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The Republic of the Union of Myanmar
Ministry of Natural Resources and Environmental Conservation
Survey Department

Determination on Three-Dimensional Position Variation of Ground Control Points

CORS Station NPT3 (Nay Pyi Taw)

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(၂) ဦးဇော်ဝင်းထွန်း၊ ဦးစီးအရာရှိ၊ နယ်နိမိတ်တိုင်းတာရေးနှင့်မြို့ပြဆောက်လုပ်ရေးမြေတိုင်း ဌာနခွဲ၊ မြေတိုင်းဦးစီးဌာန

စာတမ်းအကျဉ်း

မြေတိုင်းဦးစီးဌာနသည် နိုင်ငံတစ်ဝှမ်းတွင် မြေပြင်ထိန်းမှတ် ၁၀၀၀ ကျော်ကို တည်ဆောက်ထားပါသည်။ ထိုမြေပြင်ထိန်းမှတ်များသည် မြန်မာနိုင်ငံ၏ ပင်မမြေပြင်ထိန်းမှတ် ၉ ခုမှ ဆင့်ပွားတိုင်းတာထားခြင်းဖြစ်ပါသည်။ ပင်မမြေပြင်ထိန်းမှတ်များကို ၂၀၀၀ခုနှစ်တွင် တည်ဆောက်ခဲ့ပါသည်။ မြန်မာနိုင်ငံသည် အိန္ဒိယ-ဘားမား-ဆန္ဒ ကမ္ဘာ့ပြတ်ရွေ့ကြောတွင် တည်ရှိနေသောကြောင့် မြေပြင်ထိန်းမှတ်အားလုံးသည် လားရာအမျိုးမျိုးဖြင့် ရွေ့လျားသွားနိုင်ပါသည်။ ထို့ပြင် မည်သည့်မြေပြင်ထိန်းမှတ်များကို ၂၃နှစ်တာကာလအတွင်း အဆင့်မြှင့်တင် နိုင်သေးခြင်းမရှိကြောင်းတွေ့ရှိရပါသည်။ ၂၀၁၉ခုနှစ်၊ နှစ်ကုန်ပိုင်းတွင် မြေတိုင်းဦးစီးဌာနသည် မြန်မာနိုင်ငံ အလယ်ပိုင်းတွင် စဉ်ဆက်မပြတ်တိုင်းတာနေသော မှတ်တိုင် ၅၃ ကို စတင်တည်ဆောက်ခဲ့ပါသည်။ ထိုမှတ်တိုင်များကိုအသုံးပြု၍ ထို့ကြောင့် ကမ္ဘာ့ပြတ်ရွေ့ကြောများကြောင့် မြေပြင်ထိန်းမှတ်များ၏ ရွေ့လျားမှုကိုလေ့လာရန် အခွင့်အလမ်းကိုရရှိခဲ့ပါသည်။ ဤလေ့လာမှုသည် သုတေသီများနှင့် မြေတိုင်းတာရေး လုပ်ငန်းဆောင်ရွက်နေကြသူများကို ၂၃နှစ်တာကာလအတွင်း မြေပြင်ထိန်းမှတ်များ ရွေ့လျားမှု အခြေအနေနှင့် ၎င်းတို့၏ ရွေ့လျားမှုနှုန်းကို သိရှိနိုင်စေရန်ရည်ရွယ်ပါသည်။ ရွေးချယ်ထားသော မြေတိုင်းဦးစီးဌာန၊ နေပြည်တော်မှ မြေပြင်ထိန်းမှတ် ၃လုံးနှင့် လေ့ကျင့်သင်ကြားရေးနှင့် အမှတ် (၁)မြေတိုင်းဌာနခွဲ၊ ပြင်ဦးလွင်မှ ၂လုံး တို့တွင် Trimble R8s GNSS ကို အသုံးပြု၍ Static တိုင်းတာခြင်း၊ RTK တိုင်းတာခြင်းတို့ကို ဆောင်ရွက်ခဲ့ပါသည်။ Online GNSS တွက်ချက်ခြင်းအတွက် Static တိုင်းတာခြင်းမှရရှိခဲ့သော အချက်အလက်များကို အသုံးပြုခဲ့ ပါသည်။ တဖန် Static တိုင်းတာခြင်းမှရရှိခဲ့သော အချက်အလက်များတွက်ချက်ခြင်း လုပ်ငန်းအား Trimble Business Centre-TBC ဆော့ဝဲလ်ကို အသုံးပြု၍ ဆောင်ရွက်ခဲ့ပါသည်။ Static တိုင်းတာခြင်းမှ ရရှိသော ရလဒ်များအား RTK တိုင်းတာခြင်း လုပ်ငန်းများဆောင်ရွက်ရာတွင် စဉ်ဆက်မပြတ် တိုင်းတာနေသောမှတ်တိုင် (NPT 3 , POL 5)တို့ကို မြေပြင်ထိန်းမှတ်များအဖြစ် အသုံးပြု၍ ဆောင်ရွက်ခဲ့ပါသည်။ Static တိုင်းတာခြင်းမှ ရရှိသောရလဒ်များအား RTK တိုင်းတာခြင်းနှင့် Online GNSS တွက်ချက်ခြင်းတို့မှ ရရှိသောရလဒ်များနှင့် တိုက်ဆိုင်စစ်ဆေးရာတွင် ယုံကြည်လက်ခံနိုင်သည့် အနေအထားတွင် တွေ့ရှိခဲ့ရပါသည်။ နောက်ဆုံး၌ ကမ္ဘာ့ပြတ်ရွေ့ကြောများကြောင့် နေပြည်တော်ရှိ မြေပြင်ထိန်းမှတ်များသည် ၂၀နှစ်တာ ကာလ အတွင်း စဉ်ဆက်မပြတ်တိုင်းတာနေသောမှတ်တိုင်များကိုမူတည်၍ အရှေ့ဘက်သို့ ၁၂၂ မီလီမီတာမှ ၁၄၆

မီလီ မီတာထိ၊ တောင်ဘက်သို့ ၅ မီလီမီတာမှ ၁၅ မီလီမီတာထိနှင့် ဒေါင်လိုက် ၄၀ မီလီမီတာမှ ၁၀၆ မီလီမီတာထိ ရွှေ့လျားနေပြီး၊ ပြင်ဦးလွင်ရှိ မြေပြင်ထိန်းမှတ်များသည် အနောက်ဘက်သို့ ၄၂ မီလီမီတာမှ ၄၈ မီလီမီတာထိ၊ တောင်ဘက်သို့ ၃၂ မီလီမီတာမှ ၃၈ မီလီမီတာထိနှင့် ဒေါင်လိုက် ၁၄ မီလီမီတာမှ ၁၇ မီလီမီတာထိ ရွှေ့လျားနေကြောင်း တွေ့ရှိရပါသည်။ Online GNSS တွက်ချက်ခြင်းမှ လာရှိလာသောရလဒ်များအရ ၂၀နှစ်တာ ကာလအတွင်း မြေပြင်ထိန်းမှတ်များ၏ ရွှေ့လျားမှုနှုန်းများမှာ နေပြည်တော်တွင် တစ်နှစ်လျှင် ၁၀-၁၂ မီလီမီတာ ရှိပြီး၊ ပြင်ဦးလွင်တွင် တစ်နှစ်လျှင် ၄ မီလီမီတာ ရှိကြောင်း တွေ့ရှိခဲ့ရပါသည်။

Determination on Three-Dimensional Position Variation of Ground Control Points

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Abstract

Survey Department laid out over 1000 Ground Control Points (GCPs) throughout the country. Those GCPs were derived from 9 primary control stations in Myanmar. All primary control stations were established in 2000. Due to Myanmar lies on dynamic tectonic plates, India-Burma-Sunda Plate, all GCPs can move in some directions. Furthermore, all of the said GCPs have not been upgraded for 23 years. At the end of 2019, the Survey Department established 5 CORS in the central part of Myanmar. Therefore, the opportunity was occurred to study the variation of GCPs which caused by the movement of tectonic plates. This study aimed to inform GCPs users and surveyors about the movement of GCPs and its rate caused by tectonic plates within 23 years. Trimble R8s differential Global Navigation Satellite System (GNSS) was utilized to observe static observation and Real Time Kinematic (RTK) surveying on five selected GCPs and CPs (three GCPs from Survey Department, Nay Pyi Taw and two Control Points (CPs) from Training and No.(1) Survey Division, Pyin Oo Lwin). Then, an online GNSS solution was done by using the static observed data. Again, the Trimble Business Center (TBC) commercial software was used to process the static observation. The two CORS NPT 3 and POL 5 were used as control stations for static observation and RTK surveying. The static observation's post-processing results, RTK survey results and online GNSS solution results were reliable by comparing among them. Static observation results were used to determine the variation of GCPs and CPs. Finally, due to the movement of tectonic plates, the GCPs from Nay Pyi Taw have moved with reference to CORS within 20 years, eastward between 122 mm and 146 mm, southward between 5 mm and 15 mm and vertically between 40 mm and 106 mm, and the CPs from Pyin Oo Lwin have moved westward between 42 mm and 48 mm, southward between 32 mm and 38 mm and vertically between 14 mm and 17 mm. According to the online GNSS solution results, the shifting magnitude and direction of GCPs and CPs within 23 years from Nay Pyi Taw is is 10-12 mm/year and Pyin Oo Lwin is 4 mm/year.

Key Words: *CORS, GCPs, shifting magnitude and direction, static observation*

Determination on Three-Dimensional Position Variation of Ground Control Points

1. Introduction

1.1 Background Situation of Survey Department

Survey Department (SD) has been using topographic maps before World War II. Those classical maps were based on Lambert Conical Orthomorphic Projection. But, in 2000, SD introduced Myanmar Datum 2000 and Universal Transverse Mercator (UTM) production system cooperation with Finnmap Co. Ltd. During implementing UTM mapping system, 9 primary control stations were also laid down and observed connect with International Terrestrial Reference Frame (ITRF) 1996 based on Everest 1830 Ellipsoid. Then, more than 1000 Ground Control Points (GCPs) were set up based on 9 primary control stations to densify entire the country. In other words, those GCPs could be said for about 23 years long. In the present situation, all GCPs will definitely move from their original positions due to active tectonic plates called the India-Burma-Sunda Plate. Necessary renewals were urgently needed to upgrade the old GCPs. Therefore, SD implemented four Continuously Operating Reference Station (CORS) in ITRF 2014 with the Geodetic Reference System 1980 (GRS 80) Datum at Nay Pyi Taw Union Territory and one CORS at Pyin Oo Lwin in September 2019.

1.2 Introduction to CORS

The earth's surface is dynamic due to the movement of tectonic plates. Every plate moves in constant motion. These movement rates can be defined by using worldwide acceptance of Global Navigation Satellite System (GNSS) instruments (Marcin Jagoda, 2021) to determine their centimeter-level accuracy (Olatunji, R. I., 2019). Nowadays, the Continuously Operating Reference Station (CORS) has become a major navigation system in the world. CORS is a non-stop observed GNSS receiver. It can collect GNSS's data continuously and transmit the data via the internet to a central data server. The data can be obtained by any user by downloading from server. Moreover, high-grade accuracy observations can be done within the CORS network. The innovated technology was introduced in the late 1980s. It can support real-time correction data for establishing regional or state-wide development (Snay and Solar, 2008).

2. Objectives

The objectives of this study are:

- To determine the coordinates variations of GCPs and CPs within 20-year period using CORS network
- To evaluate the shifting magnitude and direction of selected GCPs and CPs due to the movement of tectonic plates within 23-year

3. Materials and Methods

3.1 Locations of Study Area

Three GCPs (GCP 1201, GCP 1202, and GCP 1736) and one CORS (NPT3) from Nay Pyi Taw and two Control Points (CPs) (CP 01 and CP 02) and one CORS (POL 5) from Training and No.(1) Survey Division, Pyin Oo Lwin were selected to observe three-dimensional positional variation of GCPs. The diagram of the locations of GCPs, CPs and CORS is shown in **Figure 1**.

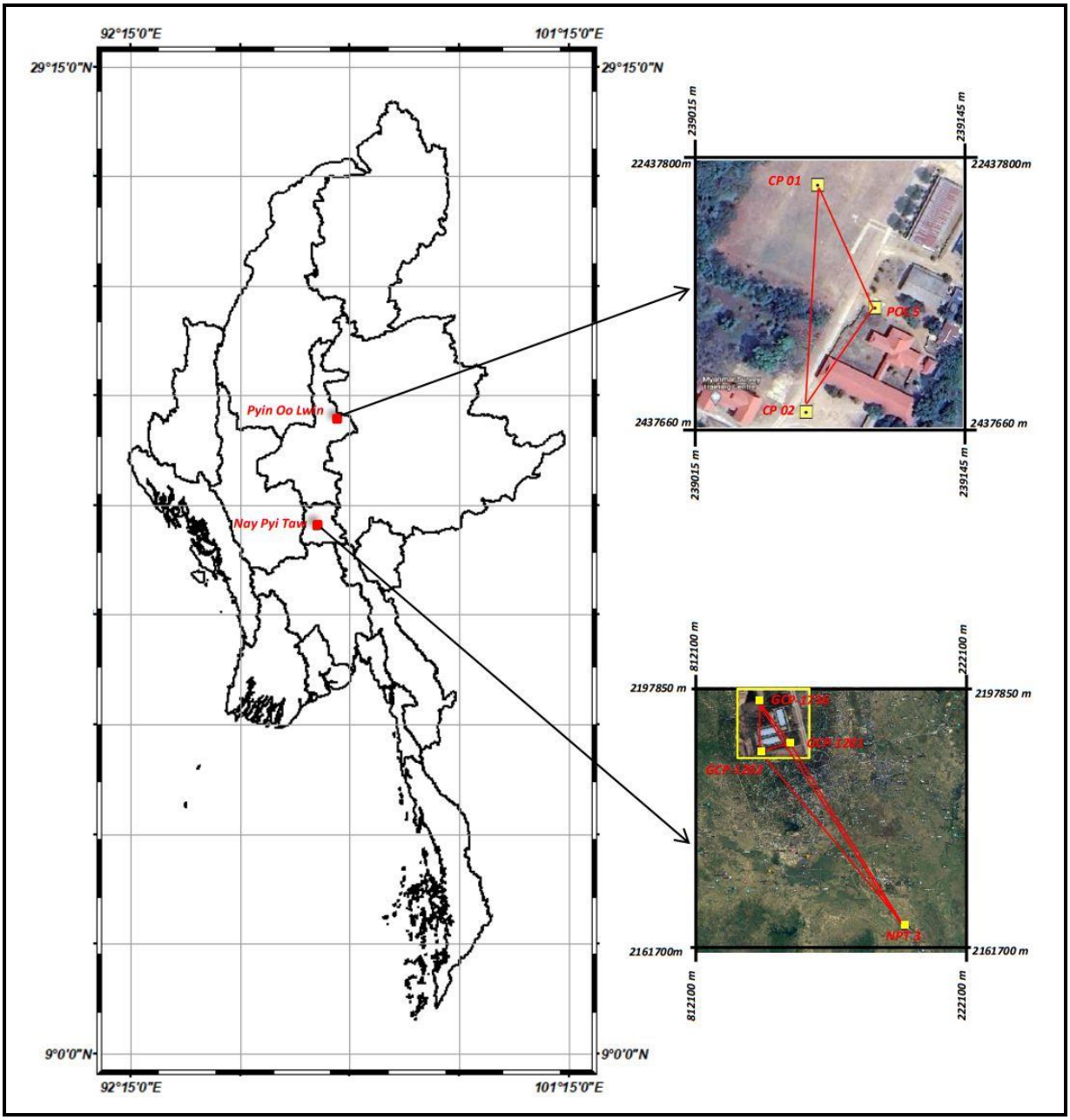


Figure 1: Locations of GCPs, CPs and CORS

3.2 Methodology Flowchart

In this study, static observation and Real Time Kinematic (RTK) surveying were conducted for the selected locations using Trimble R8s GNSS receivers. All the static observation results were sent to an online GNSS service to get the locations of selected GCPs and CPs. Necessary calculations and coordinate transformations were done using Trimble Business Center (TBC) software, global mapper software, Eye4 coordinate calculator and pinnacle coordinate calculator. Other preparations were carried out with the aid of Arc GIS software, Grapher Golden software and Microsoft Visio. The methodology flowchart is shown in **Figure 2**.

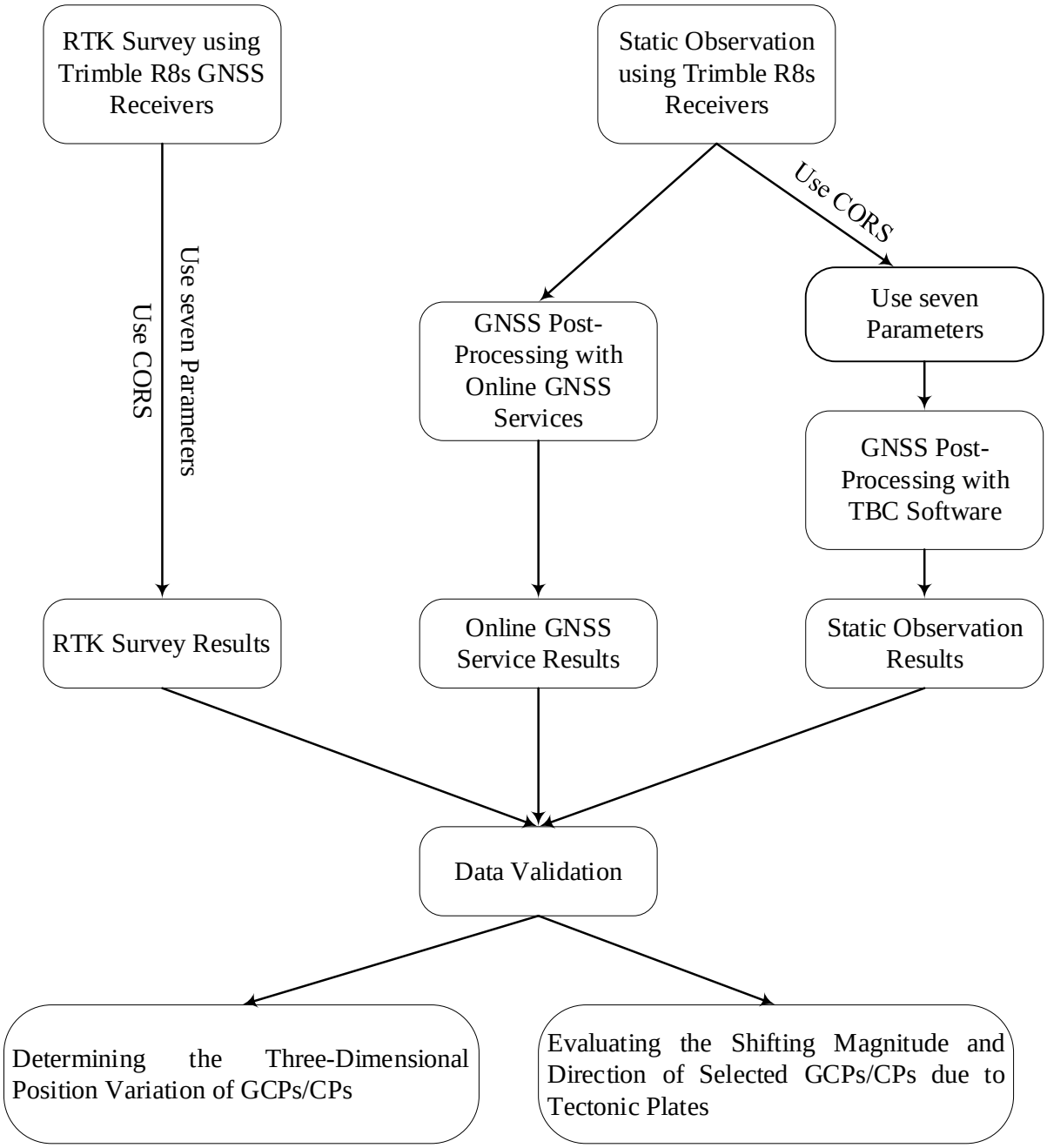


Figure 2: Methodology Flowchart

3.3 Static Observation and Data Processing

Static observation is a famous technique among geodesists that collects positioning data by connecting with available satellites and GNSS receivers over an assigned time interval at stationary locations. In this study, static observation was done by using multi-frequency/ multi-constellation Trimble R8s GNSS receivers. Observations were carried out 4 hours and 30 minutes for one section to reduce redundancy when applying least square adjustment method to get more accurate results. Trimble R8s GNSS receivers can give the positioning accuracy performance as given in **Table 1**. The condition of static observation is shown in **Table 2**.

Table 1: Accuracy performance of Trimble R8s receiver

Static GNSS Surveying	**High-Precision Static**
	- Horizontal ±3 mm + 0.1 ppm RMS
	- Vertical ±3.5 mm + 0.4 ppm RMS
	Static and Fast Static
	- Horizontal ±3 mm + 0.5 ppm RMS
	- Vertical ±5 mm + 0.5 ppm RMS
Real-Time Kinematic Surveying	**Single Baseline <30km**
	- Horizontal ±8 mm + 1 ppm RMS
	- Vertical ±15 mm + 1 ppm RMS
	Network RTK
	- Horizontal ± 8 mm + 0.5 ppm RMS
	- Vertical ±15 mm + 0.5 ppm RMS

Source: 2015-2017 Trimble Inc

Table 2 Condition of static observation

Station (s)	Receiver	Antenna Height (m)	Start Time	End Time
GCP 1201	TRIMBLE R8s	1.592	29/12/2023 10:30:00	29/12/2023 15:00:00
GCP 1202	TRIMBLE R8s	1.411	29/12/2023 10:30:00	29/12/2023 15:00:00
GCP 1736	TRIMBLE R8s	1.476	29/12/2023 10:30:00	29/12/2023 15:00:00
CP 01	TRIMBLE R8s	1.727	29/12/2023 10:30:00	29/12/2023 15:00:00
CP 02	TRIMBLE R8s	1.809	29/12/2023 10:30:00	29/12/2023 15:00:00

Before starting the static observation, the necessary internal configurations were set up: elevation mask = 10°, epoch interval = 1 second, and all available satellites were opened in all receivers. In GNSS post-processing, SD supported 1-second epoch interval results for NPT 3 and POL 5. Trimble Business Center (TBC) commercial software V 5.2 was used for data processing because it was suitable for baseline processing with a least-squares network adjustment. Post-processing procedures were done as follows:

i. CORS data was fixed as control quality.

ii. Independently measured baselines were specified and dependent baselines were removed.

iii. The logging sessions were analyzed and necessary editing was done.

iv. Minimally constrained adjustment was performed with CORS.

v. If any observation session was erroneous, then re-computation was done to the network.

vi. Fully-constrained network adjustment was done with fixed coordinates of CORS.

vii. Weighting the scalar was dressed up by seeing the reference factor (approximately 1) to reduce redundancy to attain fixed quality.

viii. The Root Mean Square (RMS) vale on the Baseline Processing Report was checked to know the quality of the solution because it is based solely on the measurement noise of the satellite ranging observations and is independent of satellite geometry. RMS indicates as the closer to zero the better the result (TBC Manual, 2019).

ix. Checking the baseline closure was carried on the covariance terms on horizontal precision ratios and 3D precision ratios to be more accurate than 1 in 100, 000 (India Department of Transportation, 2013).

3.4 RTK Surveying

RTK Surveying is a high-precision GNSS technique. It is very useful techniques to measure a position in real time with two GNSS receivers, either in the form of a rover and a fixed reference station. Accurate position of rovers can be achieved within 1 second. In this study, the three GCPs from Nay Pyi Taw were connected to NPT 3 and two CPs from Pyin Oo Lwin were connected to POL 5. RTK surveying was carried out for 5-minute to improve surveying accuracy. The data transformation parameter (7 Parameters of ITRF 2014-WGS 1984) was imported to the controller to obtain the output coordinates in UTM-WGS 1984 format.

3.5 Online GNSS Solution

In this study, Trimble RTX online service was selected even though there were many free online post-processing services. Another reason of choosing the Trimble RTX online service was that to match post-processing service and the instrument of GNSS brand which are used in the field. The website accepts only **T**axCut 20**02** (T02) file format. The accuracy of online GNSS service was adjusted by mean of Root Mean Square Error (RMSE) (Olatunji, R. I., 2019). The information on the requirements and processing options of the selected online GNSS post-processing service is shown in **Table 3**.

Table 3: The requirements and processing options of selected online GNSS post-processing service

Service Name	Organization/ Company	Support Constellation	Accepted Data Set	Available Options	Coordinates (Datum)	Websites
Trimble RTX	Trimble Navigation Limited	GPS, QZSS, GLONASS, Galileo, BeiDou	Min:1hr Max:1day	Dual frequency pseudo-range and carrier phase observations, static observations, PPP	ITRF 2014 with options for other datum, option of plate model	http://www.trimblertx.com/UploadForm.aspx

4. Results and Discussion

4.1 Post-processing Results of Static Observed Data Using Trimble Business Center

During post-processing of static observed data for both areas, the quality of the baseline processing for failure criteria was set up as 0.02 m + 1ppm for horizontal precision and 0.05 m + 1ppm for vertical precision. Then, the precision of confidence level was taken as 1-sigma. The two CORS coordinates in WGS 1984 format were assigned as the control points. The network adjustment passed with the degree of freedom (DoF) = 4.0 under a Reference Factor (RF) = 1.17. In GNSS post-processing, a large number of DoF offers a high confidence level (Lund, 2016). The three-dimensional precision ratio of each location was obtained over 1: 100,000. The observed horizontal and vertical values of static observation in UTM-WGS1984 format are represented in **Table 4**. Post-processing's Network adjustment report was attached as **Annex-I**.

Table 4: The observed horizontal and vertical values of static observation

GCP Name	Post-processing Results (UTM-WGS 1984)		
	Easting (m)	Northing (m)	Ellipsoidal Height (m)
GCP 1201	192287.339	2194897.530	100.894
GCP 1202	192450.076	2194933.707	97.673
GCP 1736	192276.705	2195191.303	97.476
CP 01	239078.396	2437791.523	1030.339
CP 02	239070.571	2437670.766	1031.647

4.2 RTK Surveying Results

RTK surveying was done at the same static observed locations of GCPs and CPs. The obtained coordinates in UTM-WGS1984 format of RTK surveying results are shown in **Table 5**.

Table 5: The observed horizontal and vertical values of RTK Survey

GCP Name	7 Parameters Result (UTM-WGS 1984)		
	Easting (m)	Northing (m)	Ellipsoidal Height (m)
GCP 1201	192287.339	2194897.502	100.864
GCP 1202	192450.080	2194933.677	97.665
GCP 1736	192276.703	2195191.273	97.442
CP 01	239078.383	2437791.525	1030.319
CP 02	239070.554	2437670.775	1031.607

4.3 Online GNSS Solution Results

The static observed T02 files (4 hours and 30 minutes time taken) were uploaded to the Trimble RTX website. The website sent the results by email for download. The provided data from website was based on the International GNSS Service (IGS) realization of the ITRF2014 reference frame. Therefore, the downloaded data needs to be converted into UTM-WGS1984 coordinate format by using suitable coordinate converter software. The three-dimensional positions of the online GNSS solution are listed in **Table 6**. Trimble online solution results were attached as **Annex-II** to **Annex-VI**.

Table 6: The three-dimensional positions of online GNSS solution

GCP Name	ITRF2014-GRS1980			UTM-WGS 1984		
	Latitude	Longitude	Ellipsoidal Height (m)	Easting (m)	Northing (m)	Ellipsoidal Height (m)
GCP 1201	19° 49' 33.40644"	96° 03' 45.26604"	96.958	192287.457	2194897.513	100.892
GCP 1202	19° 49' 34.67402"	96° 03' 50.83155"	93.723	192450.194	2194933.697	97.657
GCP 1736	19° 49' 42.94523"	96° 03' 44.72522"	93.551	192276.818	2195191.293	97.485
CP 01	22° 01' 31.24634"	96° 28' 20.50486"	1026.483	239078.502	2437791.499	1030.345
CP 02	22° 01' 27.31834"	96° 28' 20.30163"	1027.789	239070.671	2437670.739	1031.651

4.4 Old Coordinates of GCPs and CPs

SD constructed GCP 1201 and GCP 1202 in 2012, and GCP 1736 in 2017 at Nay Pyi Taw. On the other hand, SD laid down CP 01 and CP 02 in 2015 at Pyin Oo Lwin. All GCPs' and CPs' GNSS observations were derived from 9 primary control stations. These control stations have defined their easting, northing, elevation coordinates since 2000. The old coordinates of GCPs and CPs are shown in **Table 7**.

Table 7: The old coordinates of GCPs and CPs

GCP Name	Old Coordinates of GCPs and CPs (UTM-WGS 1984)		
	Easting (m)	Northing (m)	Ellipsoidal Height (m)
GCP1201	192287.202	2194897.535	100.823
GCP1202	192449.930	2194933.716	97.567
GCP1736	192276.583	2195191.318	97.516
CP 01	239078.438	2437791.555	1030.353
CP 02	239070.619	2437670.804	1031.664

4.5 Data Validation

4.5.1 Static Observation Results vs RTK Survey Results

By comparing the static observation results and RTK survey results, the two results are acceptable because the difference between these two observations has millimeter to centimeter accuracies that closes the receiver's performance limitations, as mentioned in Table 1. The difference between the static observation results and RTK survey results is shown in **Table 8**.

Table 8: The difference between the static observation results and RTK survey results

GCP Name	Difference in Easting (m)	Difference in Northing (m)	Difference in Ellipsoidal Height (m)
GCP1201	0.000	0.028	0.030
GCP1202	-0.016	0.030	0.008
GCP1376	0.009	0.030	0.034
CP01	0.013	-0.002	0.020
CP02	0.017	-0.009	0.040

4.5.2 Static Observation Results vs Online GNSS Solution Results

Again, the static observation results and online GNSS solution results were also compared to confirm the positions of all GCPs. The difference between these two results differed in centimeter accuracy because online GNSS processing results are globalized results and GNSS post-processing results are localized results. The difference between the static observation results and online GNSS solution results is shown in **Table 9**.

Table 9: The difference between the static observation results and online GNSS solution results

GCP Name	Difference in Easting (m)	Difference in Northing (m)	Difference in Ellipsoidal Height (m)
GCP1201	-0.118	0.017	0.002
GCP1202	-0.118	0.010	0.016
GCP Name	**Difference in Easting (m)**	**Difference in Northing (m)**	**Difference in Ellipsoidal Height (m)**
GCP1376	-0.113	0.010	-0.009
CP01	-0.106	0.024	-0.006
CP02	-0.100	0.027	-0.004

4.6 Finding the Three-Dimensional Positions Variation between Old and New Observations

It was found that the static observation is more accurate than RTK surveying and online GNSS solution. Thus, three-dimensional position variation of GCPs and CPs was determined based on static observation results. As the GNSS post-processing was done by using CORS as a control points, the GCPs' and CPs' positions variation can be determined within the 20-year period (2000-2020) because SD assigned the CORS coordinates in 2020. This study found that, the maximum shifting GCPs location at Nay Pyi Taw was 146 mm in the southeastward direction and the maximum shifting CPs location at Pyi Oo Lwin was 61 mm in the southwestward direction within 20-year period. The movement direction of the two areas was not equal. The reason was that CORS's coordinates were calculated by combining with 9 primary control stations which had been assigned since 2000 and IGS (International GNSS Service) stations. Therefore, all the locations of primary control stations had definitely moved in some directions due to the movement of tectonic plates. Consequently, any coordinates derived from primary control stations also moved in some directions. One different situation is the coordinates of IGS stations are updated coordinates and CORS coordinates are assigned coordinates. Thus, the calculation had been implemented to be harmonized with CORS's coordinates and IGS coordinates of different situations. The CORS coordinates were adjusted coordinates all observation with reference to CORS also adjusted coordinates. Thus, the movement directions cannot be equal between IGS

coordinates and CORS coordinates. The shifting positions of GCP 1201, GCP 1202, GCP 1736, CP 01 and CP 02 are displayed in **Figure 3.**

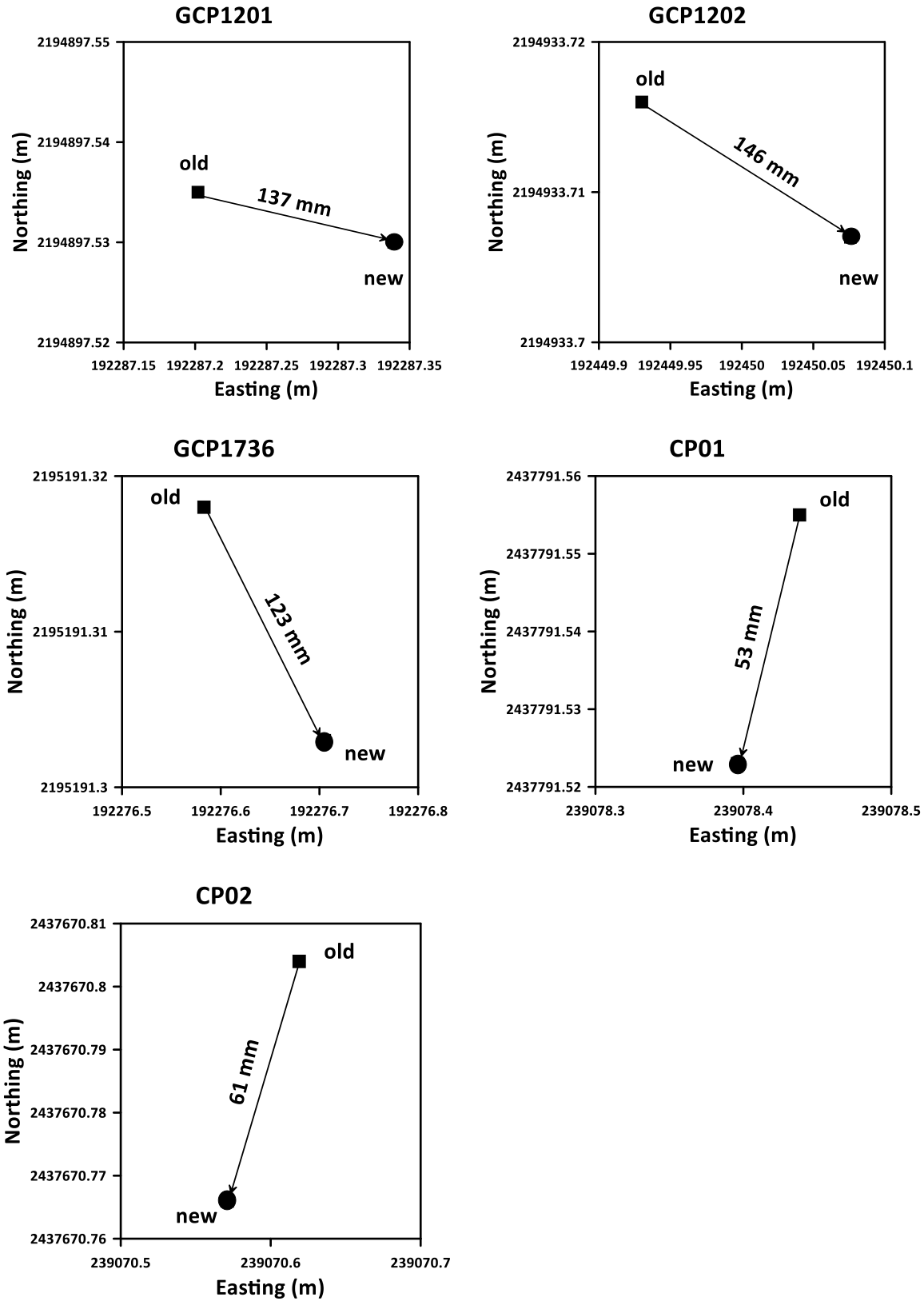


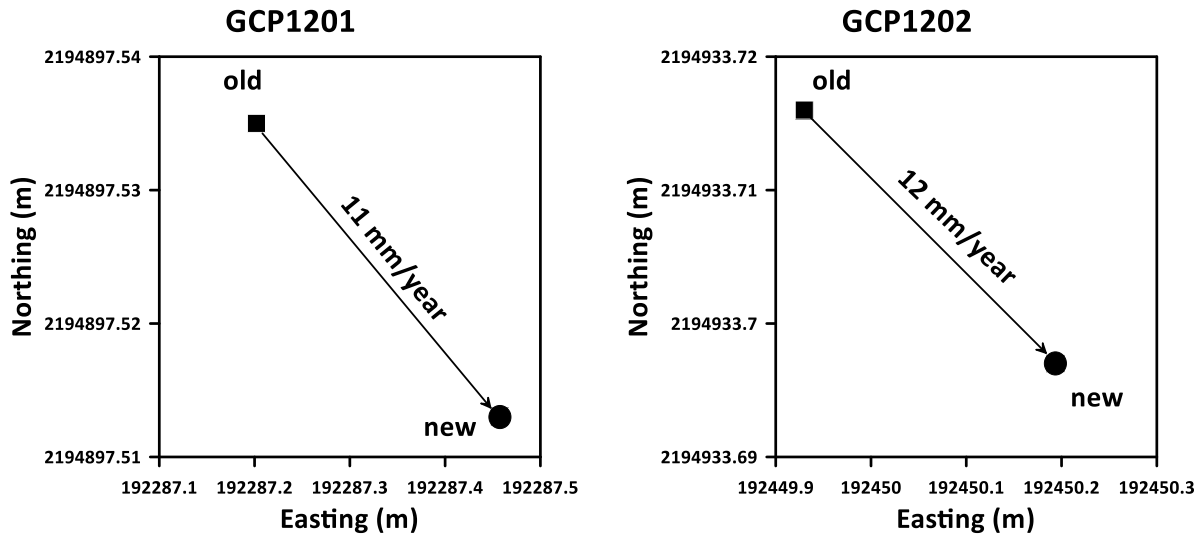
Figure 3: The shifting positions of GCPs and CPs

Based on the study, the shifting magnitude and direction can only determine based on online GNSS service results by comparing with old coordinates of GCPs and CPs. The difference between the old GCPs' and CPs' coordinates and online GNSS solution results is shown in **Table 10**.

Table 10: The difference between the old GCPs' and CPs' coordinates and online GNSS solution results

GCP Name	Difference in Easting (m)	Difference in Northing (m)	Difference in Ellipsoidal Height (m)	Horizontal Difference	Shifting magnitude (mm/year)	Shifting Direction
GCP1201	-0.255	0.022	0.069	0.255947	11	SE
GCP1202	-0.264	0.019	0.090	0.264683	12	SE
GCP1376	-0.235	0.025	-0.031	0.236326	10	SE
CP01	-0.064	0.056	-0.008	0.085041	4	SE
CP02	-0.052	0.065	-0.013	0.083241	4	SE

The results show all GCPs and CPs moved to the southeast direction. Therefore, the shifting magnitude and directions of GCPs and CPs within 23-year can be determined: all GCPs at Nay Pyi Taw have 10-12 mm/year, and all CPs at Pyin Oo Lwin have 4 mm/year. Those shifting magnitude and directions are convinced in comparing with the old research. Wang et al., (2011) observed that Myanmar is located on India-Burma-Sunda plate and the subduction of those plates emerged the Sagaing Fault. The eastern part of that fault has a moving rate of 11-18 mm/year to the southeast. They considered globalized factors to determine the movement rate. In this study, the shifting magnitude and direction of GCPs was 4-12 mm/year according to online GNSS results. Therefore, the previous study result for wide area and the present result for specific area are approximately equal, and the online results are reliable. The shifting magnitude and direction of GCPs and CPs are shown in **Figure 4.**



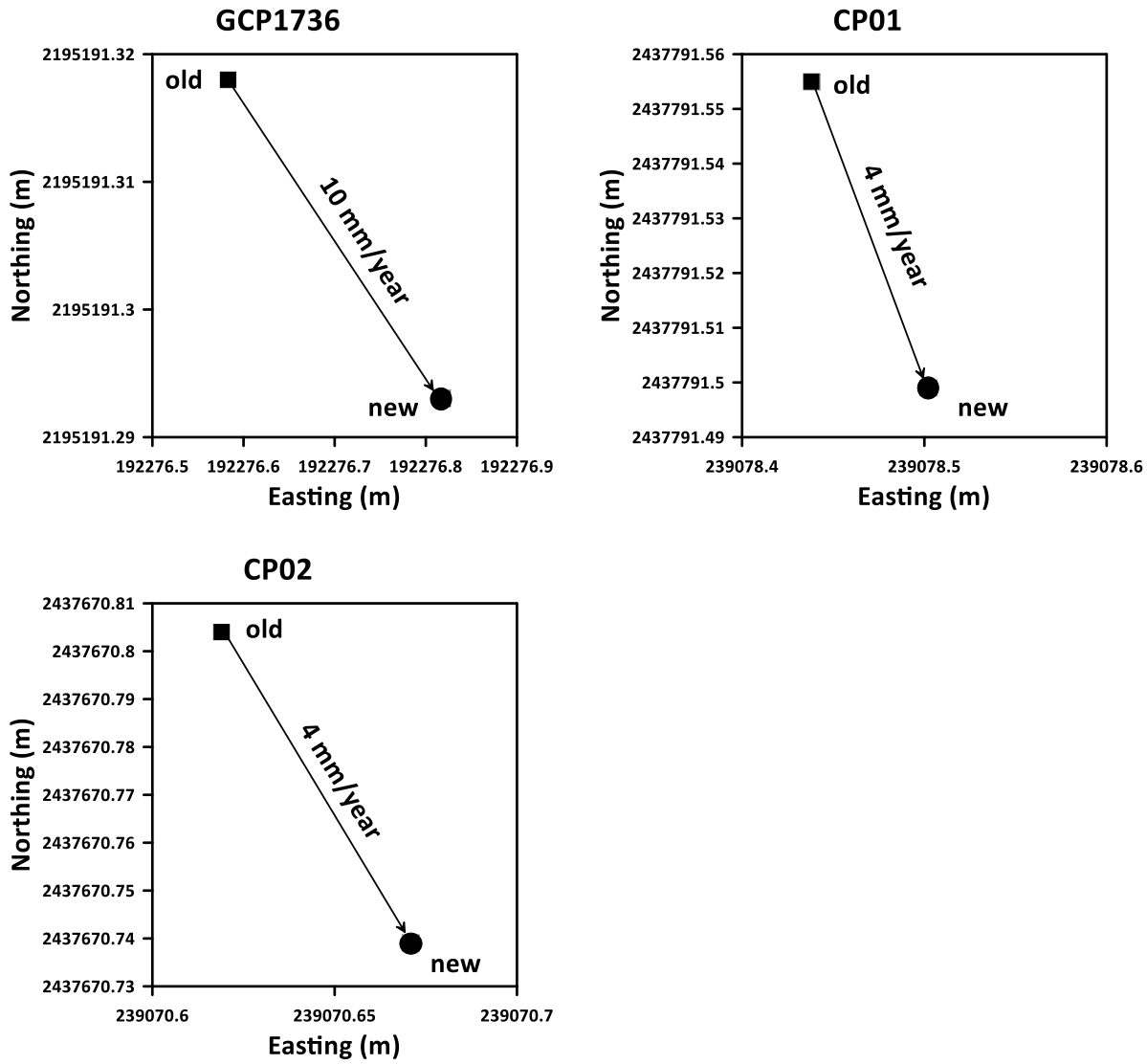


Figure 4: The shifting magnitude and direction of GCPs and CPs

5. Conclusion

Due to the tectonic plate's movement, the GCPs from Nay Pyi Taw have moved with reference to CORS within 20 years, eastward between 122 mm and 146 mm, southward between 5 mm and 15 mm and vertically between 40 mm and 106 mm, and the CPs from Pyin Oo Lwin have moved westward between 42 mm and 48 mm, southward between 32 mm and 38 mm and vertically between 14 mm and 17 mm. The shifting magnitude and direction of GCPs/CPs from Nay Pyi Taw is 10-12 mm/year (SE) and Pyin Oo Lwin is 4 mm/year (SE). Regarding this study, the old GCPs and CPs move to the southeast direction obviously. But to get more accurate and reliable results, a lot of distributed GCPs should be considered throughout the country. Moreover, SD needs to upgrade the existing national network frame at a convenient time. Even though all GCPs and CPs moved as above mentioned, the maps produced by SD is still reliable due to the 1:50000 mapping scales. It is clear that 1mm on the map represent 50000mm on the ground according to the map scale. For example, in this study, the maximum movement of GCPs on ground 146 mm has 0.003 mm on map. It is less than 1mm and it cannot affect on the maps. Therefore, maps produced by SD are confidently addicted to every map user.

6. Acknowledgement

First of all, we would like to extend our great thanks to the Ministry of Natural Resources and Environmental Conservation and Survey Department for giving us the opportunity to do this research paper.

Again, we would like to show our deepest respects to my honorable Director General U Sein Min, Deputy Director General U Ze Ya Htwe. We would like to thank to Director, U Htay Hlaing from the International Boundary and Civil Construction Survey Division and all officers from the Survey Department for their giving conceptual knowledge on my research paper. It is very useful and it can fully support our paper writing.

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7. References

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Annex-I

Project File Data		Coordinate System	
Name:	F:\Paper.vce	Name:	World wide/UTM
Size:	236 KB	Datum:	WGS 1984
Modified:	1/10/2024 4:11:06 PM (UTC:6)	Zone:	47 North
Time zone:	Myanmar Standard Time	Geoid:	
Reference number:		Vertical datum:	
Description:		Calibrated site:	
Comment 1:			
Comment 2:			
Comment 3:			

Network Adjustment Report

Adjustment Settings

Set-Up Errors
GNSS
Error in Height of Antenna: 0.003 m
Centering Error: 0.000 m
Covariance Display
Horizontal:
Propagated Linear Error [E]: U.S.
Constant Term [C]: 0.000 m
Scale on Linear Error [S]: 1.000
Three-Dimensional
Propagated Linear Error [E]: U.S.
Constant Term [C]: 0.000 m
Scale on Linear Error [S]: 1.000

Adjustment Statistics

Number of Iterations for Successful Adjustment: 2
Network Reference Factor: 1.17
Chi Square Test (95%): Passed
Precision Confidence Level: 1-sigma
Degrees of Freedom: 4

Post Processed Vector Statistics

Reference Factor: 1.17

Redundancy Number: 4.00
A Priori Scalar: 1.00

Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
NPT3	Global	Fixed	Fixed	Fixed	
POL5	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
CP01	239078.396	0.000	2437791.523	0.000	?	?	
CP02	239070.571	0.001	2437670.766	0.001	?	?	
GCP1201	192287.339	0.002	2194897.530	0.002	?	?	
GCP1202	192450.076	0.002	2194933.707	0.002	?	?	
GCP1736	192276.705	0.002	2195191.303	0.002	?	?	
NPT3	209741.025	?	2165204.329	?	?	?	LLh
POL5	239104.839	?	2437723.734	?	?	?	LLh

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
CP01	N22°01'31.23844"	E96°28'20.44003"	1030.339	0.005	
CP02	N22°01'27.31053"	E96°28'20.23701"	1031.647	0.007	
GCP1201	N19°49'33.40263"	E96°03'45.20704"	100.894	0.017	
GCP1202	N19°49'34.67000"	E96°03'50.77253"	97.673	0.016	
GCP1736	N19°49'42.94123"	E96°03'44.66642"	97.476	0.017	
NPT3	N19°33'38.11194"	E96°14'01.08074"	60.109	?	LLh
POL5	N22°01'29.05002"	E96°28'21.40065"	1039.205	?	LLh

Adjusted ECEF Coordinates

Point ID	X (Meter)	X Error (Meter)	Y (Meter)	Y Error (Meter)	Z (Meter)	Z Error (Meter)	3D Error (Meter)	Constraint
CP01	-666916.761	0.001	5878679.824	0.005	2377401.063	0.002	0.005	
CP02	-666916.220	0.001	5878726.711	0.007	2377289.535	0.003	0.007	
GCP1201	-633948.924	0.003	5968923.076	0.016	2149614.627	0.006	0.017	
GCP1202	-634108.262	0.003	5968889.811	0.015	2149650.197	0.006	0.016	
GCP1736	-633922.433	0.003	5968822.606	0.016	2149889.401	0.006	0.018	
NPT3	-652839.029	?	5976806.047	?	2121943.397	?	?	LLh
POL5	-666947.912	?	5878709.971	?	2377341.977	?	?	LLh

Error Ellipse Components

Point ID	Semi-major axis (Meter)	Semi-minor axis (Meter)	Azimuth
CP01	0.000	0.000	103°
CP02	0.001	0.001	105°
GCP1201	0.003	0.002	130°
GCP1202	0.002	0.002	130°
GCP1736	0.003	0.002	130°

Adjusted GNSS Observations

Transformation Parameters

Azimuth Rotation: 0.102 sec **(1-sigma)** 0.004 sec

Scale Factor: 1.00000012 **(1-sigma)** 0.00000003

Observation ID		Observation	A-posteriori Error	Residual	Standardized Residual
POL5 --> NPT3 (PV17)	**Az.**	185°15'14"	0.004 sec	0.018 sec	1.658
	ΔHt.	-979.097 m	0.000 m	0.062 m	1.229
	Ellip Dist.	273948.933 m	0.008 m	0.001 m	0.085
CP01 --> CP02 (PV32)	**Az.**	182°45'32"	0.812 sec	-0.037 sec	-1.569
	ΔHt.	1.308 m	0.005 m	0.000 m	0.501
	Ellip Dist.	120.957 m	0.000 m	0.000 m	0.385
GCP1201 --> GCP1736 (PV23)	**Az.**	356°55'48"	0.587 sec	-0.046 sec	-1.555
	ΔHt.	-3.418 m	0.005 m	0.000 m	-0.543
	Ellip Dist.	293.739 m	0.001 m	0.000 m	0.664
GCP1202 --> GCP1201 (PV24)	**Az.**	256°28'13"	0.748 sec	0.031 sec	0.964
	ΔHt.	3.221 m	0.005 m	0.000 m	-0.526
	Ellip Dist.	166.581 m	0.001 m	0.000 m	1.529
POL5 --> CP01 (PV30)	**Az.**	337°44'30"	1.076 sec	0.035 sec	1.424
	ΔHt.	-8.867 m	0.005 m	0.000 m	0.495
	Ellip Dist.	72.732 m	0.000 m	0.000 m	-1.055
NPT3 --> GCP1202 (PV19)	**Az.**	328°53'03"	0.014 sec	-0.003 sec	-1.329
	ΔHt.	37.564 m	0.016 m	-0.003 m	-0.551
	Ellip Dist.	34367.820 m	0.002 m	0.000 m	1.120
GCP1736 --> CP02 (PV34)	**Az.**	9°52'31"	0.004 sec	-0.002 sec	-0.775
	ΔHt.	934.170 m	0.018 m	-0.014 m	-0.283
	Ellip Dist.	246804.853 m	0.008 m	0.002 m	0.211

Covariance Terms

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
CP01	CP02	Az.	182°45'32"	0.810 sec	1 : 268239	1 : 266219
		ΔHt.	1.308 m	0.005 m		
		ΔElev.	?	?		
		Ellip Dist.	120.957 m	0.000 m		
GCP1202	GCP1201	Az.	256°28'13"	0.748 sec	1 : 258697	1 : 257228
		ΔHt.	3.221 m	0.005 m		
		ΔElev.	?	?		
		Ellip Dist.	166.581 m	0.001 m		
GCP1736	CP02	Az.	9°52'31"	0.002 sec	1 : 101042459	1 : 100587768
		ΔHt.	934.171 m	0.018 m		
		ΔElev.	?	?		
		Ellip Dist.	246804.884 m	0.002 m		
GCP1736	GCP1201	Az.	176°55'47"	0.586 sec	1 : 393897	1 : 389883
		ΔHt.	3.418 m	0.005 m		
		ΔElev.	?	?		
		Ellip Dist.	293.739 m	0.001 m		
NPT3	GCP1202	Az.	328°53'03"	0.013 sec	1 : 14342313	1 : 14320334
		ΔHt.	37.564 m	0.016 m		
		ΔElev.	?	?		
		Ellip Dist.	34367.824 m	0.002 m		
NPT3	POL5	Az.	5°10'08"	0.000 sec	1 : 0	1 : 0
		ΔHt.	979.096 m	0.000 m		
		ΔElev.	?	?		
		Ellip Dist.	273948.967 m	0.000 m		
POL5	CP01	Az.	337°44'30"	1.077 sec	1 : 201933	1 : 102616
		ΔHt.	-8.867 m	0.005 m		
		ΔElev.	?	?		
		Ellip Dist.	72.732 m	0.000 m		

Date: 1/11/2024 5:54:19 PM	Project: F:\Paper.vce	Trimble Business Center

Annex-II

Post-Processing Service Based on RTX Technology

TrimbleRTX.com

Contributor: naungnaunghtwesurvey@gmail.com
Reference Name: 01543630.T02
Upload Date: 01/04/2024 15:16:10 UTC
Report Time Frame:
  Start Time: 12/29/2023 03:49:57 UTC
  End Time: 12/29/2023 08:37:47 UTC
Observation File Type(s): T02
Observation File(s): 01543630.T02
Antenna:
  Name: TRMR8S NONE
  Height: 1.592 m
  Reference: Bottom of antenna mount Receiver
  Name: TRIMBLE R8S
Coordinate Systems: ITRF2014
Tectonic Plate: India (Auto-detected)
Tectonic Plate Model: MORVEL56
Processing Interval: 10 s

Statistics

# Total Obs	# Usable Obs	# Used Obs	Percent
17271	1727	1727	100

Used Satellites

# Total Satellites:	39
GPS:	G02 G03 G04 G07 G08 G09 G10 G14 G16 G21 G26 G27 G28 G30 G31 G32
GLONASS:	R02 R03 R04 R05 R13 R14 R15 R16 R17 R18 R24
Galileo:	E04 E05 E09 E10 E11 E12 E19 E21 E24 E25 E31 E33

Processing Results

ITRF2014 at Epoch 2010.0		
Coordinate	**Value**	**σ**
X	-633949.615 m	0.004 m
Y	5968919.421 m	0.011 m
Z	2149612.900 m	0.005 m
Latitude	19° 49' 33.38910" N	0.003 m
Longitude	96° 03' 45.24391" E	0.004 m
El. Height	96.957 m	0.011 m

ITRF2014 at Epoch 2023.99		
Coordinate	**Value**	**σ**
X	-633950.236 m	0.004 m
Y	5968919.174 m	0.011 m
Z	2149613.402 m	0.005 m
Latitude	19° 49' 33.40644" N	0.003 m
Longitude	96° 03' 45.26604" E	0.004 m
El. Height	96.958 m	0.011 m

Report Information

Trimble RTX Solution ID: 29589857
Solution Type: Static
Software Version: 8.5.1.20196
Creation Date: 01/04/2024 15:16:53 UTC

Disclaimer

Trimble Navigation Limited does not guarantee availability, reliability, and performance of the current RTX Post-Processing service and accepts no legal liability arising from, or connected to, the use of information on this document or use of this service.

Annex-III

Post-Processing Service Based on RTX Technology

TrimbleRTX.com

Contributor: naungnaunghtwesurvey@gmail.com
Reference Name: 00583630.T02
Upload Date: 01/04/2024 15:14:14 UTC
Report Time Frame:
  Start Time: 12/29/2023 03:52:42 UTC
  End Time: 12/29/2023 08:40:31 UTC
Observation File Type(s): T02
Observation File(s): 00583630.T02
Antenna:
  Name: TRMR8S NONE
  Height: 1.411 m
  Reference: Bottom of antenna mount
  Receiver Name: TRIMBLE R8S
Coordinate Systems: ITRF2014
Tectonic Plate: India (Auto-detected)
Tectonic Plate Model: MORVEL56
Processing Interval: 10 s

Statistics

# Total Obs	# Usable Obs	# Used Obs	Percent
17270	1727	1727	100

Used Satellites

# Total Satellites:	40
GPS:	G02 G03 G04 G07 G08 G09 G10 G14 G16 G17 G21 G26 G27 G28 G30 G31 G32
GLONASS:	R02 R03 R04 R05 R13 R14 R15 R16 R17 R18 R19 R24
Galileo:	E04 E05 E09 E10 E11 E19 E21 E24 E25 E31 E33

Processing Results

ITRF2014 at Epoch 2010.0		
Coordinate	**Value**	**σ**
X	-634108.952 m	0.004 m
Y	5968886.140 m	0.009 m
Z	2149648.472 m	0.004 m
Latitude	19° 49' 34.65669" N	0.003 m
Longitude	96° 03' 50.80943" E	0.004 m
El. Height	93.722 m	0.010 m

ITRF2014 at Epoch 2023.99		
Coordinate	**Value**	**σ**
X	-634109.573 m	0.004 m
Y	5968885.893 m	0.009 m
Z	2149648.974 m	0.004 m
Latitude	19° 49' 34.67402" N	0.003 m
Longitude	96° 03' 50.83155" E	0.004 m
El. Height	93.723 m	0.010 m

Report Information

Trimble RTX Solution ID: 29589842
Solution Type: Static
Software Version: 8.5.1.20196
Creation Date: 01/04/2024 15:14:55 UTC

Annex-IV

Post-Processing Service Based on RTX Technology

TrimbleRTX.com

Contributor: naungnaunghtwesurvey@gmail.com
Reference Name: 01183631.T02
Upload Date: 01/04/2024 15:15:11 UTC
Report Time Frame:
  Start Time: 12/29/2023 03:56:05 UTC
  End Time: 12/29/2023 08:31:18 UTC
Observation File Type(s): T02
Observation File(s): 01183631.T02 Antenna:
  Name: TRMR8S NONE
  Height: 1.476 m
  Reference: Bottom of antenna mount
  Receiver Name: TRIMBLE R8S
Coordinate Systems: ITRF2014
Tectonic Plate: India (Auto-detected)
Tectonic Plate Model: MORVEL56
Processing Interval: 10 s

Statistics

# Total Obs	# Usable Obs	# Used Obs	Percent
16514	1651	1651	100

Used Satellites

# Total Satellites:	39
GPS:	G02 G03 G04 G07 G08 G09 G10 G14 G16 G21 G26 G27 G28 G30 G31 G32
GLONASS:	R02 R03 R04 R05 R13 R14 R15 R16 R17 R18 R24
Galileo:	E04 E05 E09 E10 E11 E12 E19 E21 E24 E25 E31 E33

Processing Results

ITRF2014 at Epoch 2010.0		
Coordinate	**Value**	**σ**
X	-633923.118 m	0.005 m
Y	5968818.959 m	0.010 m
Z	2149887.684 m	0.005 m
Latitude	19° 49' 42.92790" N	0.003 m
Longitude	96° 03' 44.70310" E	0.004 m
El. Height	93.550 m	0.011 m

ITRF2014 at Epoch 2023.99		
Coordinate	**Value**	**σ**
X	-633923.740 m	0.005 m
Y	5968818.712 m	0.010 m
Z	2149888.186 m	0.005 m
Latitude	19° 49' 42.94523" N	0.003 m
Longitude	96° 03' 44.72522" E	0.004 m
El. Height	93.551 m	0.011 m

Report Information

Trimble RTX Solution ID: 29589849
Solution Type: Static
Software Version: 8.5.1.20196
Creation Date: 01/04/2024 15:15:52 UTC

Annex-V

Post-Processing Service Based on RTX Technology

TrimbleRTX.com

Contributor: naungnaunghtwesurvey@gmail.com
Reference Name: 04103632.T02
Upload Date: 01/04/2024 15:17:11 UTC
Report Time Frame:
  Start Time: 12/29/2023 04:00:36 UTC
  End Time: 12/29/2023 08:28:12 UTC
Observation File Type(s): T02
Observation File(s): 04103632.T02
Antenna:
  Name: TRMR8S NONE
  Height: 1.727 m
  Reference: Bottom of antenna mount
  Receiver Name: TRIMBLE R8S
Coordinate Systems: ITRF2014
Tectonic Plate: Eurasia (Auto-detected)
Tectonic Plate Model: MORVEL56
Processing Interval: 10 s

Statistics

# Total Obs	# Usable Obs	# Used Obs	Percent
16057	1605	1601	99

Used Satellites

# Total Satellites:	30
GPS:	G02 G03 G04 G07 G08 G09 G16 G21 G26 G27 G28 G31 G32
GLONASS:	R02 R03 R04 R05 R14 R15 R16 R17 R18 R24
Galileo:	E04 E05 E09 E24 E25 E31 E33

Processing Results

ITRF2014 at Epoch 2010.0		
Coordinate	**Value**	**σ**
X	-666917.873 m	0.005 m
Y	5878675.975 m	0.013 m
Z	2377399.924 m	0.006 m
Latitude	22° 01' 31.24923" N	0.003 m
Longitude	96° 28' 20.49367" E	0.004 m
El. Height	1026.483 m	0.014 m

ITRF2014 at Epoch 2023.99		
Coordinate	**Value**	**σ**
X	-666918.196 m	0.005 m
Y	5878675.972 m	0.013 m
Z	2377399.842 m	0.006 m
Latitude	22° 01' 31.24634" N	0.003 m
Longitude	96° 28' 20.50486" E	0.004 m
El. Height	1026.483 m	0.014 m

Report Information

Trimble RTX Solution ID: 29589866
Solution Type: Static
Software Version: 8.5.1.20196
Creation Date: 01/04/2024 15:17:46 UTC

Annex-VI

Post-Processing Service Based on RTX Technology

TrimbleRTX.com

Contributor: naungnaunghtwesurvey@gmail.com
Reference Name: 04183630.T02
Upload Date: 01/04/2024 15:18:03 UTC
Report Time Frame:
  Start Time: 12/29/2023 04:04:51 UTC
  End Time: 12/29/2023 08:28:31 UTC
Observation File Type(s): T02
Observation File(s): 04183630.T02
Antenna:
  Name: TRMR8S NONE
  Height: 1.809 m
  Reference: Bottom of antenna mount
  Receiver Name: TRIMBLE R8S
Coordinate Systems: ITRF2014
Tectonic Plate: Eurasia (Auto-detected)
Tectonic Plate Model: MORVEL56
Processing Interval: 10 s

Statistics

# Total Obs	# Usable Obs	# Used Obs	Percent
15821	1582	1582	100

Used Satellites

# Total Satellites:	29
GPS:	G02 G03 G04 G07 G08 G09 G16 G21 G26 G27 G28 G31 G32
GLONASS:	R02 R03 R04 R05 R14 R15 R17 R18 R24
Galileo:	E04 E05 E09 E19 E24 E31 E33

Processing Results

ITRF2014 at Epoch 2010.0		
Coordinate	**Value**	**σ**
X	-666917.326 m	0.005 m
Y	5878722.862 m	0.015 m
Z	2377288.394 m	0.007 m
Latitude	22° 01' 27.32123" N	0.004 m
Longitude	96° 28' 20.29044" E	0.005 m
El. Height	1027.789 m	0.016 m

ITRF2014 at Epoch 2023.99		
Coordinate	**Value**	**σ**
X	-666917.649 m	0.005 m
Y	5878722.859 m	0.015 m
Z	2377288.311 m	0.007 m
Latitude	22° 01' 27.31834" N	0.004 m
Longitude	96° 28' 20.30163" E	0.005 m
El. Height	1027.789 m	0.016 m

Report Information

Trimble RTX Solution ID: 29589871
Solution Type: Static
Software Version: 8.5.1.20196
Creation Date: 01/04/2024 15:18:37 UTC