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Comparison of Results of Different GPS Post-processing Software

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Abstract In order to obtain high-precision GPS control point results and provide high-precision known points for various projects, this study uses a variety of mature GPS post-processing software to process the observation data of the GPS control network of Guanyinge Reservoir, and compares the results obtained by several kinds of software. According to the test results, the reasons for the accuracy differences between different software are analyzed, and the optimal results are obtained in the analysis and comparison. The purpose of this paper is to provide useful reference for GPS software users to process data.

Key words GPS, Data processing, Point position, Precision

1 Introduction

In recent years, GPS satellite positioning technology has been widely used, which has brought about a major technological reform in traditional control measurement. As a result, different GPS instrument manufacturers are constantly updating and improving their post-processing software performance, and a large quantity of new GPS software and hardware at home and abroad is constantly emerging.

Therefore, it is very necessary to study and compare different GPS post-processing software, so as to study the characteristics of different software. There are not many researches on this aspect at home and abroad before, but the research on different GPS post-processing software has theoretical and practical significance for both scientific research and production departments and construction application departments. The study takes the static GPS data of Guanyinge Reservoir as the original data, and uses five kinds of GPS post-processing software at home and abroad (Tianbao TGO, Topcon Pinnacle, Ashtech Solution, Hi - Target HDS2003, South GPSADJ) to calculate. The baseline, closed loop, non-constrained adjustment and constrained adjustment of different software are compared, the accuracy difference between different software is analyzed, and the reasons of the difference between the software are studied. Finally, some suggestions are drawn from the reasons.

2 Software introduction

2.1 Tianbao TGO This software is the latest generation of data processing and management software of Trimble Company. Based on GPSurvey software, DTMLink (generating DTM and contour map) and RoadLink (road design, lofting, *etc.*) program modules are added, and it is improved into a whole omnipotent measurement data processing software with pure Windows interface.

2.2 Ashtech Solution The software is a GPS survey data post-processing software recently launched by Thales Navigation. Ashtech's Solution software takes all the advantages of the Windows operating system. It can guide users to perform tasks at different stages such as job planning, data processing, quality control, result reporting and data output, making the operation very simple.

2.3 Topcon Pinnacle The software has the function of solution wizard, which enables beginners, including non-professionals, to complete the task of data solution independently in the default state, and can give the primary results and accuracy. The software has a fast calculation speed. In the project, it has three columns (RawDataSession, Solution and Sub-net) to manage and process data.

2.4 South GPSADJ Compared with the previous software, GPSADJ baseline processing and adjustment software has a great improvement. It mainly carries on the baseline processing to the GPS ephemeris data, and carries on the constraint whole network adjustment to get the final result of the control network. The software can process the static GPS data of South Company, all kinds of imported GPS receiver RINEX standard format data.

2.5 Hi - Target HDS2003 The software is the ephemeris data processing software launched by Hi - Target Company, which has the functions of baseline solution, non-constrained adjustment and constrained adjustment. Compared with the software in the early stage, it has been improved, and has been well received by the majority of users. But HDS2003 data processing software is still in the development, so many functions still need to be perfected.

3 Results and analysis

3.1 Baseline comparison A point in the network is fixed, five baselines of 6 000 - 12 000 m and five baselines of 300 - 1 000 m are listed and compared in terms of relative accuracy of coordinates. Five baselines of 6 000 - 12 000 m: BTC1-00B5 (6 720.803 m), 0401-0203 (7 831.308 m), 0403-0203 (8 210.847 m), 0403-ODYG (10 556.212 m), 0403-0801 (11 478.807 m); five baselines of 1 000 - 5 300 m: 00B6-00B7 (560.677 m), 00B2-00B1 (372.945 m), 00B2-BTC1 (920.549 m), 0901-0903 (495.819 m), 0103-0102 (351.046 m). The above ten baselines are arranged in

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sequence as baseline 1, 2, 3, ..., 10.

In the long baseline group in Table 1, it can be seen that TGO and Solutions have similar good accuracy for 6 000 – 12 000 m baseline solution, while Pinnacle, GPSADJ and HD2003 have similar and slightly poor accuracy. For 300 – 1 000 m baseline, the accuracy of TGO and Solutions is slightly lower, while the accuracy of Pinnacle, GPSADJ and HD2003 is better.

Table 1 Comparison of baseline relative errors

	Relative error				
	TGO	Solution	Pinnacle	GPSADJ	HD2003
Baseline 1	1/992123	1/983862	1/897426	1/963298	1/858345
Baseline 2	1/1398473	1/1387134	1/1164894	1/1363284	1/1265748
Baseline 3	1/1328721	1/1264792	1/1084310	1/939342	1/1008411
Baseline 4	1/1409876	1/987358	1/983924	1/816824	1/779840
Baseline 5	1/1448940	1/1317589	1/1287647	1/1325301	1/1073147
Baseline 6	1/100150	1/110162	1/117080	1/121444	1/120037
Baseline 7	1/50284	1/48831	1/50026	1/52395	1/49882
Baseline 8	1/112801	1/126496	1/129003	1/128081	1/126548
Baseline 9	1/49876	1/51178	1/60025	1/59014	1/54382
Baseline 10	1/79440	1/89012	1/81247	1/80721	1/81549

From Table 2, it can be seen that the accuracy of TGO and Solutions is better than that of the other three kinds of software, but the accuracy of software is not much different.

From the comparison of the above 10 baselines, it can be seen that the maximum and minimum values of the errors of baselines basically appear on the same baseline except Solutions, because Solutions is single-frequency solution. TGO and Solutions have a better solution effect on 6 000 – 12 000 m baseline, but a little worse effect on 300 – 1 000 m baseline; the other three are the opposite.

Table 2 Comparison of errors in baseline

	Mean square error				
	TGO	Solution	Pinnacle	GPSADJ	HD2003
Baseline 1	0.007	0.004	0.010	0.007	0.009
Baseline 2	0.002	0.007	0.008	0.006	0.005
Baseline 3	0.008	0.006	0.008	0.009	0.010
Baseline 4	0.011	0.012	0.014	0.013	0.015
Baseline 5	0.008	0.009	0.008	0.009	0.008
Baseline 6	0.009	0.003	0.005	0.005	0.007
Baseline 7	0.008	0.008	0.006	0.007	0.006
Baseline 8	0.008	0.010	0.009	0.007	0.009
Baseline 9	0.010	0.010	0.009	0.008	0.008
Baseline 10	0.005	0.007	0.007	0.004	0.006

3.2 Comparison of closed loops The total number of closed loops in this project is 992, including 420 synchronous loops and 572 asynchronous loops. The side length closing error and relative error of the closed loop are compared below (Table 3).

The results show that the precision of GPSADJ software is a little better, but the precision of TGO, Solutions, Pinnacle and HD2003 closed loop is a little worse; however, the accuracy of such software accords with the requirements of engineering precision.

Table 3 Comparison of closing errors and relative errors of all closed loops

Software	Side length (loop) closing error // mm			Relative error // mm		
	Maximum	Minimum	Average	Maximum	Minimum	Average
TGO	23.112	0.453	5.115	4.9	0.5	1.9
Solution	19.328	0.549	5.164	5.9	0.6	1.8
Pinnacle	24.853	0.399	8.647	6.7	0.8	2.4
GPSADJ	20.575	0.351	5.034	4.7	0.2	1.3
HD2003	21.774	0.546	5.001	5.6	0.3	2.1

3.3 Comparison of non-constrained adjustments The so-called non-constrained adjustment is the 3D free network adjustment under WGS-84. By comparing the relative error and point position accuracy of the free network adjustment baseline, the characteristics of software can be compared. The relative errors of non-constrained adjustment baselines are studied and compared with the above 10 baselines, and individual points in the network are compared. It can be seen from Table 4 – 7 that TGO and Solution still have good effect for baselines with a length of 6 000 – 12 000 m, while Pinnacle, GPSADJ and HD2003 have good solution effect for baselines with a length of 300 – 1 000 m; the maximum and minimum errors of software basically appear on the same baseline (GPSADJ has the best overall solution accuracy).

Table 4 Comparison of baseline relative errors

	Relative error				
	TGO	Solution	Pinnacle	GPSADJ	HD2003
Baseline 1	1/3995201	1/3599750	1/3256002	1/3340496	1/3096578
Baseline 2	1/3900683	1/3885392	1/3555279	1/3859555	1/2997420
Baseline 3	1/4002386	1/3884590	1/3309833	1/3647640	1/3007846
Baseline 4	1/7904377	1/8093744	1/5800047	1/6923122	1/6734590
Baseline 5	1/9758452	1/9977593	1/9035800	1/8688818	1/9065100
Baseline 6	1/206349	1/198563	1/209746	1/279187	1/239953
Baseline 7	1/179474	1/126472	1/168466	1/174372	1/200754
Baseline 8	1/583664	1/492470	1/600024	1/563259	1/611987
Baseline 9	1/1409876	1/168744	1/154978	1/178060	1/103168
Baseline 10	1/110067	1/107538	1/120673	1/117759	1/114258

Table 5 Precision comparison in X direction

Software	X-offset // mm				
	00B1	1002	0301	0A07	00B6
TGO	2.004	2.336	2.590	2.863	1.542
Solution	1.903	2.572	3.026	3.047	1.021
Pinnacle	1.573	2.974	2.620	2.991	1.034
GPSADJ	1.413	2.055	2.554	2.963	1.410
HD2003	1.245	3.003	2.762	3.074	1.339

Table 6 Precision comparison in Y direction

Software	Y-offset // mm				
	00B1	1002	0301	0A07	00B6
TGO	2.063	2.557	3.855	3.014	2.984
Solution	1.905	1.896	3.083	3.586	2.063
Pinnacle	3.102	2.893	2.965	2.994	3.111
GPSADJ	2.450	2.810	3.318	2.725	2.310
HD2003	2.721	3.004	3.695	2.635	2.062

Table 7 Precision comparison in Z direction

Software	Z-offset // mm				
	00B1	1002	0301	0A07	00B6
TGO	1.964	2.075	2.960	3.852	1.989
Solution	2.479	4.774	4.903	4.002	1.990
Pinnacle	1.537	2.647	3.096	3.003	1.548
GPSADJ	1.630	2.582	3.290	2.735	1.760
HD2003	1.992	2.078	3.894	3.077	2.035

In the above comparison of the point position precision, we can know that the precision of the four kinds of software except Solutions is relatively good and relatively stable (GPSADJ has the best precision).

3.4 Comparison of constrained adjustments As shown in Fig. 1, after statistical processing of all coordinates, the overall point accuracy of GPSADJ is better than that of other software, and due to the small data dispersion, it can be used as the optimal result of this project.

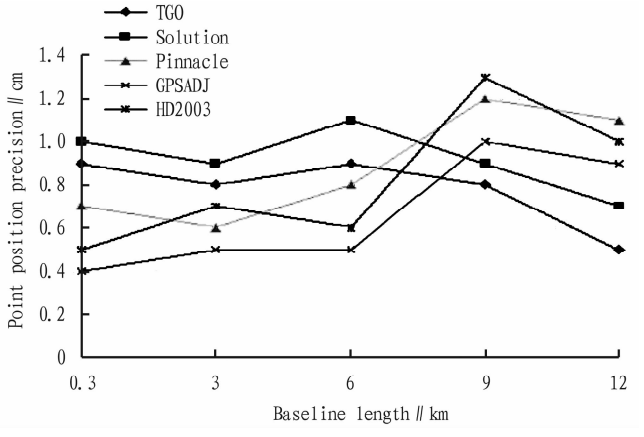

Fig. 1 Comparison of point position precision

3.5 Analysis of the reasons for the differences The five kinds of software involved in the baseline solution mainly consider the following factors: ionospheric correction model, tropospheric correction model, satellite and receiver antenna phase center correction, cutoff height angle, epoch interval, iteration times and so on. The software adopts different mathematical models and algorithms, so the solution results must be different.

The original data of the project are measured by the Lingrui S86GPS receiver of South Company, and only GPSADJ software can edit the original data in terms of antenna height and antenna type when data is imported; the data used by other software are RINEX standard format data exported by GPSADJ software. Therefore, other software-related settings can only the format of GPSADJ as default format, which may not exactly match the software itself.

In the process of baseline solution, different software has different unqualified baselines for the same data, and the number of unqualified baselines is also different; the operation is different when debugging unqualified baselines. Therefore, the original unqualified baselines after different adjustments will have an impact on the overall network node structure, resulting in differences in the accuracy of different software.

4 Discussion and conclusions

4.1 Discussion It can be seen from the solution of medium and long baselines that GPSADJ, HD2003 and Pinnacle have poor accuracy in the solution of 6 000 – 12 000 m baselines, while TGO and Solution have better results. In 300 – 1 000 m baseline solution, GPSADJ, HD2003 and Pinnacle baseline results are close to each other and have good accuracy, especially the baseline obtained by GPSADJ has good repeatability and small discreteness; the data of TGO and Solution are poor, but they also meet the requirements of engineering accuracy. It can be seen that the point coordinates of GPSADJ are relatively good, and the discreteness is relatively small. From the comparison of closed loops, the precision of TGO, Solution, GPSADJ, HD2003 and Pinnacle is close, and the precision of GPSADJ is the best. From the network adjustment, it can be found that HD2003 and Pinnacle are close to GPSADJ and have better precision, while the other two (TGO and Solution) are slightly worse.

4.2 Conclusions (i) As far as this project is concerned, TGO and Solution have a slightly better effect in solving 6 000 – 12 000 m baseline, while GPSADJ, HD2003 and Pinnacle have a better effect in solving 300 – 1 000 m baseline; the precision of the software in the duplicate measure baseline is equivalent. Since there are only 21 baselines longer than 6 000 m in this project, the overall precision of TGO and Solution is slightly poor.

(ii) Since 90% of the closed loops are composed of baselines within 6 000 m in this project, the precision of GPSADJ, HD2003 and Pinnacle closed loops is slightly higher than that of TGO and Solution.

(iii) GPSADJ has the best overall point position precision and small dispersion in this solution, so it can be used as the optimal solution for this project.

(iv) The above is only the conclusion drawn in this example. The five kinds of software are all mature software and have complete functions. For the static data solution of E-level GPS control network, all of them can meet the engineering accuracy requirements. Users can choose different software to get the optimal results according to the different requirements of engineering accuracy in engineering projects.

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