing duration by using the GLONASS solution (4 hrs) in 2018

Baseline observation	Maximum PDOP	Processing Duration (H:M:S)
NZRT- ARUC	19.926	03:28:00
NZRT- MATE	19.843	03:17:30
NZRT - RAMO	03.651	00:55:30
NZRT - MERS	19.837	03:33:30
NZRT - NICO	19.305	03:41:00
NZRT - ISBA	15.887	03:02:00
NZRT - ELAT	18.753	03:30:00

Table 11: The maximum PDOP and the actual processing duration by using the GLONASS solution (8 hrs) in 2018

Baseline observation	Maximum PDOP	Processing Duration (H:M:S)
NZRT- ARUC	19.926	07:59:00
NZRT- MATE	19.843	07:36:00
NZRT- RAMO	19.462	05:01:00
NZRT- MERS	19.837	07:59:30
NZRT- NICO	19.370	07:59:00
NZRT- ISBA	19.554	07:59:30
NZRT- ELAT	19.530	07:59:30

7. Conclusions

- Most of the baselines (with variant lengths) that were processed by using two solutions GPS and (GPS+GLONASS) gave VLE within 1 cm at duration time of processing (4 Hrs) for both 2014 and 2018 years data.
- Our use of GPS observation only in processing is enough to get the best results due to convergence of results obtained when processing the different baselines lengths by using GPS only or combined GPS+GLONASS.
- The use of GLONASS satellites only in processing different baseline lengths requires a duration time of processing up to 16 Hrs to reach into the same results obtained by using the GPS solution.
- The VLE obtained by processing baseline lengths do not depend on the length of the baseline and time span only but also depended on the PDOP.
- The PDOP is an effect on accuracy of baseline lengths. By using the long processing duration can minimize this effect.

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