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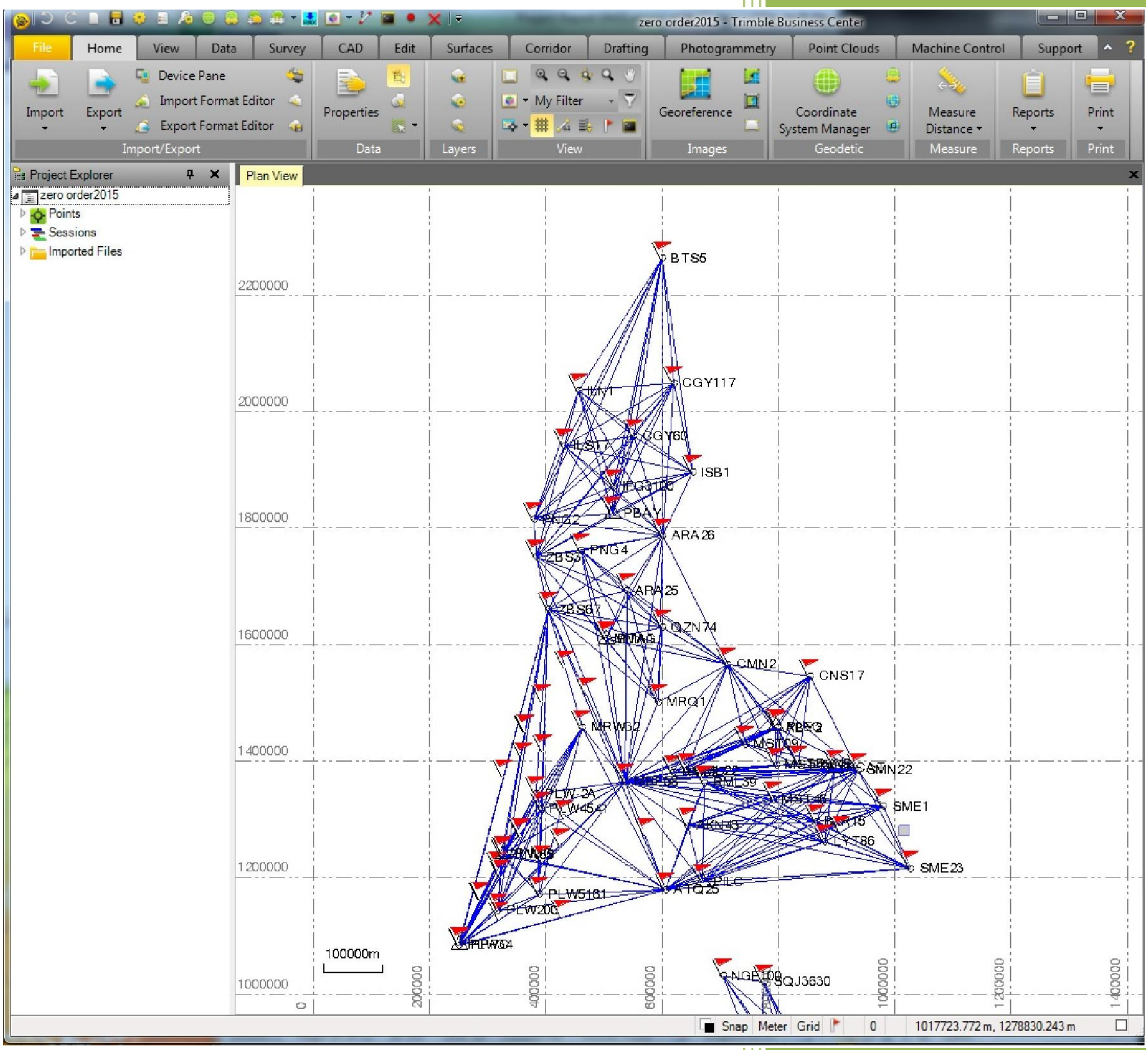
Identifying the Survey Error Indicators in GNSS Data Processing



Geodesy Division

Mapping and Geodesy Branch - NAMRIA

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Identifying the Survey Error Indicators in GNSS Data Processing

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ABSTRACT

This article discusses the various manifestations of survey errors in GNSS data processing using Trimble Business Center (TBC) software. Six cases of possible survey errors and its indicators in data processing has been presented. Processing GNSS data without entering the precise coordinates as well as entering wrong coordinates of the reference station was also expounded. Similarly, processing results using Broadcast and Precise satellite ephemerides were compared. Lastly, processing results using the new Precise Point Positioning (PPP) was compared with the relative positioning technique. Solution/s for the indicated survey and processing errors were offered as remedy during processing of GNSS data.

INTRODUCTION

GNSS surveying is relatively straightforward, a surveyor will just set-up a GNSS receiver on a point, wait for the specified time of observation then pack up and leave afterwards. To ensure good data, this convenience have to be combined with proper survey preparation and procedures, such as clear view of the sky, correct station name, correct antenna height, properly centered and plumbed GNSS antenna, and sufficient amount of data gathered.

Amateur GNSS observers are mostly oblivious of the requirements of a good GNSS Survey. A careless observer may have forgotten to indicate the correct antenna height or station name or even occupied a different station or reference point. A wrong station may have been entered while converting to RINEX and so on. The data processor in the office can look out for these signs during processing and adjustment of GNSS data.

The aim of this paper is to investigate and identify the different manifestation of survey errors in GNSS data processing and adjustment using Trimble Business Center Software (TBC). To capture these survey errors, some scenarios were intentionally set up during the study. Solution/s to these errors will also be offered as a remedy during data processing.

It is assumed that the reader is familiar with the TBC software in order to fully appreciate and comprehend the results of this study.

The possible error/s in conducting a GNSS survey is categorized into cases as shown below:

1. **Survey Procedure Case:**

CASE I:	Wrong point occupied
CASE II:	The bubble of the antenna not centered
CASE III:	Wrong antenna height
CASE IV:	Wrong input of reference station name
CASE V:	Obstructed stations
CASE VI:	Receivers have different log rates

2. **Data and Processing Procedure Case:**

CASE VII:	Wrong coordinates entered as reference
CASE VIII:	Processing data before entering reference coordinates
CASE IX:	IGS Final Orbits vs. Daily Broadcast Ephemeris
CASE X:	Precise Point Positioning (PPP) vs. Relative Positioning -use IGS final orbits ephemeris in relative positioning

The objectives of the study are:

1. To identify survey error indicators in GNSS Data Processing.
2. To determine the solutions for these survey errors.
3. To compare the results of processing using precise and broadcast ephemeris
4. To compare the results of processing using PPP and relative positioning

MATERIALS AND METHODS

Test Network

A network of ten (10) points inside the compound of NAMRIA was selected as testing points for the study, these points are also used as calibration points for the ten receivers utilized for the projects of the division (Figure 1). Two of the selected points are located in areas with obstructions (LM2 and PT3), two other points are existing NAMRIA GCP (MMA3 and MMA4), two Benchmarks (LM2 and BM2), and others are installed around the office compound. The longest baseline of the test network is about 135 meters. This network will be used in all cases of the study.

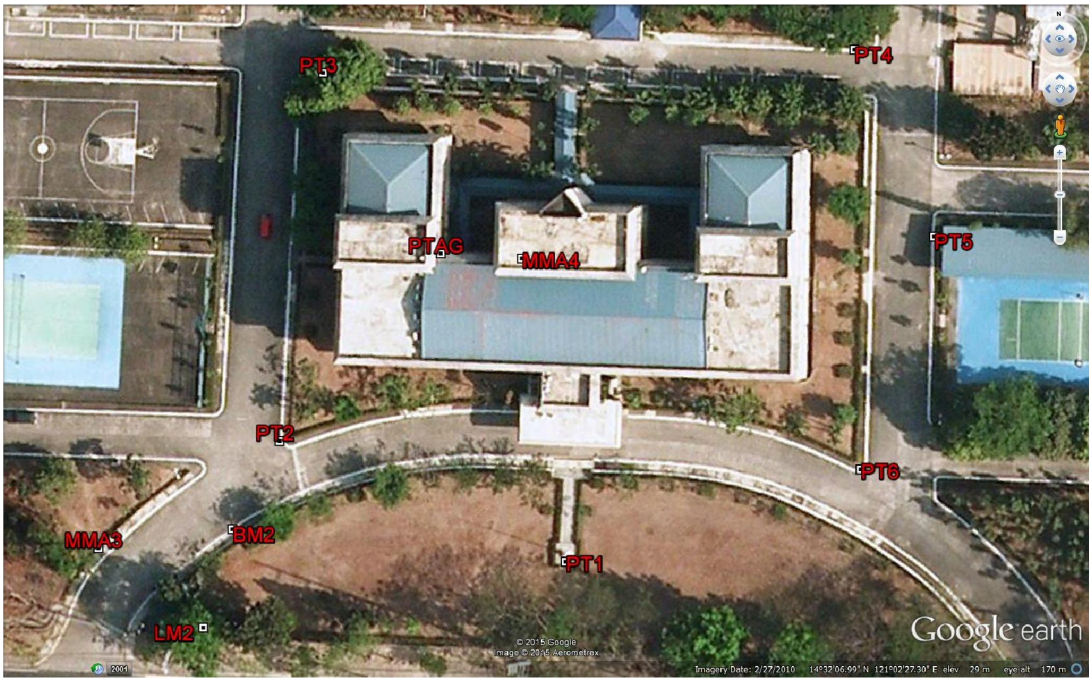

Figure 1. Testing points used for the study. Some points are intentionally installed in obstructed area.

Instruments and Personnel

Trimble R10 dual frequency GNSS receivers were used for the study and Trimble Business Center (TBC) software is used in the processing and adjustment of the GNSS data. The test observation for each case was conducted on January 5-12 and September 8, 2015 by the Geodesy Division personnel listed below:

1. Aila Leana Sampana - Processor
2. Ferdinand Fernandez - GNSS Observer
3. Elias Calucag, Jr. - GNSS Observer
4. Dexter Alamar - GNSS Observer
5. Quenie Belarmino - GNSS Observer
6. Vanessa Alcala - GNSS Observer
7. Christian Samin - GNSS Observer
8. Joel Panes, Jr. - GNSS Observer
9. Gerick Aquino - GNSS Observer
10. Aries Zafra - GNSS Observer
11. Melchor Degollado, Jr. - GNSS Observer
12. Arnold Santos - GNSS Observer

Establishment of the Test Network

The 10 testing points were observed simultaneously (with correct settings and procedures) for about an hour to establish the coordinates of the stations, using PTAG (in Local WGS84) as reference. These coordinates will then be compared to the different study cases. Table 1 lists the adjusted coordinates (in WGS-UTM Grid) of the test points with all processing solutions fixed (no floats).

Station ID	TestNetwork (Daily Broadcast)in Local WGS		
	Easting (m)	Northing (m)	Ell. Hts (m)
BM2	288851.758	1607806.414	71.499
LM2	288846.996	1607792.112	71.817
MMA03	288831.414	1607804.300	71.509
MMA04	288896.495	1607844.936	86.298
PT1	288901.297	1607799.910	72.513
PT2	288859.200	1607819.175	71.201
PT3	288867.431	1607874.190	68.064
PT4	288947.782	1607874.286	69.387
PT5	288958.215	1607845.739	70.570
PT6	288945.511	1607811.823	72.244
PTAG	288884.325	1607846.163	88.057

Table 1. Established coordinates with 1-hr observations of the test network in N, E, and ellipsoidal height.

RESULTS AND DISCUSSION

The different cases were grouped into two categories, the Survey Procedure cases and the Data and Processing Procedure cases.

1. Survey Procedure cases:

***CASE I**: **Wrong Point Occupied**.* We have done four tests for this case; one test involves two unknown points eccentrically occupied and the other three tests involve occupying the wrong reference stations.

Test A: Two unknown points incorrectly occupied in **1 of 2 sessions**.
Field procedures: PTAG as reference, 1-hr observation, for 2 sessions.
Session 1: all receivers occupied the correct stations.
Session 2: two receivers set up at approximately 5m away from the correct point.

Error Indicators in Processing:

1. FLOAT solutions in processing are those baselines connected to the wrong occupied points; horizontal and vertical precision is about 0.264 m.
2. After the first adjustment, the scalar is too high, i.e. 712.89 (normal is <10).
3. The error ellipse components of all stations is from 0.272 m up to 1.074 m and the control coordinate comparisons of the reference PTAG is more than normal, i.e. ΔE -0.011, ΔN -0.032, ΔHt 0.115 (normal is <0.01).
4. Most of the baselines that became outliers in the adjustment are connected to the incorrectly occupied points. Also, these outliers are from the second session of

observation where in the *wrong occupation* was introduced (two receivers were set up 5m away from their original locations).

5. The range of point coordinate differences compared to Table 1 after removing all outliers are:

±0.056 - 1.589cm	(ΔEasting)
±0.006 - 1.353cm	(ΔNorthing)
±0.098 - 2.929cm	(ΔEllipsoidal Heights)

   The incorrectly occupied stations somehow influence the coordinates of the other points.

Test B: Two reference stations incorrectly occupied at **1 session only**.
Field procedures: PT1 and MMA4 as references, 1-hr observation, for 1 session only. Receiver at the reference stations were set-up approximately 5m away from their correct locations.

Error Indicators in Processing:

1. After a free adjustment, *control coordinate comparisons* show apparent movement of the reference stations.

PT1	ΔE = 0.416m	ΔN = -0.253m	ΔHt = 0.020m
MMA4	ΔE = -4.157m	ΔN = 2.533m	ΔHt = -0.228m

2. Fixing both references yielded more outliers which are those baselines connected to the reference. The error ellipse components of all stations range from 0.074m to 0.275m; and the scalar is high, i.e. 118.05.
3. After removing all the outliers and adjusting the network, the range of coordinate differences compared to Table 1 are:

±473.641 - 477.032cm	(ΔEasting)
±222.915 – 225.741cm	(ΔNorthing)
±0.153 – 3.815cm	(ΔEllipsoidal Heights)

   This indicates apparent movement of the stations, which is not true. The inaccurate occupation of the reference controls affects the coordinates of the new points. Examining the *control coordinate comparisons* is the only way of recognizing this survey error.

Test C: Two reference stations incorrectly occupied in **1 of 2 sessions**.
Field procedures: PT1 and MMA4 as references, 1-hr observation, for 2 sessions.
Session 1: all receivers stationed to the correct stations.
Session 2: receiver at reference points were set-up approximately 5m away from their correct locations

Error Indicators in Processing:

1. FLOAT solutions in processing are those baselines connected to the wrong occupied points.
2. After the free adjustment, the scalar value is high, i.e. 716.81.
3. The error ellipse components of all stations and the control coordinate comparisons of the references are large.

PT1	ΔE = 1.079m	ΔN = 1.283m	ΔHt = -1.804m
MMA4	ΔE = -0.595m	ΔN = 4.411m	ΔHt = 0.052m

4. Most of the baselines that became outliers in adjustment are connected to the incorrectly occupied stations. Also, these outliers are from the second session of observation where in the receivers were moved from their original locations.
5. The range of coordinate differences compared to Table 1 are:

±0.170 – 3.112cm	(ΔEasting)
±0.256 – 2.558cm	(ΔNorthing)
±0.004 – 2.481cm	(ΔEllipsoidal Heights)

The automatic merging of points while importing the 2 sessions introduced an error in processing which gives an apparent movement of the two reference controls and the new points. The second session data of this survey was made useless due to occupation error.

Test D: One reference station incorrectly occupied in **2 sessions**.
Field procedures: PTAG, MMA3, and MMA4 as references, 1-hr observation, for 2 sessions. Session 1 and 2: receiver at reference point MMA4 was set-up approximately 20m away from the correct location.

Error Indicators in Processing:
1. FLOAT solutions in processing are mostly those baselines connected to the wrong occupied reference (MMA4).
2. After the free adjustment, the scalar value is small, i.e. 4.85.
3. The error ellipse components of all stations are small; ranging from 0.003 – 0.014 in semi-major axis and 0.003 – 0.009 in semi-minor axis.
4. There are no outliers but the *control coordinate comparisons* of the references are large.

MMA3	ΔE = 9.218m	ΔN = 6.961m	ΔHt = -7.323m
MMA4	ΔE = -11.073m	ΔN = -8.353m	ΔHt = 8.734m
PTAG	ΔE = 9.233m	ΔN = 6.960m	ΔHt = -7.287m

The comparisons show that the two other references (PTAG & MMA3) are affected by the incorrectly occupied point, but it is noticeable that the erroneously occupied reference have the largest comparison and the other two have ***similar coordinate differences***. Fixing the references (MMA3 and PTAG) with the smallest and similar coordinate comparisons generated no outliers, small error ellipse components, and with the following control coordinate comparisons on MMA4:

MMA4	ΔE = -20.310m	ΔN = -15.313m	ΔHt = 16.024m

Trying to fix the third reference MMA4 will generate an error message: "*Network adjustment could not be successfully completed. The inverse of the normal equation matrix could not be computed. There may be an error in your data*". MMA4 should never be fixed in this case because it has been incorrectly occupied.

Recommended Solutions:

The possible solution that can be done for the *wrong point occupation error* is to review the GNSS loop closure results. The GNSS loop closure results show the number of loops observed and the status of each loop, i.e. failed or passed. Review the failed loop results to determine any bad vectors and points. In the summary of the results, the worst loop with the highest PPM is shown together with its horizontal, vertical, and 3D accuracy. From this WORST loop, explode each point and look at all the observations connected to it. Exploding the points will separate the points occupied for each session. These points should be given a different name to distinguish it from the correct control. The incorrectly occupied stations may be deleted (or renamed) from the network to prevent further confusion. In cases where the station names are interchanged during the survey or downloading, exploding the points will separate the data and relocate the points to its "right" position. The relocated points must be properly *renamed and merged* to its duplicate.

When reference station/s are incorrectly occupied, analyzing the control coordinate comparisons will detect the point occupation error. Reference Controls with large (but similar) coordinate comparisons indicate that they are consistent therefore correctly occupied. The reference/s with *different coordinate comparison value* among the rest is/are suspect as erroneously occupied. Remove the *Office Entered Coordinates* of this reference/s and re-adjust the network. Check the coordinate comparisons and look out for large values; if there are none, then all remaining references are correctly occupied.

To check the consistency of the network adjustment, plot the network to Google Earth and check their locations. If the points are consistent with Google Earth, then you are confident of your adjustment.

It is always prudent to have 2 sessions and as many references (more than one) in all GNSS surveys. Using only one (incorrectly occupied) reference point will shift the network of points to the amount and direction of the occupation error.

CASE II: Centering Error

Field procedures: PTAG as reference, 1-hr observation for **2 sessions**.
Session 1: all receivers with bubble centered.
Session 2: two stations with bubble not centered.

Error Indicators in Processing:

1. No visible indicator in processing for the centering error.
2. The range of coordinate differences compared to Table 1 are:

   ±0.022 – 1.763cm (ΔEasting)
   ±0.038 – 4.283cm (ΔNorthing)
   ±0.001 – 2.110cm (ΔEllipsoidal Heights)
   Error in centering slightly degrades the accuracy of the coordinates.

CASE III: Antenna Height Error

Field procedures: PTAG as reference, 1-hr observation, for **2 sessions**.
Session 1: all receivers with correct antenna heights.
Session 2: two stations with wrong antenna heights (PT6 and MMA4).

Error Indicators in Processing:
There are outliers in the network adjustment. They are the ΔHt component of the baselines connected to points 6 and MMA4 in the second session where the surveyor input the wrong antenna heights. The points with wrong antenna heights became outliers in the adjustment and is rendered useless.

Recommended Solution:
When most outliers during adjustment are the ΔHt component of the baselines, take note of the stations connected to those baselines and compare the imported antenna heights to the GNSS Field Sheet of each observed station. Review and modify the antenna heights in the *occupation spreadsheet* (TBC) then reprocess the baselines and readjust.

CASE IV: Reference Naming Error. Two tests were conducted for this case. Test A involves 2 sessions; one session with their correct station names, the other with the interchanged station name of the references. Test B involves 1 session only with the interchanged reference name.

Test A:
Field procedures: PT1 and MMA4 as references, 1-hr observation, for **2 sessions**.
Session 1: all station with correct names.
Session 2: wrong station names entered for the references.

Error Indicators in Processing:

1. During data importing of the second session, a merge window appeared indicating the horizontal and vertical distances of the interchanged points with respect to its plotted position from the first session.

PT1	H. Dist. = 44.597 m	V. Dist. = 17.956 m
MMA4	H. Dist. = 45.839 m	V. Dist. = 7.778 m

2. Merging the first and second session data resulted into 17.273% of FLOAT solutions baselines after processing.
3. All FLOAT solutions are those baselines connected to the reference points.
4. In the free network adjustment, the scalar is 10.11 and the *control coordinate comparisons* show almost the same differences for both reference:

PT1	ΔE = 1.417	ΔN = -2.665	ΔHt = 0.831
MMA4	ΔE = 1.417	ΔN = -2.665	ΔHt = 0.830

5. Fixing all the references yielded small coordinate differences compared to Table 1 (all outliers removed):

±0.007 – 0.955cm	(ΔEasting)
±0.004 – 0.801cm	(ΔNorthing)
±0.000 – 1.313cm	(ΔEllipsoidal Heights)

   The reference coordinates appear to have moved, showing large coordinate differences. The good observations of the incorrectly named stations has become outliers and are made useless.

Test B:
Field procedures: PT1 and MMA4 as references. **One session** only of 1-hr observation with interchanged station names of references.

Error Indicators in Processing:
1. Almost all of the baselines have FLOAT solutions (92.727%).
2. Most of the baselines FAILED the horizontal and vertical precision tolerance (horizontal precision > 0.100m+1.0ppm; vertical precision > 0.200m+1.0ppm).
3. In the free network adjustment, there are no outliers and the scalar is small but the error ellipse components are high, and the control coordinate comparisons show large differences:

PT1	ΔE = 4.152	ΔN = -45.912	ΔHt = -12.689
MMA4	ΔE = -5.391	ΔN = 44.208	ΔHt = 14.985

4. The network cannot be adjusted after fixing the references showing an error message that says: "*Network adjustment could not be successfully completed. The inverse of the normal equation matrix could not be computed. There may be an error in your data".*

Recommended Solutions:
It is recommended that when a merge window appears during data import, lookout for the indicated horizontal and vertical distances. When the distances exceed 5 meters, do not merge the points, they are most probably different. Check the coordinates of the stations written in the GNSS Field Sheet and compare it to the plotted position generated in TBC. Rename the suspect station/s in its correct location before *merging* and processing.
In the case of one session only, there is no way of detecting the error except in the control coordinate comparisons. View the points in Google Earth using the TBC toolbar and check if the location of the reference are the same as in the point description sheet. Rename and edit the coordinates, reprocess then adjust.

CASE V: Obstructed Stations

Field procedures: PTAG as reference.
Session 1: 5-min observation time.
Session 2: 10-min observation time.

Error Indicators in Processing:

1. Baselines connected to the points that are located in obstructed areas have FLOAT solutions.
2. Outliers in adjustment are connected to points with obstructions.
3. Fixing all the references yielded the following coordinate differences from Table 1:

±0.073 – 1.815cm	(ΔEasting)
±0.014 – 1.609cm	(ΔNorthing)
±0.106 – 9.665cm	(ΔEllipsoidal Heights)

Recommended Solutions:

After importing GNSS data, the Time-based View may be displayed to see how the occupations and sessions relate to each other and check for valid sessions. Review sessions and occupations properties and edit if necessary. Disable problematic baselines that should not be processed or cross-out sections of GPS observations containing large number of cycle slips and residuals to improve baseline processing results.

Process and review GNSS baselines, fixed solution are the primary indicator of a quality data that indicate precise position solutions. Flag indicators in the horizontal and vertical columns also indicate the precision of baselines. Review the processing details in the Baseline Processing Reports to determine why certain baselines were flagged or failed to process. Take note of all the baselines with float solutions then check the GNSS loop closure. Bear in mind that longer baselines need longer observation times; and obstructed stations have multipath and cycle slips.

CASE VI: Inconsistent Logging Rates

Field procedures: PTAG as reference, 1-hr observation.
Session 1: all receivers with 15s logging rate.
Session 2: two receivers with 5s and 10s logging rate.

Error Indicators in Processing:

1. The logging rate (update rate) can be seen in the properties of the *imported files*.
2. No visible indicator for the inconsistent logging rates except for more compressed residual plots.
   There is no significant coordinate dissimilarity with Table 1.

2. Data and Processing Procedure cases:

CASE VII: Wrong Coordinates Entered as Reference

Procedure: PTAG as reference, 1-hr observation 1 session only.
Before data processing, wrong coordinates are entered to the reference station PTAG.

Error Indicators in Processing:

1. There are no outliers and the control coordinate comparison shows small differences:

   PTAG ΔE = -0.001 ΔN = 0.003 ΔHt = -0.008

2. No visible indicator for the error during processing and adjustment, but comparing the generated coordinates to the coordinates in Table 1, the differences of 3D coordinates are almost the same for all points.

Station ID	Differences in centimeters		
	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	-669.230	-1737.677	-194.291
LM2	-668.844	-1737.856	-194.614
MMA03	-669.435	-1737.654	-194.558
MMA04	-669.185	-1737.765	-194.361
PT1	-669.196	-1737.780	-194.489
PT2	-669.308	-1737.736	-194.424
PT3	-669.678	-1737.396	-194.435
PT4	-669.239	-1737.603	-194.249
PT5	-668.943	-1738.025	-194.640
PT6	-669.233	-1737.733	-194.364
PTAG	-669.232	-1737.813	-194.300

Table 2. Differences of resulting coordinates with Table 1 for case vii

Recommended Solutions:

The error could not be detected until coordinates are compared to known stations. Double check the coordinates of the reference before processing; and always use two or more reference stations in GNSS surveys. Always plot coordinates of the processing results to Google Earth to check location accuracy. The accuracy of the new points greatly depends on the accuracy of the reference coordinates.

CASE VIII: Processing Data before Entering Reference Coordinates

Procedure: PTAG as reference, 1-hr observation.
Coordinates of reference PTAG were entered after processing the data.

Error Indicators in Processing:

1. The Scalar, Error Ellipse Components, and Control Coordinates Comparisons are all larger than the generated values from the processed data where in the coordinates of the reference was entered before processing.
2. There are also more baselines that became outliers during the adjustment.
3. After entering the reference coordinates and performed the final adjustment, the coordinate differences compared to Table 1 are:

Station ID	Differences in centimeters		
	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	-0.002	-0.006	0.065
LM2	0.000	-0.009	0.021
MMA03	0.019	-0.058	-0.006
MMA04	-0.007	0.000	0.051
PT1	0.028	-0.041	-0.029
PT2	-0.007	-0.004	0.046
PT3	-0.405	0.401	-0.520
PT4	-0.006	-0.007	0.047
PT5	0.041	-0.066	-0.024
PT6	-0.032	0.020	0.137
PTAG	0.000	0.000	0.000

Table 3. Differences of resulting coordinates with Table 1 for case viii

Recommended Solutions:

Remove processing results and enter the correct coordinates then reprocess baselines. Although there is not much difference in the resulting coordinates for this case, some of the data became outliers and are wasted.

CASE IX: IGS Final Orbits vs. Daily Broadcast Ephemeris

In this case, five (5) hours of GPS data were processed in Local WGS84 datum using the daily broadcast ephemeris and IGS final orbits. Table 4 shows the differences of coordinates using the IGS Final Orbits versus the Daily Broadcast Ephemeris with Iono Model. The highest difference is about 0.060 cm. in Easting, 0.055 cm. in Northing, and 0.20 cm. in Ellipsoidal Heights.

Station ID	Differences in centimeters		
	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	-0.002	-0.002	-0.006
LM2	0.029	-0.055	0.168
MMA03	0.001	-0.010	0.041
MMA04	0.000	-0.001	-0.027
PT1	-0.004	0.004	-0.004
PT2	-0.007	-0.004	-0.011
PT3	0.060	-0.038	0.173
PT4	0.000	0.033	0.202
PT5	0.011	-0.039	-0.084
PT6	-0.001	0.001	0.001
PTAG	0.000	0.000	0.000

Table 4. Resulting Coordinate differences using IGS Final Orbits and Daily Broadcast Ephemeris.

CASE X: PPP vs. Relative Positioning

Test A: PPP_CSRS vs. ITRF_TBC

In this case, five (5) hours of Rinex data were sent to Canadian Spatial Reference System (CSRS) to determine the Precise Point Positioning (PPP) coordinates of the test points. Since the PPP coordinates are in ITRF, IGS Final Orbits and ITRF coordinates are used for the relative positioning using TBC. The comparison of coordinates show millimeter to centimeter differences in the Easting, Northing and Ellipsoidal Heights. The highest difference in Easting is 14.194 cm. and 7.632 cm. in Northing with approximately 115.221 cm. difference in Ellipsoidal Height.

Station ID	Differences in centimeters		
	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	-2.646	-0.129	-2.035
LM2	-14.194	-7.632	-11.449
MMA03	8.410	1.032	8.092
MMA04	0.529	0.247	2.738
PT1	0.965	-0.080	-2.503
PT2	0.597	-0.566	6.080
PT3	-6.435	-6.561	-115.221
PT4	-3.576	2.004	-19.125
PT5	1.708	1.032	13.151
PT6	0.838	-0.075	6.500
PTAG	1.092	-0.541	1.300

Table 5. Resulting Coordinate differences between PPP (using CSRS) and Relative Positioning (using TBC). LM2 and PT3 are obstructed points.

Test B: PPP_TBC vs. ITRF_TBC

Five (5) hours of GPS data was processed to determine the PPP and relative coordinates of the test points using TBC. The highest difference in Easting is 38.01cm, Northing is 13.029cm, and 39.051cm in Ellipsoidal Height.

Station ID	Differences in centimeters		
	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	22.854	-13.029	0.865
LM2	21.606	-4.032	39.051
MMA03	38.010	-9.068	16.692
MMA04	22.429	-12.353	4.038
PT1	22.065	-12.380	-0.703
PT2	22.197	-12.366	4.180
PT3	28.065	-10.561	18.479
PT4	18.824	-11.596	-8.825
PT5	21.508	-11.868	8.151
PT6	23.138	-11.675	8.400
PTAG	21.792	-12.841	2.300

Table 6. Resulting Coordinate differences between PPP and Relative Positioning using TBC.

Test C: PPP_TBC vs. ITRF_AUSPOS

Relative positioning coordinates of the test points was computed using the AUSPOS Online GPS Processing Service and PPP using TBC. The comparison shows large differences from centimeter to meter. The highest difference is 78.719m in Latitude, 74.047m in Longitude, and 31.802m in Ellipsoidal Height.

Station ID	Differences in meters		
	ΔLatitude (m)	ΔLongitude (m)	ΔEll. Ht. (m)
BM2	46.508	-26.919	37.236
LM2	6.372	-12.280	-13.064
MMA03	0.586	11.603	-20.685
MMA04	-0.116	0.221	0.146
PT1	-0.117	0.208	0.128
PT2	-0.119	0.216	0.135
PT3	78.719	74.047	31.802
PT4	-0.116	0.171	0.023
PT5	-0.120	0.203	0.044
PT6	-0.110	0.220	0.182
PTAG	-0.121	0.208	0.017

Table 7. Resulting Coordinate differences between PPP (using TBC) and Relative Positioning (using AUSPOS).

Stations with large differences are located in obstructed areas.

CONCLUSION

Various types of survey errors committed in the field and their indicators in GNSS data processing have been investigated. Six cases of field survey errors and two cases of processing errors were presented.

In the following field survey errors; station is incorrectly occupied (Case I); station is incorrectly named (Case IV); and station located in obstructed area (Case V), the indicators of error are those baselines with float solutions in processing and those that became outliers in network adjustment. Those baselines are connected to incorrectly occupied, incorrectly named, and obstructed stations. The control coordinate comparisons can expose an incorrectly occupied or named reference station. Controls with similar coordinate comparisons suggest that they are correctly occupied and the control/s that deviates among the rest are suspects. Outliers with ΔHt component of the baselines during adjustment indicates that the stations connected to those baselines have wrong antenna heights (Case III). For the centering error (Case II) and for different logging rates (Case VI), there is no obvious error indicator.

The solution for the wrong point occupation, station naming error and antenna height error is to thoroughly check the imported data before doing the baseline processing. Check the date and time of data files, receiver details, and antenna details. Change the station name or antenna height if necessary by comparing the imported data to the data written in the GNSS Field Sheet of each observed station. If a merge window appears during data import, do not merge the points when the horizontal and vertical distance is greater than 5 meters. Compare the processed coordinates generated in TBC to the coordinates written in the GNSS Field Sheet and rename the suspect stations before processing. It is also advisable to review the GNSS loop closure results and look for the failed loops or the worst loop in the network. Explode each point from the worst loop to separate the points for each session and to see if there is any incorrectly occupied stations. Separated points that are incorrectly occupied may be deleted from the network to ensure the quality of data. For the stations located in obstructed areas, analyze the Time-based View before processing to see how the occupations and sessions relate to each other. Check for valid sessions and disable or cross-out sections of GPS observations containing large number of cycle slips to improve baseline processing results.

Data processing errors such as wrong coordinates entered as reference (Case VII) and processing data before entering reference coordinates (Case VIII) were also analyzed. The error of entering wrong coordinates as reference could not be detected until the results from its processing is compared with that of the correct reference coordinates. To avoid wrong input of reference coordinates, always double check the input coordinates of references before processing.

Error indicators in processing GNSS data without reference coordinates are large error ellipse components, scalar, control coordinates comparisons, and the outliers during adjustment. The solution is to remove processing result, enter the reference coordinates, and reprocess the baselines.

GNSS processing using the *IGS Final Orbits* versus the *Daily Broadcast Ephemeris with Iono Model* were also explored. Only millimeter differences in the Easting (E), Northing (N), and Ellipsoidal Heights (h) are seen in the comparison. This may be due to refined satellite orbits and advance GNSS processing.

Finally, the accuracy of PPP technique is compared with relative positioning technique. Three (3) tests were performed for this comparison. First, the PPP coordinates processed by the CSRS was compared to the relative coordinates processed by TBC. The coordinates show millimeter to centimeter differences in the E, N and h. The second test compares the PPP coordinates and relative coordinates both processed by TBC. The 3D comparison shows centimeter differences. Lastly, PPP coordinates computed using TBC is compared to relative coordinates processed by the AUSPOS Online GPS Processing Service. The comparison shows large differences from centimeter to meter in Latitude, Longitude, and height in obstructed stations; but the “good” stations give 10 – 20 cm in N, E, Up.

APPENDICES

APPENDIX A. Coordinate Differences on Survey Procedure Cases

Station ID	TestNetwork (Daily Broadcast)WGS			caseItestA (*Wrong Stationed Pts_2sessions*)			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.758	1607806.414	71.499	288851.752	1607806.414	71.504	0.633	0.039	-0.434
LM2	288846.996	1607792.112	71.817	288846.987	1607792.126	71.846	0.946	-1.353	-2.929
MMA03	288831.414	1607804.300	71.509	288831.417	1607804.302	71.522	-0.301	-0.230	-1.368
MMA04*	288896.495	1607844.936	86.298	288896.494	1607844.936	86.299	0.056	0.006	-0.098
PT1*	288901.297	1607799.910	72.513	288901.284	1607799.920	72.530	1.331	-0.981	-1.769
PT2	288859.200	1607819.175	71.201	288859.199	1607819.174	71.202	0.114	0.022	-0.142
PT3	288867.431	1607874.190	68.064	288867.415	1607874.203	68.081	1.589	-1.306	-1.604
PT4	288947.782	1607874.286	69.387	288947.777	1607874.290	69.388	0.474	-0.362	-0.116
PT5	288958.215	1607845.739	70.570	288958.225	1607845.737	70.565	-0.999	0.181	0.487
PT6	288945.511	1607811.823	72.244	288945.512	1607811.822	72.242	-0.162	0.175	0.216
PTAG	288884.325	1607846.163	88.057	288884.325	1607846.163	88.057	0.000	0.000	0.000

Station ID	TestNetwork (Daily Broadcast)WGS			caseItestB (*Wrong Stationed Reference Pts_1ses*)			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.758	1607806.414	71.499	288846.993	1607804.162	71.498	476.527	225.263	0.153
LM2	288846.996	1607792.112	71.817	288842.228	1607789.883	71.855	476.837	222.915	-3.815
MMA03	288831.414	1607804.300	71.509	288826.665	1607802.053	71.525	474.956	224.740	-1.676
MMA04*	288896.495	1607844.936	86.298	288896.495	1607844.936	86.298	-0.007	-0.004	0.000
PT1*	288901.297	1607799.910	72.513	288901.297	1607799.911	72.513	-0.009	-0.014	0.000
PT2	288859.200	1607819.175	71.201	288854.444	1607816.923	71.200	475.570	225.160	0.089
PT3	288867.431	1607874.190	68.064	288862.660	1607871.958	68.074	477.032	223.246	-0.964
PT4	288947.782	1607874.286	69.387	288943.021	1607872.040	69.381	476.085	224.549	0.575
PT5	288958.215	1607845.739	70.570	288953.479	1607843.482	70.566	473.641	225.741	0.473
PT6	288945.511	1607811.823	72.244	288940.759	1607809.569	72.239	475.229	225.419	0.463
PTAG	288884.325	1607846.163	88.057	288879.571	1607843.913	88.054	475.445	225.011	0.279

Station ID	TestNetwork (Daily Broadcast)WGS			caseItestC (*Wrong Stationed Reference Pts_2ses*)			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.758	1607806.414	71.499	288851.751	1607806.392	71.499	0.727	2.255	0.004
LM2	288846.996	1607792.112	71.817	288846.988	1607792.099	71.842	0.798	1.373	-2.481
MMA03	288831.414	1607804.300	71.509	288831.411	1607804.274	71.516	0.355	2.558	-0.774
MMA04*	288896.495	1607844.936	86.298	288896.495	1607844.936	86.298	-0.007	-0.004	0.000
PT1*	288901.297	1607799.910	72.513	288901.297	1607799.911	72.513	-0.009	-0.014	0.000
PT2	288859.200	1607819.175	71.201	288859.196	1607819.158	71.198	0.358	1.693	0.318
PT3	288867.431	1607874.190	68.064	288867.400	1607874.204	68.072	3.112	-1.428	-0.774
PT4	288947.782	1607874.286	69.387	288947.784	1607874.311	69.383	-0.170	-2.528	0.406
PT5	288958.215	1607845.739	70.570	288958.242	1607845.754	70.560	-2.699	-1.484	1.002
PT6	288945.511	1607811.823	72.244	288945.535	1607811.826	72.238	-2.414	-0.256	0.644
PTAG	288884.325	1607846.163	88.057	288884.322	1607846.160	88.057	0.305	0.283	0.009

Station ID	TestNetwork (Daily Broadcast)WGS			caseII (*Centering Error*)			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.758	1607806.414	71.499	288851.753	1607806.413	71.500	0.479	0.097	-0.018
LM2	288846.996	1607792.112	71.817	288846.985	1607792.121	71.832	1.096	-0.884	-1.462
MMA03*	288831.414	1607804.300	71.509	288831.432	1607804.257	71.530	-1.763	4.283	-2.110
MMA04*	288896.495	1607844.936	86.298	288896.500	1607844.933	86.295	-0.494	0.326	0.259
PT1	288901.297	1607799.910	72.513	288901.297	1607799.909	72.515	-0.022	0.162	-0.263
PT2	288859.200	1607819.175	71.201	288859.198	1607819.174	71.201	0.209	0.089	0.001
PT3	288867.431	1607874.190	68.064	288867.416	1607874.199	68.060	1.495	-0.864	0.481
PT4	288947.782	1607874.286	69.387	288947.783	1607874.279	69.392	-0.096	0.669	-0.496
PT5	288958.215	1607845.739	70.570	288958.220	1607845.739	70.571	-0.500	-0.038	-0.021
PT6	288945.511	1607811.823	72.244	288945.511	1607811.822	72.245	-0.058	0.113	-0.063
PTAG	288884.325	1607846.163	88.057	288884.325	1607846.163	88.057	0.000	0.000	0.000

Station ID	TestNetwork (Daily Broadcast)WGS			caseIII *(Antenna Height Error)*			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.758	1607806.414	71.499	288851.756	1607806.416	71.501	0.214	-0.150	-0.205
LM2	288846.996	1607792.112	71.817	288846.989	1607792.118	71.827	0.733	-0.538	-0.956
MMA03	288831.414	1607804.300	71.509	288831.415	1607804.297	71.521	-0.075	0.297	-1.211
MMA04*	288896.495	1607844.936	86.298	288896.494	1607844.935	86.306	0.036	0.056	-0.855
PT1	288901.297	1607799.910	72.513	288901.296	1607799.910	72.518	0.101	0.071	-0.563
PT2	288859.200	1607819.175	71.201	288859.197	1607819.174	71.202	0.321	0.056	-0.142
PT3	288867.431	1607874.190	68.064	288867.424	1607874.190	68.071	0.654	0.000	-0.659
PT4	288947.782	1607874.286	69.387	288947.780	1607874.286	69.390	0.157	-0.034	-0.294
PT5	288958.215	1607845.739	70.570	288958.211	1607845.742	70.574	0.420	-0.253	-0.353
PT6*	288945.511	1607811.823	72.244	288945.508	1607811.824	72.255	0.242	-0.018	-1.061
PTAG	288884.325	1607846.163	88.057	288884.325	1607846.163	88.057	0.000	0.000	0.000

Station ID	TestNetwork (Daily Broadcast)WGS			caseIVtestA *(Reference Name Error)*			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.758	1607806.414	71.499	288851.750	1607806.415	71.506	0.807	-0.125	-0.629
LM2	288846.996	1607792.112	71.817	288846.988	1607792.120	71.824	0.877	-0.801	-0.738
MMA03	288831.414	1607804.300	71.509	288831.418	1607804.295	71.522	-0.406	0.521	-1.313
MMA04*	288896.495	1607844.936	86.298	288896.495	1607844.936	86.298	-0.007	-0.004	0.000
PT1*	288901.297	1607799.910	72.513	288901.297	1607799.911	72.513	-0.009	-0.014	0.000
PT2	288859.200	1607819.175	71.201	288859.201	1607819.175	71.202	-0.108	0.012	-0.081
PT3	288867.431	1607874.190	68.064	288867.423	1607874.192	68.065	0.774	-0.244	-0.004
PT4	288947.782	1607874.286	69.387	288947.779	1607874.287	69.384	0.325	-0.070	0.297
PT5	288958.215	1607845.739	70.570	288958.225	1607845.737	70.566	-0.955	0.159	0.403
PT6	288945.511	1607811.823	72.244	288945.513	1607811.823	72.244	-0.174	0.050	0.011
PTAG	288884.325	1607846.163	88.057	288884.326	1607846.163	88.058	-0.120	-0.055	-0.062

Station ID	TestNetwork (Daily Broadcast)WGS			caseV *(Insufficient Data)*			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.758	1607806.414	71.499	288851.740	1607806.413	71.507	1.815	0.165	-0.790
LM2	288846.996	1607792.112	71.817	288846.981	1607792.128	71.901	1.552	-1.609	-8.414
MMA03	288831.414	1607804.300	71.509	288831.432	1607804.291	71.605	-1.742	0.862	-9.665
MMA04	288896.495	1607844.936	86.298	288896.495	1607844.935	86.304	-0.073	0.095	-0.593
PT1	288901.297	1607799.910	72.513	288901.301	1607799.897	72.529	-0.425	1.292	-1.635
PT2	288859.200	1607819.175	71.201	288859.202	1607819.175	71.219	-0.178	0.014	-1.812
PT3	288867.431	1607874.190	68.064	288867.413	1607874.203	68.108	1.771	-1.348	-4.325
PT4	288947.782	1607874.286	69.387	288947.774	1607874.277	69.386	0.786	0.896	0.106
PT5	288958.215	1607845.739	70.570	288958.224	1607845.733	70.578	-0.890	0.648	-0.737
PT6	288945.511	1607811.823	72.244	288945.514	1607811.818	72.251	-0.338	0.551	-0.675
PTAG	288884.325	1607846.163	88.057	288884.325	1607846.163	88.057	0.000	0.000	0.000

Station ID	TestNetwork (Daily Broadcast)WGS			caseVI *(Inconsistent Logging Rates)*			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.758	1607806.414	71.499	288851.757	1607806.414	71.495	0.083	0.037	0.435
LM2	288846.996	1607792.112	71.817	288846.993	1607792.115	71.823	0.357	-0.300	-0.581
MMA03	288831.414	1607804.300	71.509	288831.409	1607804.300	71.524	0.501	-0.040	-1.559
MMA04	288896.495	1607844.936	86.298	288896.494	1607844.936	86.299	0.052	-0.038	-0.122
PT1	288901.297	1607799.910	72.513	288901.297	1607799.910	72.515	0.014	0.036	-0.264
PT2	288859.200	1607819.175	71.201	288859.201	1607819.174	71.201	-0.062	0.040	-0.018
PT3	288867.431	1607874.190	68.064	288867.421	1607874.195	68.070	0.993	-0.451	-0.531
PT4	288947.782	1607874.286	69.387	288947.783	1607874.288	69.392	-0.097	-0.196	-0.501
PT5	288958.215	1607845.739	70.570	288958.222	1607845.735	70.560	-0.712	0.431	0.996
PT6	288945.511	1607811.823	72.244	288945.512	1607811.821	72.242	-0.160	0.215	0.150
PTAG	288884.325	1607846.163	88.057	288884.325	1607846.163	88.057	0.000	0.000	0.000

APPENDIX B. Coordinate Differences on Data and Processing Procedure Cases

Station ID	TestNetwork (Daily Broadcast)WGS			caseVII *(WrongCoordinatesEnteredAsReference)1hr*			Differences in centimeters		
	Easting (m)	Northing (m)	Ellipsoidal Heights	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.758	1607806.414	71.499	288858.451	1607823.791	73.442	-669.230	-1737.677	-194.291
LM2	288846.996	1607792.112	71.817	288853.685	1607809.491	73.763	-668.844	-1737.856	-194.614
MMA03	288831.414	1607804.300	71.509	288838.109	1607821.677	73.454	-669.435	-1737.654	-194.558
MMA04	288896.495	1607844.936	86.298	288903.187	1607862.313	88.241	-669.185	-1737.765	-194.361
PT1	288901.297	1607799.910	72.513	288907.989	1607817.288	74.458	-669.196	-1737.780	-194.489
PT2	288859.200	1607819.175	71.201	288865.893	1607836.552	73.145	-669.308	-1737.736	-194.424
PT3	288867.431	1607874.190	68.064	288874.128	1607891.564	70.009	-669.678	-1737.396	-194.435
PT4	288947.782	1607874.286	69.387	288954.474	1607891.662	71.329	-669.239	-1737.603	-194.249
PT5	288958.215	1607845.739	70.570	288964.905	1607863.119	72.517	-668.943	-1738.025	-194.640
PT6	288945.511	1607811.823	72.244	288952.203	1607829.201	74.188	-669.233	-1737.733	-194.364
PTAG	288884.325	1607846.163	88.057	288891.017	1607863.541	90.000	-669.232	-1737.813	-194.300

Station ID	TestNetwork (Daily Broadcast)WGS			caseVIII *(ProcessingDataBeforeEnteringRefCoords)1hr*			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.758	1607806.414	71.499	288851.758	1607806.414	71.499	-0.002	-0.006	0.065
LM2	288846.996	1607792.112	71.817	288846.996	1607792.112	71.817	0.000	-0.009	0.021
MMA03	288831.414	1607804.300	71.509	288831.414	1607804.301	71.509	0.019	-0.058	-0.006
MMA04	288896.495	1607844.936	86.298	288896.495	1607844.936	86.297	-0.007	0.000	0.051
PT1	288901.297	1607799.910	72.513	288901.297	1607799.911	72.513	0.028	-0.041	-0.029
PT2	288859.200	1607819.175	71.201	288859.200	1607819.175	71.200	-0.007	-0.004	0.046
PT3	288867.431	1607874.190	68.064	288867.435	1607874.186	68.070	-0.405	0.401	-0.520
PT4	288947.782	1607874.286	69.387	288947.782	1607874.286	69.386	-0.006	-0.007	0.047
PT5	288958.215	1607845.739	70.570	288958.215	1607845.740	70.571	0.041	-0.066	-0.024
PT6	288945.511	1607811.823	72.244	288945.511	1607811.823	72.243	-0.032	0.020	0.137
PTAG	288884.325	1607846.163	88.057	288884.325	1607846.163	88.057	0.000	0.000	0.000

Daily Broadcast vs Final Orbits

Station ID	5hrObservation (Daily Broadcast)WGS			caseIX5hrObservation (Final Orbits)WGS			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.744	1607806.419	71.489	288851.744	1607806.419	71.489	-0.002	-0.002	-0.006
LM2	288846.981	1607792.127	71.861	288846.981	1607792.127	71.860	0.029	-0.055	0.168
MMA03	288831.413	1607804.298	71.527	288831.413	1607804.298	71.526	0.001	-0.010	0.041
MMA04	288896.493	1607844.938	86.297	288896.493	1607844.938	86.298	0.000	-0.001	-0.027
PT1	288901.292	1607799.905	72.511	288901.292	1607799.904	72.511	-0.004	0.004	-0.004
PT2	288859.192	1607819.176	71.201	288859.192	1607819.176	71.202	-0.007	-0.004	-0.011
PT3	288867.409	1607874.200	68.061	288867.409	1607874.200	68.060	0.060	-0.038	0.173
PT4	288947.770	1607874.283	69.391	288947.770	1607874.283	69.389	0.000	0.033	0.202
PT5	288958.226	1607845.735	70.562	288958.225	1607845.735	70.563	0.011	-0.039	-0.084
PT6	288945.512	1607811.821	72.245	288945.512	1607811.821	72.245	-0.001	0.001	0.001
PTAG	288884.325	1607846.163	88.057	288884.325	1607846.163	88.057	0.000	0.000	0.000

PPP_CSRS vs Relative_TBC

Station ID	caseXtestA(PPP_CSRS)			caseXtestA(Relative_TBC)			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.012	1607811.263	70.107	288850.986	1607811.262	70.087	-2.646	-0.129	-2.035
LM2	288846.366	1607797.046	70.571	288846.224	1607796.970	70.457	-14.194	-7.632	-11.449
MMA03	288830.572	1607809.130	70.044	288830.656	1607809.140	70.125	8.410	1.032	8.092
MMA04	288895.729	1607849.778	84.866	288895.734	1607849.780	84.893	0.529	0.247	2.738
PT1	288900.523	1607804.748	71.134	288900.533	1607804.747	71.109	0.965	-0.080	-2.503
PT2	288858.428	1607824.024	69.737	288858.434	1607824.018	69.798	0.597	-0.566	6.080
PT3	288866.714	1607879.107	67.811	288866.650	1607879.041	66.659	-6.435	-6.561	-115.221
PT4	288947.048	1607879.106	68.177	288947.012	1607879.126	67.986	-3.576	2.004	-19.125
PT5	288957.451	1607850.567	69.025	288957.468	1607850.577	69.157	1.708	1.032	13.151
PT6	288944.745	1607816.665	70.776	288944.753	1607816.664	70.841	0.838	-0.075	6.500
PTAG	288883.556	1607851.011	86.64	288883.567	1607851.006	86.653	1.092	-0.541	1.300

PPP_TBC vs Relative_TBC

Station ID	caseXtestB(PPP_TBC)			caseXtestB(Relative_TBC)			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288850.757	1607811.392	70.078	288850.986	1607811.262	70.087	22.854	-13.029	0.865
LM2	288846.008	1607797.010	70.066	288846.224	1607796.970	70.457	21.606	-4.032	39.051
MMA03	288830.276	1607809.231	69.958	288830.656	1607809.140	70.125	38.010	-9.068	16.692
MMA04	288895.510	1607849.904	84.853	288895.734	1607849.780	84.893	22.429	-12.353	4.038
PT1	288900.312	1607804.871	71.116	288900.533	1607804.747	71.109	22.065	-12.380	-0.703
PT2	288858.212	1607824.142	69.756	288858.434	1607824.018	69.798	22.197	-12.366	4.180
PT3	288866.369	1607879.147	66.474	288866.650	1607879.041	66.659	28.065	-10.561	18.479
PT4	288946.824	1607879.242	68.074	288947.012	1607879.126	67.986	18.824	-11.596	-8.825
PT5	288957.253	1607850.696	69.075	288957.468	1607850.577	69.157	21.508	-11.868	8.151
PT6	288944.522	1607816.781	70.757	288944.753	1607816.664	70.841	23.138	-11.675	8.400
PTAG	288883.349	1607851.134	86.63	288883.567	1607851.006	86.653	21.792	-12.841	2.300

PPP_TBC vs Relative_AUSPOS

Station ID	caseXtestC(PPP_TBC)			caseXtestC(Relative_AUSPOS)			Differences in meters		
	Latitude (")	Longitude (")	Ell. Hts (m)	Latitude (")	Longitude (")	Ell. Hts (m)	ΔLatitude (m)	ΔLongitude (m)	ΔEll. Ht. (m)
BM2	6.292	25.670	70.078	7.843	24.773	107.314	46.508	-26.919	37.236
LM2	5.823	25.516	70.066	6.036	25.107	57.002	6.372	-12.280	-13.064
MMA03	6.216	24.987	69.958	6.236	25.374	49.273	0.586	11.603	-20.685
MMA04	7.558	27.154	84.853	7.554	27.161	84.999	-0.116	0.221	0.146
PT1	6.094	27.327	71.116	6.090	27.334	71.244	-0.117	0.208	0.128
PT2	6.709	25.916	69.756	6.705	25.923	69.891	-0.119	0.216	0.135
PT3	8.501	26.172	66.474	11.125	28.641	98.276	78.719	74.047	31.802
PT4	8.526	28.859	68.074	8.522	28.865	68.097	-0.116	0.171	0.023
PT5	7.601	29.216	69.075	7.597	29.222	69.119	-0.120	0.203	0.044
PT6	6.494	28.800	70.757	6.490	28.808	70.939	-0.110	0.220	0.182
PTAG	7.594	26.747	86.63	7.590	26.754	86.647	-0.121	0.208	0.017

PPP_CSRS vs PPP_TBC

Station ID	caseXtestD(PPP_CSRS)			caseXtestD(PPP_TBC)			Differences in centimeters		
	Easting (m)	Northing (m)	Ell. Hts (m)	Easting (m)	Northing (m)	Ell. Hts (m)	ΔE (cm)	ΔN (cm)	ΔEll. Ht. (cm)
BM2	288851.012	1607811.263	70.107	288850.757	1607811.392	70.078	-25.500	12.900	-2.900
LM2	288846.366	1607797.046	70.571	288846.008	1607797.010	70.066	-35.800	-3.600	-50.500
MMA03	288830.572	1607809.130	70.044	288830.276	1607809.231	69.958	-29.600	10.100	-8.600
MMA04	288895.729	1607849.778	84.866	288895.51	1607849.904	84.853	-21.900	12.600	-1.300
PT1	288900.523	1607804.748	71.134	288900.312	1607804.871	71.116	-21.100	12.300	-1.800
PT2	288858.428	1607824.024	69.737	288858.212	1607824.142	69.756	-21.600	11.800	1.900
PT3	288866.714	1607879.107	67.811	288866.369	1607879.147	66.474	-34.500	4.000	-133.700
PT4	288947.048	1607879.106	68.177	288946.824	1607879.242	68.074	-22.400	13.600	-10.300
PT5	288957.451	1607850.567	69.025	288957.253	1607850.696	69.075	-19.800	12.900	5.000
PT6	288944.745	1607816.665	70.776	288944.522	1607816.781	70.757	-22.300	11.600	-1.900
PTAG	288883.556	1607851.011	86.64	288883.349	1607851.134	86.63	-20.700	12.300	-1.000

Relative_TBC vs Relative_AUSPOS

Station ID	caseXtestE(Relative_TBC)			caseXtestE(Relative_AUSPOS)			Differences in meters		
	Latitude (")	Longitude (")	Ell. Hts (m)	Latitude (")	Longitude (")	Ell. Hts (m)	ΔLatitude (m)	Longitude (m	ΔEll. Ht. (m)
BM2	6.288	25.678	70.087	7.843	24.773	107.314	46.634	-27.149	37.227
LM2	5.822	25.523	70.457	6.036	25.107	57.002	6.410	-12.496	-13.455
MMA03	6.213	25.000	70.125	6.236	25.374	49.273	0.671	11.222	-20.852
MMA04	7.554	27.161	84.893	7.554	27.161	84.999	0.003	-0.004	0.106
PT1	6.090	27.335	71.109	6.090	27.334	71.244	0.002	-0.014	0.135
PT2	6.705	25.923	69.798	6.705	25.923	69.891	-0.001	-0.008	0.093
PT3	8.497	26.182	66.659	11.125	28.641	98.276	78.820	73.765	31.617
PT4	8.523	28.866	67.986	8.522	28.865	68.097	-0.005	-0.018	0.111
PT5	7.597	29.223	69.157	7.597	29.222	69.119	-0.007	-0.014	-0.038
PT6	6.490	28.808	70.841	6.490	28.808	70.939	0.002	-0.013	0.098
PTAG	7.590	26.755	86.653	7.590	26.754	86.647	0.003	-0.012	-0.006

Reference

Online help TBC Software; *Trimble Business Center Help*