GEOSolution

User manual

Geoelectron

Content

Chapter 1 Installation & Uninstallation

1.1 Introduction

GEOSolution is mainly for processing baselines of GPS ephemeris data, then the result will be used to adjust constrained network, so as to obtain final report for control network.

This software is capable of processing data in two formats: RINEX standard data of GPS receivers and *.dat data.

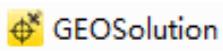
Integrated with friendly interface, all-English operating environment, processed management and operation as well as better graphical operation interface and graphics service, it perfectly performs export and save of a variety of graphics including baseline network diagrams and error ellipses.

Using management of establishing project file, that engineering project exists in the form of a file, reliability is greatly enhanced. GEOSolution provides users the convenience to customize the project ellipsoid parameters and select diverse coordinate system. The entire process, including baseline solution, network adjustment and other operations, are operating in the project files under save path. This software records all operations automatically, and it can export the progress of processed date which is saved at any time, then to continue processing or check the results.

It is more powerful than previous versions, enjoying higher automation as well as more convenient operation of baseline vector solution, closed loop searching, network adjustment processing functions.

Using GEOSolution to process baseline, it can easily set solution conditions and solver type of any baseline. For independent synchronous loop, asynchronous loop and repeating baseline, it can search automatically. In the network adjustment process, it has increased 3D constrained adjustment, plane adjustment and vertical adjustment.

1.2 Installation

Download GEOSolution installation package as shown in Figure 1-1, run the installation program as an administrator, and select the installation language as shown in Figure 1-2. After that, click [OK] and then an interface appears in several seconds as shown in Figure 1-3. Click [Next], choose the installation path as shown in Figure 1-4 and the default installation path is C:\Program Files (x86) \ STONEX\GEOSolution without modification. Click [Finish] in the pop-up interface as shown in Figure 1-5, which means successful installation and then the software automatically creates a GEOSolution shortcut on the desktop (

) and the start menu. Double click the GEOSolution shortcut as shown in Figure 1-6, and the main interface appears as shown in Figure 1-7. Now a series of operations could be done in the main interface, such as new project establishment, baseline solution, and network adjustment.

Note: If your computer is Win10 system, please don't install the GEOSolution in disk C, or you need to run GEOSolution as administrator.

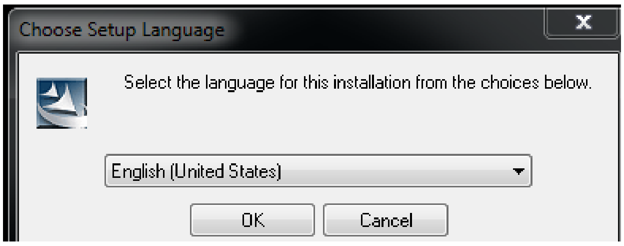


Figure 1-1 Figure 1-2

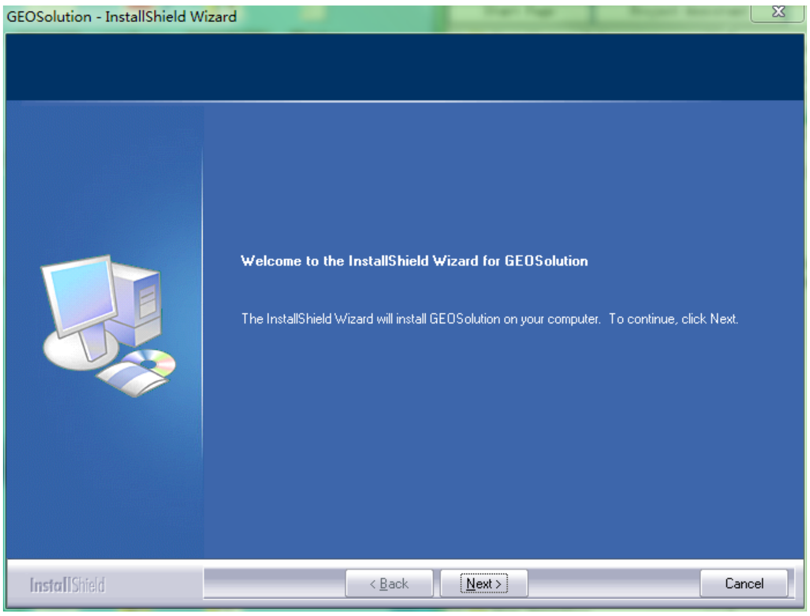


Figure 1-3

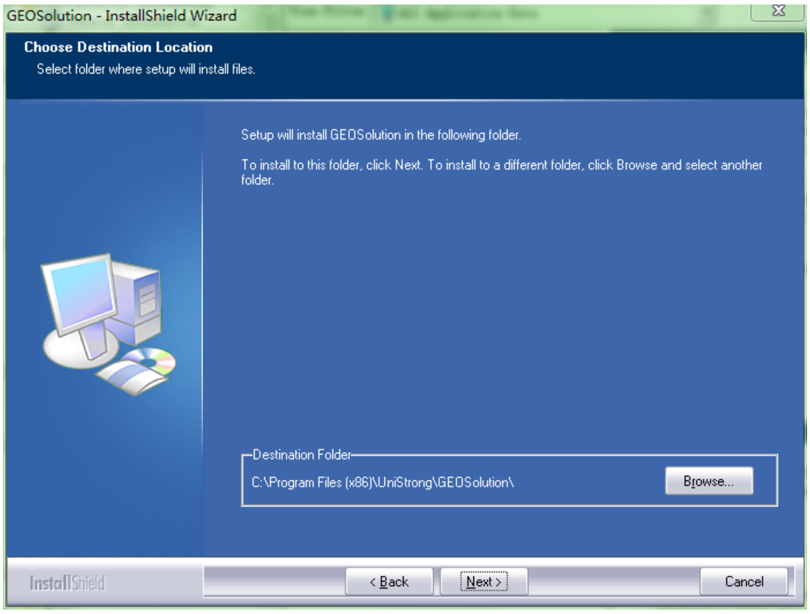


Figure 1-4

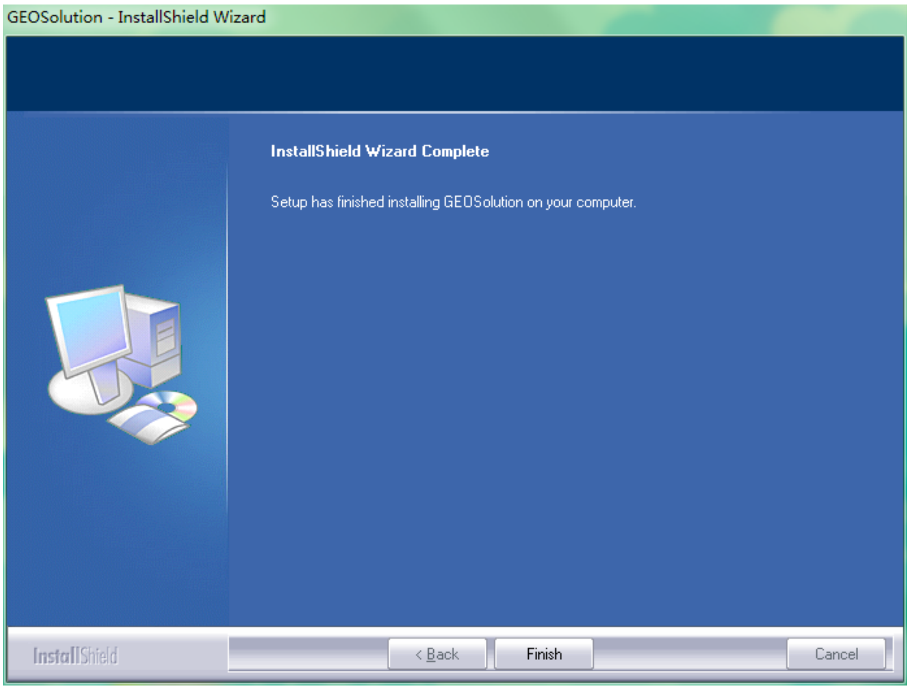


Figure 1-5

Figure 1-6

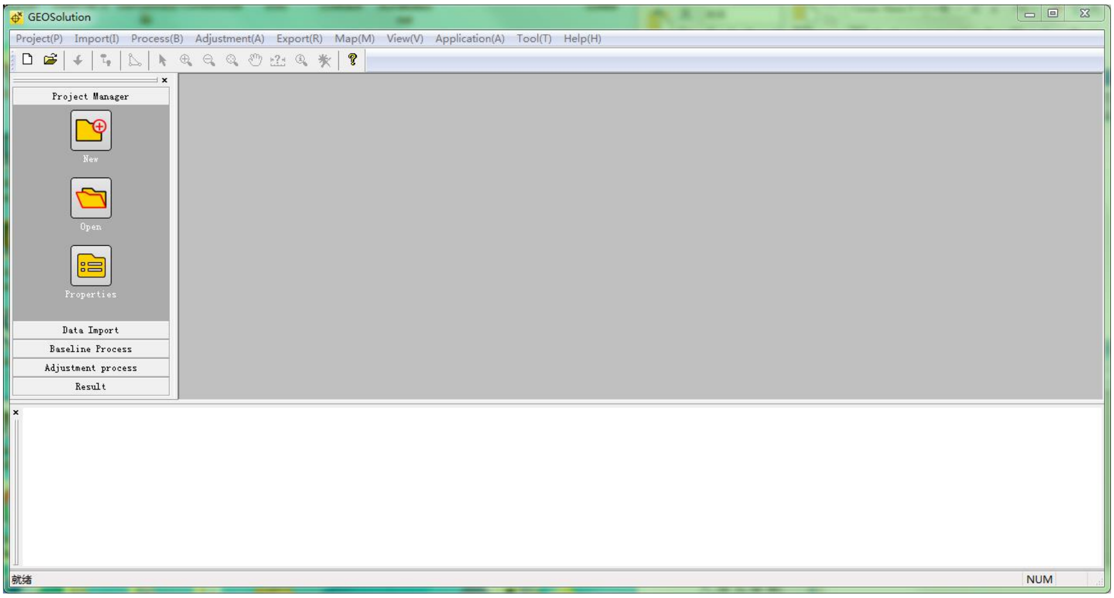


Figure 1-7

1.3 Software uninstallation

1)Shortcut uninstallation

Firstly, find and open the GEOSolution installation folder in the “start” menu Bar as shown in Figure 1-8. Next, click [Uninstall] and the pop-up interface as shown in Figure 1-9. Lastly, click [Yes] and the software starts to uninstall as shown in Figure 1-10. When the desktop and the start menu Bar have no GEOSolution shortcut, it indicates that the software uninstallation is completed.

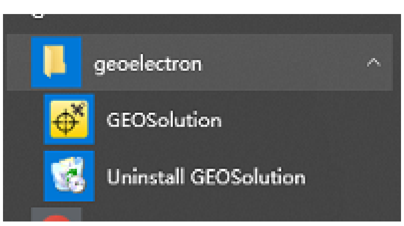


Figure 1-8

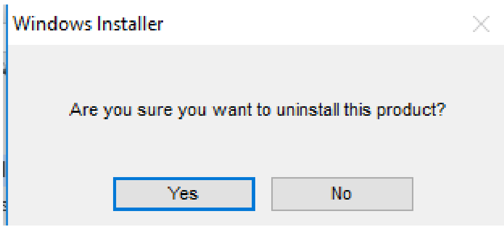


Figure 1-9

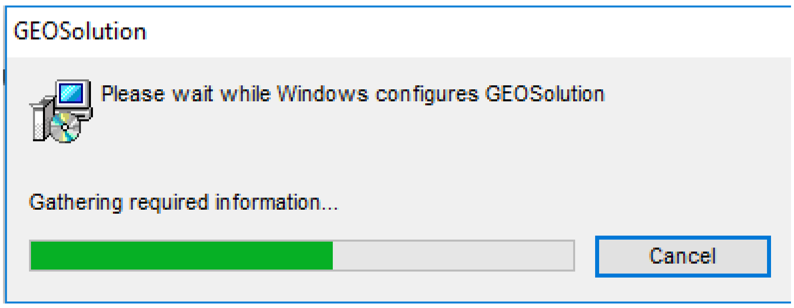


Figure 1-10

2)System uninstallation

Click Start menu to enter Control panel, and choose delete programs. Find GEOSolution in the interface as shown in Figure 1-11, click [Uninstall] and the pop-up interface as shown in Figure 1-12, which means the program is uninstalled successfully.

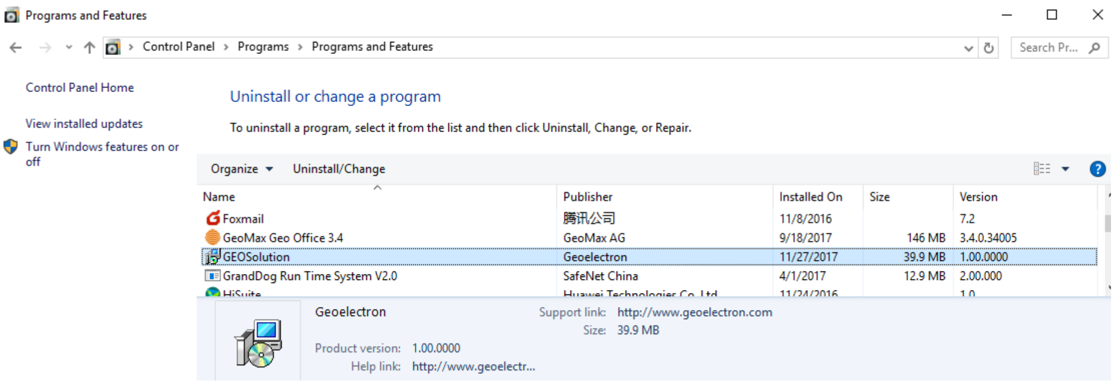


Figure 1-11

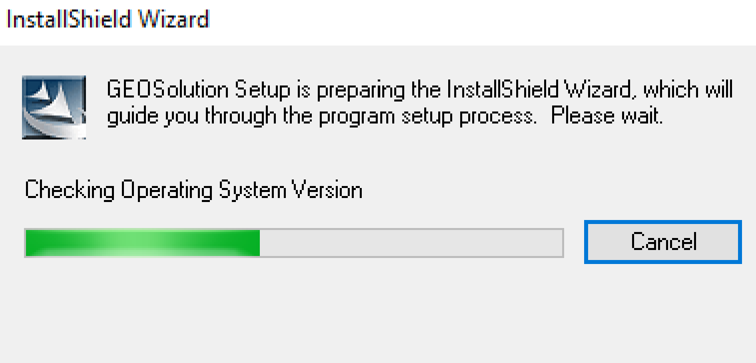


Figure 1-12

Chapter 2 Data processing

This chapter mainly explains the simple procedure that GEOSolution data processing software processes static GPS data and dynamic post-differential data, so that the user can quickly understand how to use the software in a short time. The data processing process is briefly described below. Other more detailed introduction please refer to the following sections.

2.1 Static GPS data processing

1) New project

Click [Project] – [New], then pops up the interface as shown in Figure 2-1. Project name is necessary, while other items are optional. Click [Coordinate Sys.] as shown in Figure 2-2. The users could set Ellipsoid Parameter, Projections Parameter and other information in this interface.

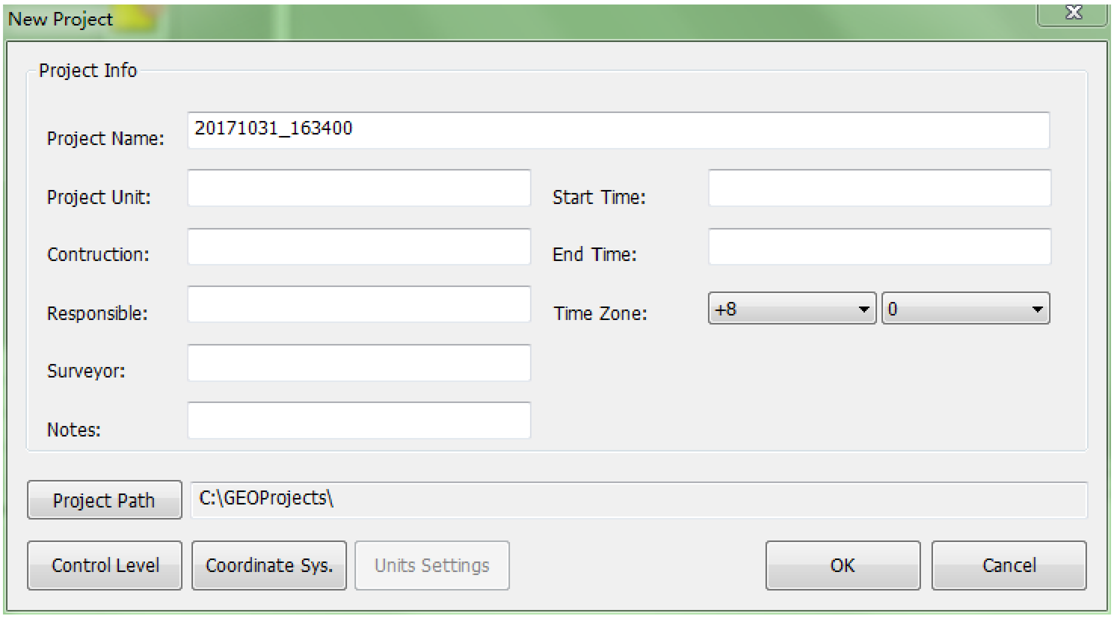


Figure 2-1

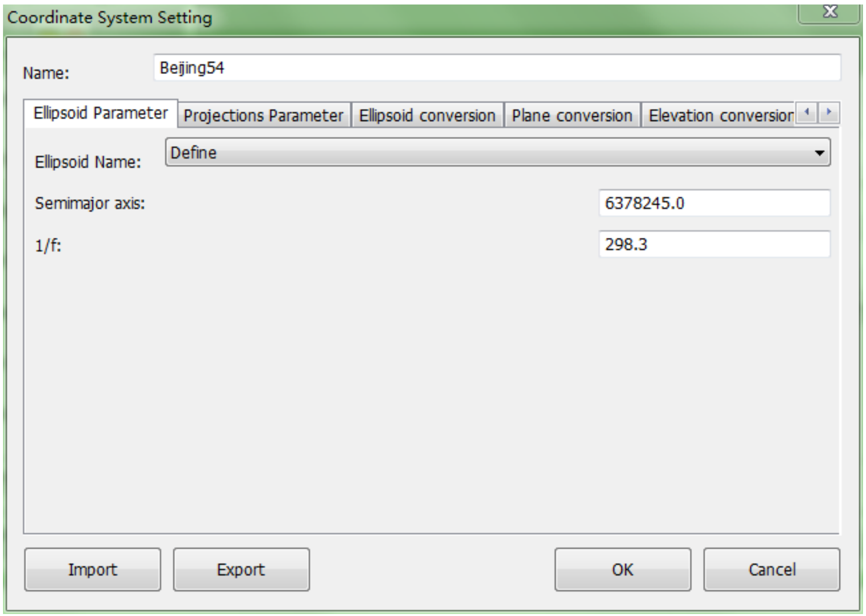


Figure 2-2

2) Import data

Click [Import] - [Observation Data] as shown in Figure 2-3, then choose the data file and click [Open]. Import succeeds as shown in Figure 2-4.

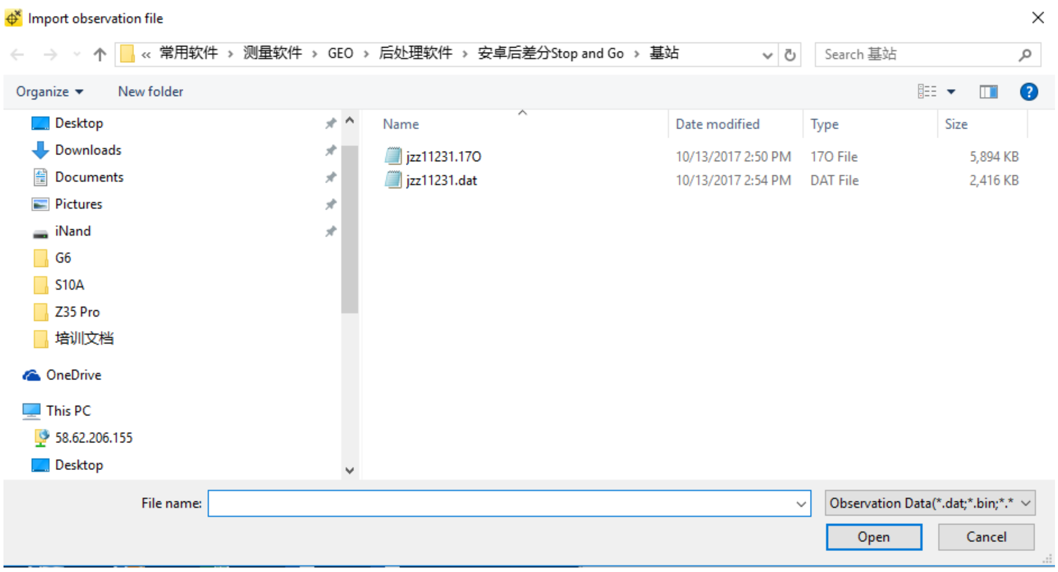


Figure 2-3

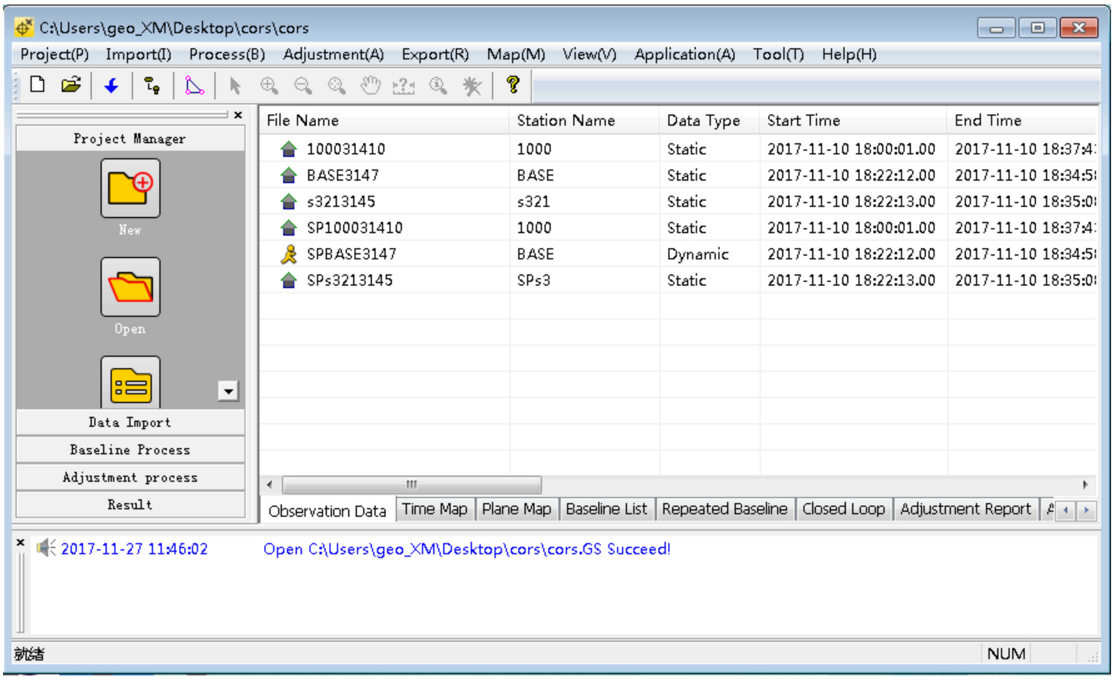


Figure 2-4

3) Static Options setting

Click [Process] - [Static Options] as shown in Figure 2-5, and click [OK] when finishing setting.

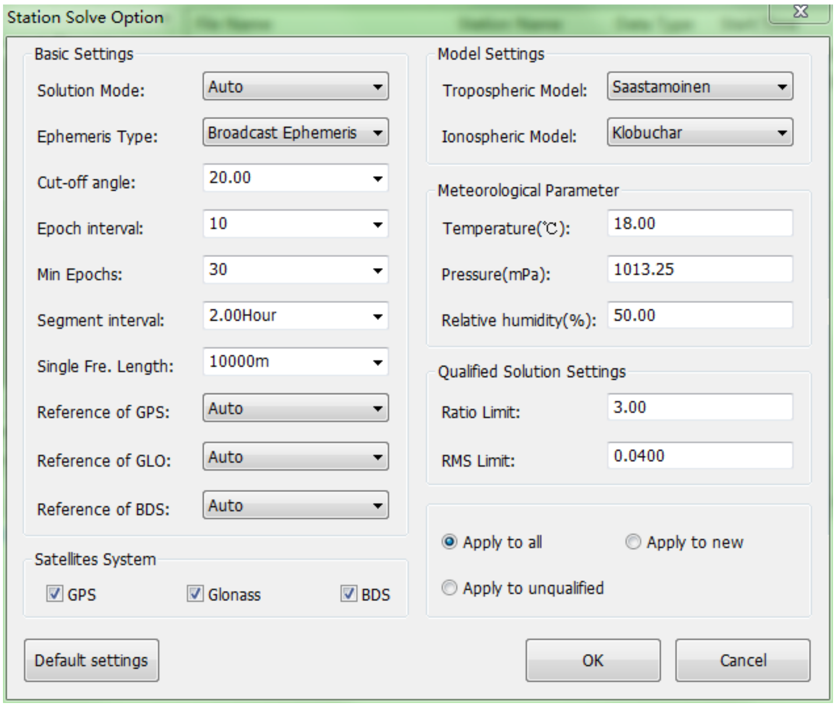


Figure 2-5

4) Baseline process

a. Click [Process] - [Process all baselines] to process all the baselines as shown in

Figure 2-6. When the Figure 2-7 appears, it means process complete. Green refers to baselines that succeed to process, while red refers to those failed.

b. Right-click the unqualified baselines in the baseline table, then choose [Processing settings], and modify the static setting parameters to reprocess this baseline.

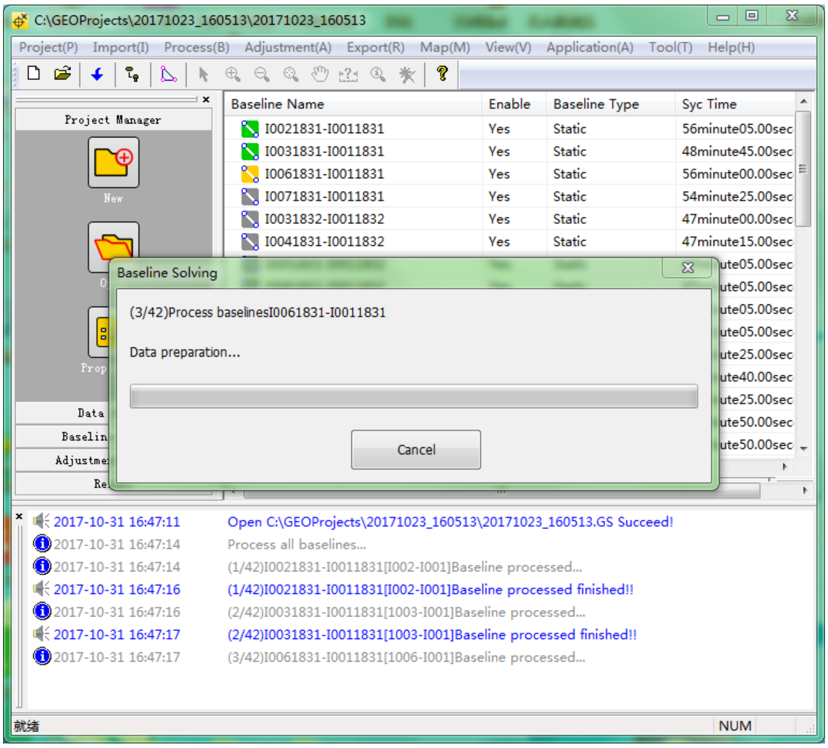


Figure 2-6

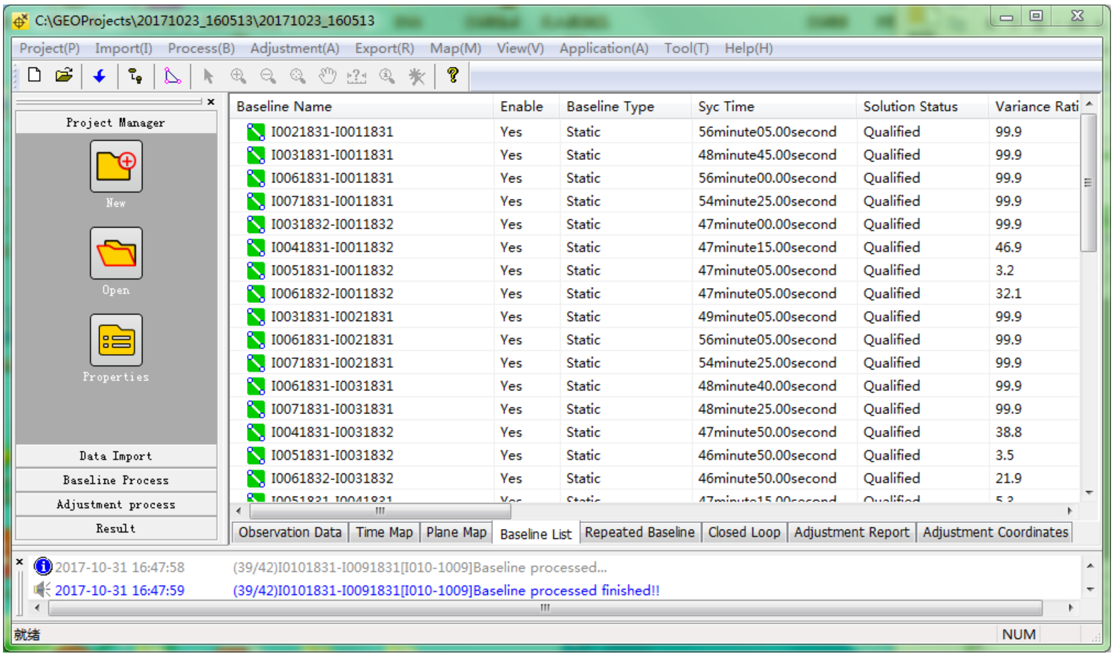


Figure 2-7

5) Network Adjustment

a. Click [Adjustment] - [Adjustment Settings] as shown in Figure 2-8.

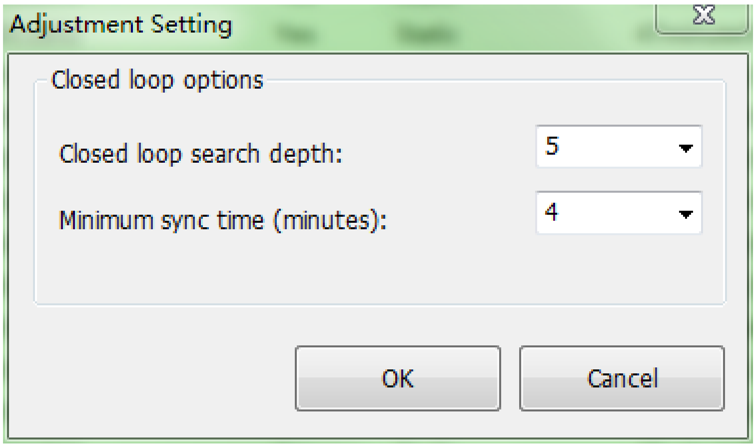


Figure 2-8

b. Click [Import] - [Known Coordinates] as shown in Figure 2-9.

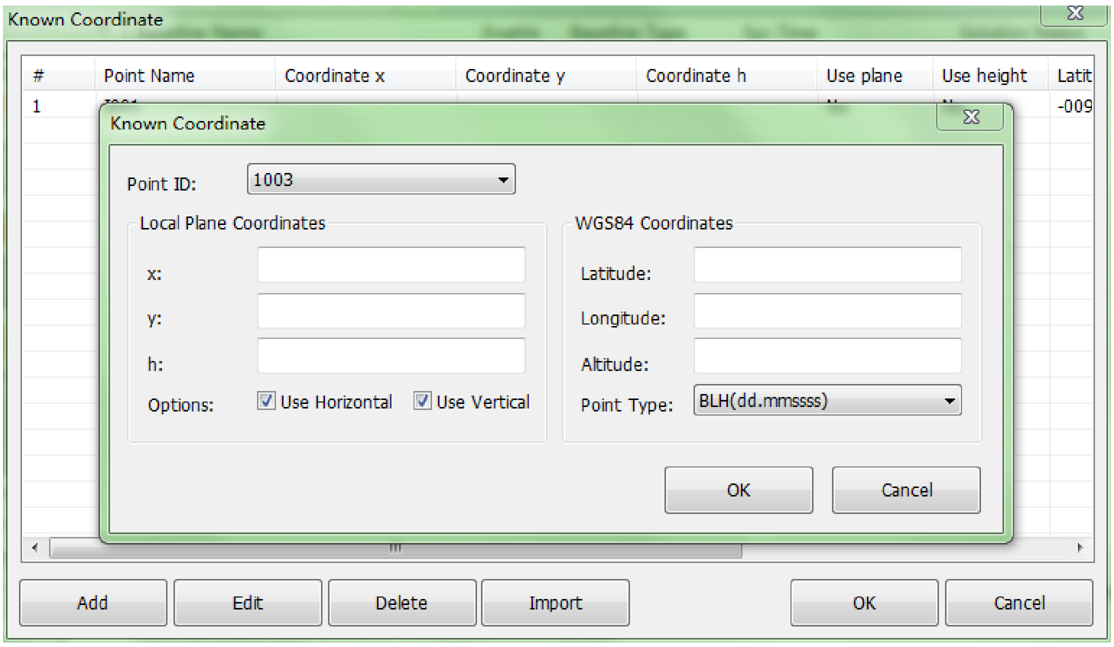


Figure 2-9

c. Click [Adjustment] - [Adjustment Processing], the adjustment report is as shown in Figure 2-10.

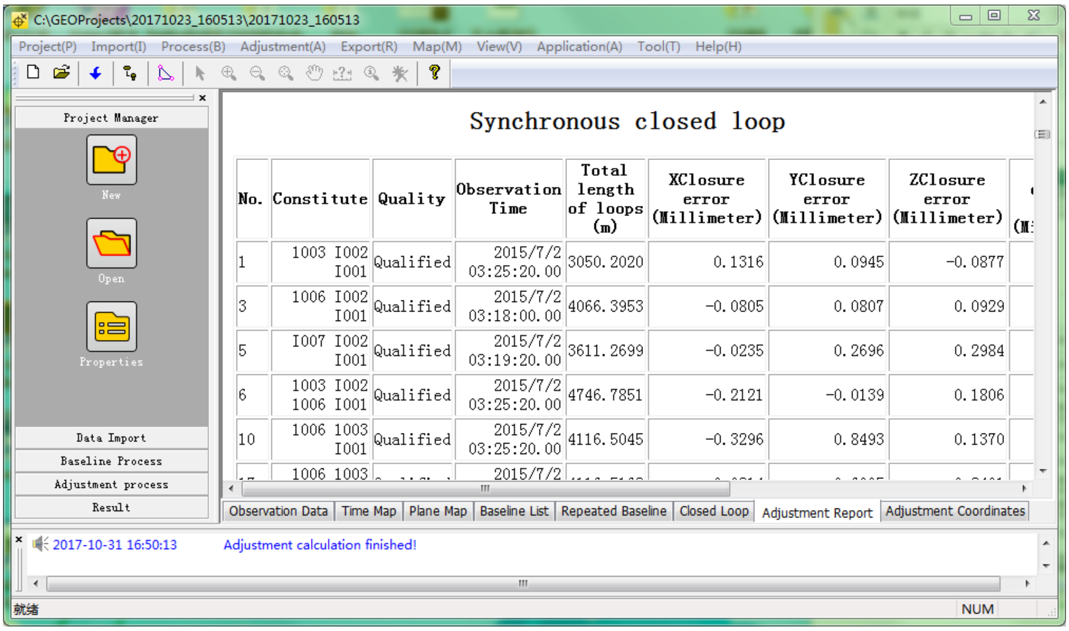


Figure 2-10

6) Export processing results

Click [Export] - [Static Processing Results] as shown in Figure 2-11. After choosing the file type and save path, click [Export], then the processing result could be exported.

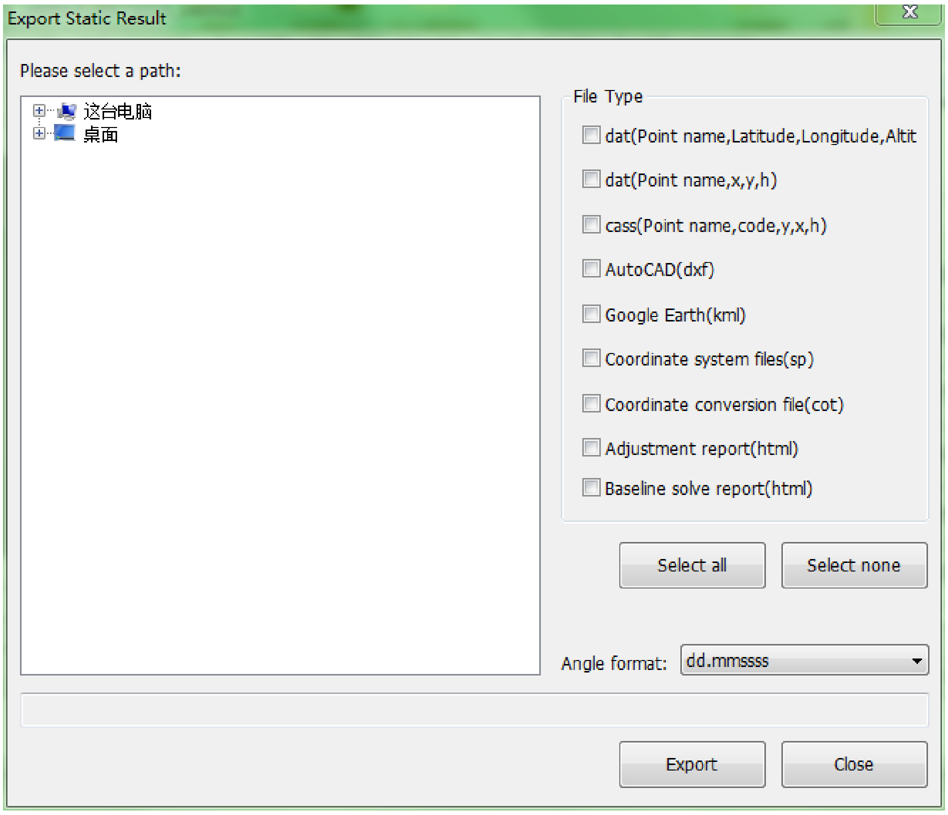


Figure 2-11

2.2 Dynamic GPS data processing

1) New project

Click [Project] - [New], pops up the interface as shown in Figure 2-12. Project name is necessary, while the other items are optional. Click [Coordinates Sys.] as shown in Figure 2-13, the users can set ellipsoid parameter and projections parameter and other information.

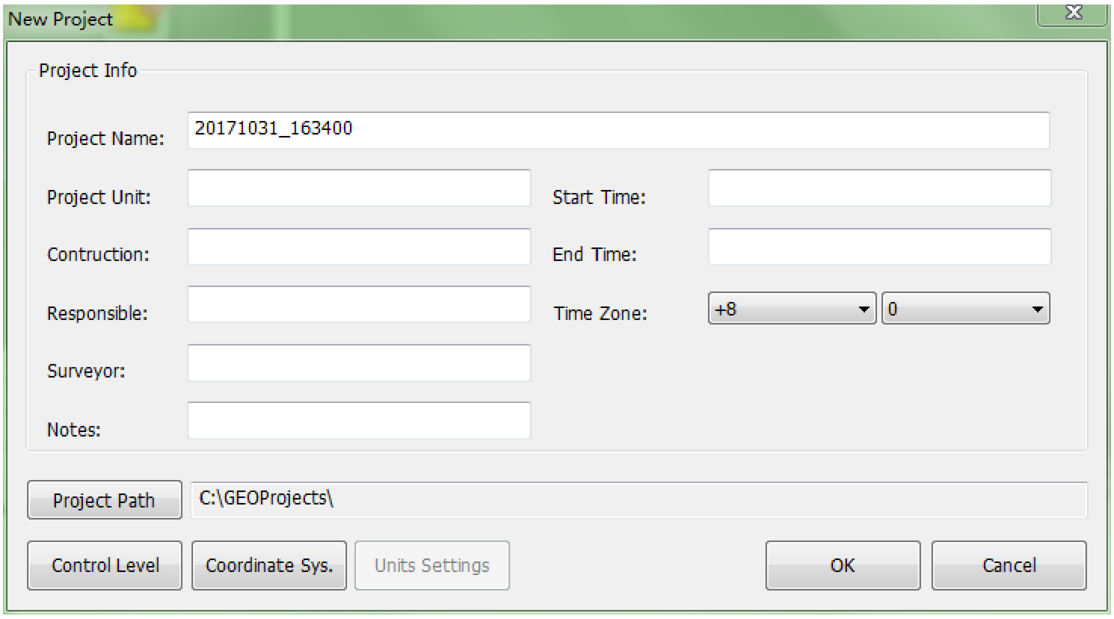


Figure 2-12

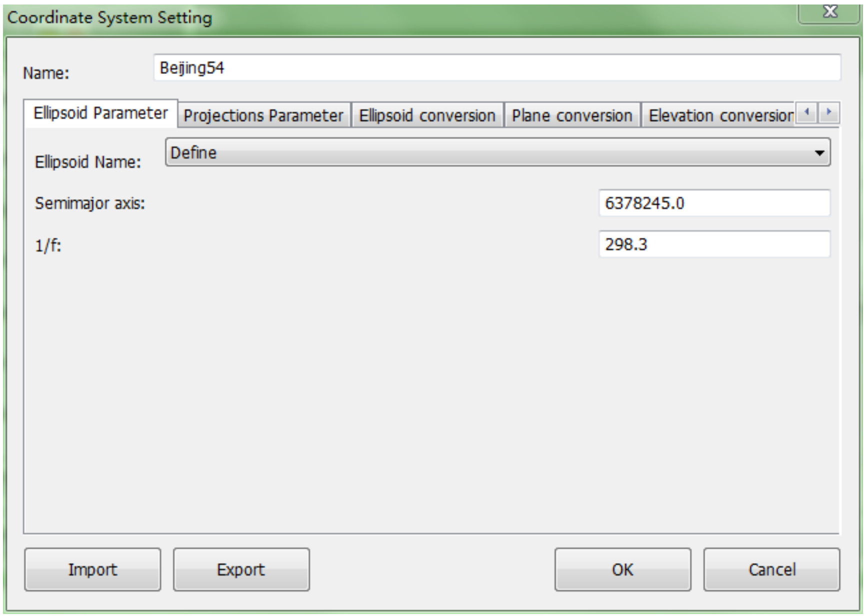


Figure 2-13

2) Import data

Click [Import] - [Observation Data] as shown in Figure 2-14, choose the data file and click [Open]. The interface as shown in the Figure 2-15 means import succeed. The imported observation data should contain two kinds of data files, base station and rover.

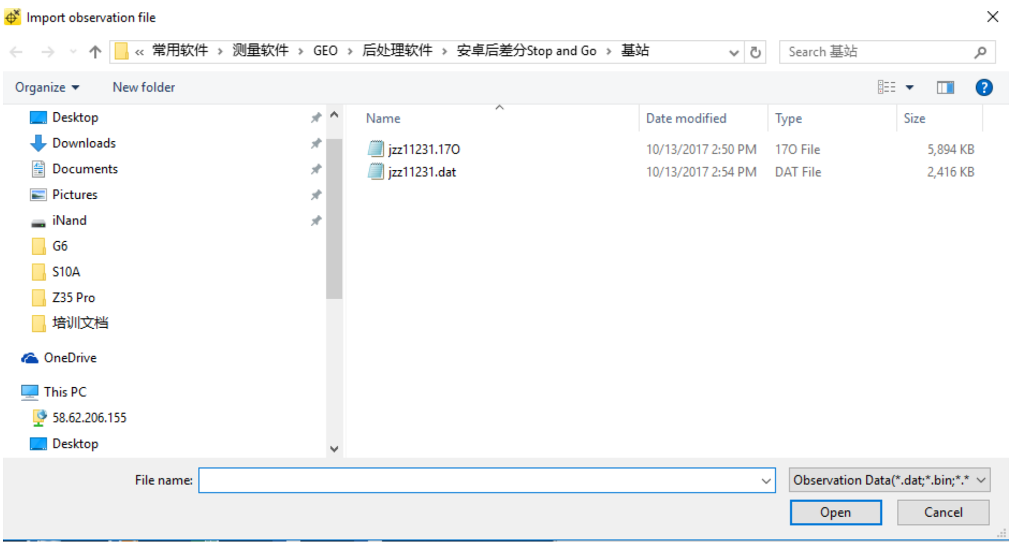


Figure 2-14

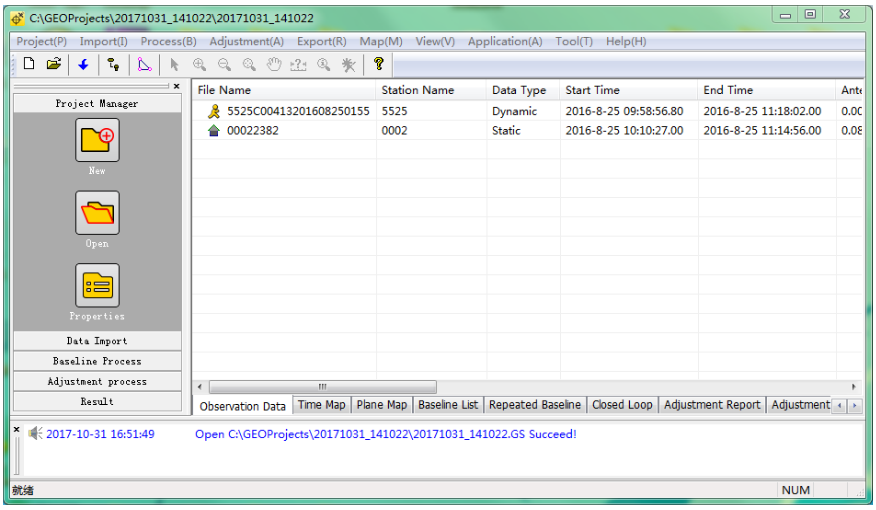


Figure 2-15

3) Modify dynamic options

Click [Process] - [Dynamic Options] as shown in Figure 2-16. Click [OK] after setting up the parameters.

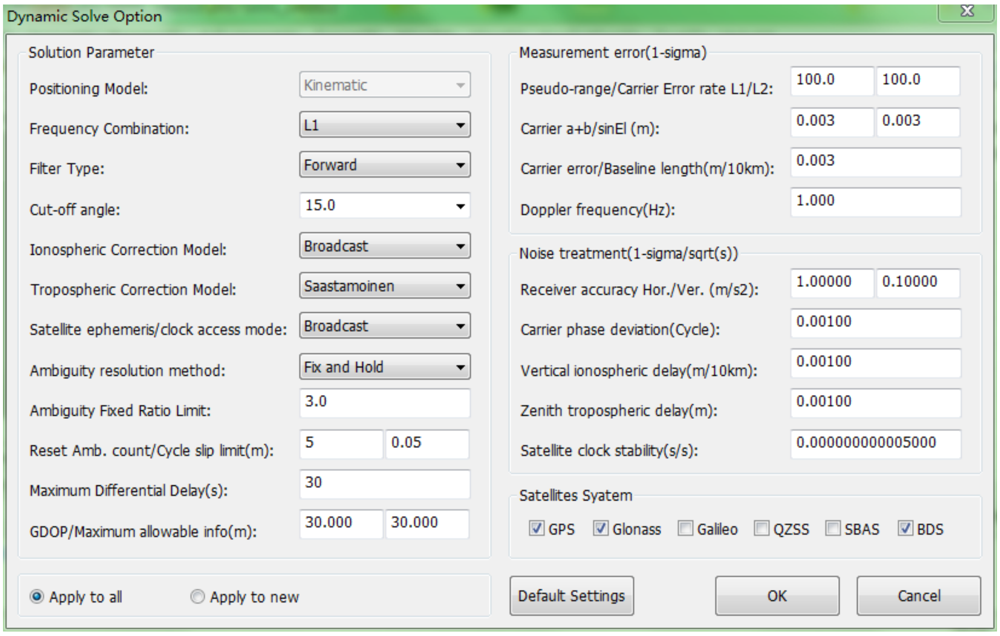


Figure 2-16

4) Baseline Processing

Click [Process] - [Process all baselines] to process all the baselines as shown in Figure 2-17. Process completes as shown in Figure 2-18. Green refers to baselines that succeed to process, while red refers to those failed.

a. Right click the unqualified dynamic baseline in the baseline table, choose [Processing settings], then modify the dynamic setting parameters to process this baseline again.

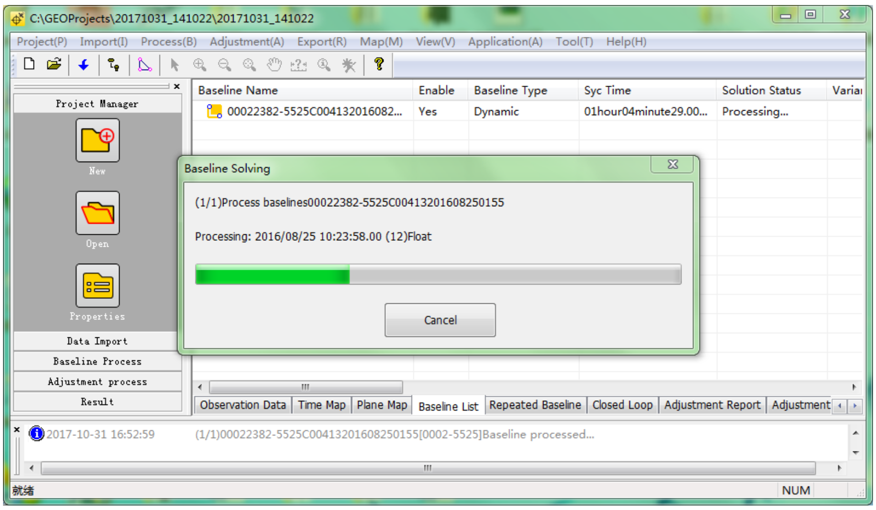


Figure 2-17

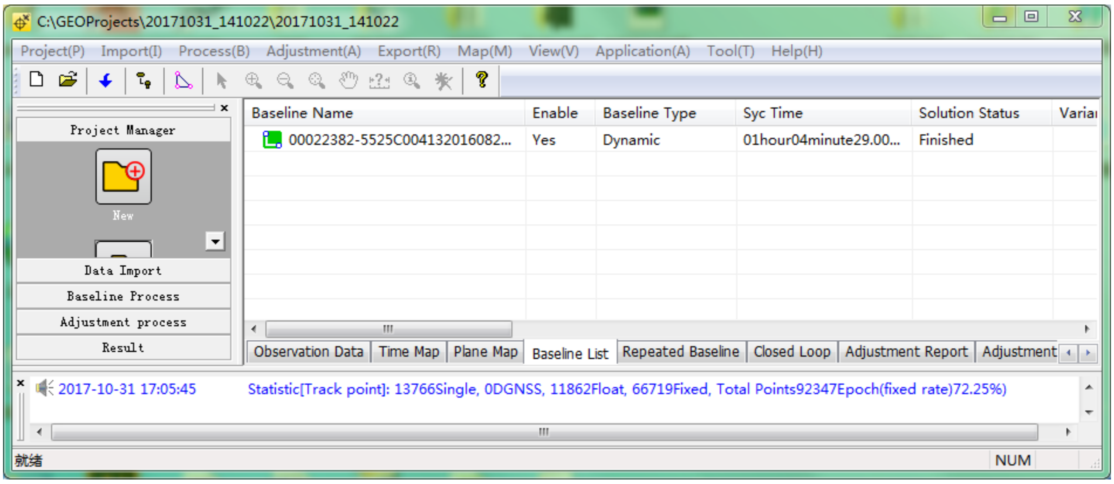


Figure 2-18

5) Check the results of the dynamic baseline solution.

Click [Result] - [View dynamic data] as shown in Figure 2-19. Green refers to points in fixed solution, yellow to points in float solution and red to points in single solution.

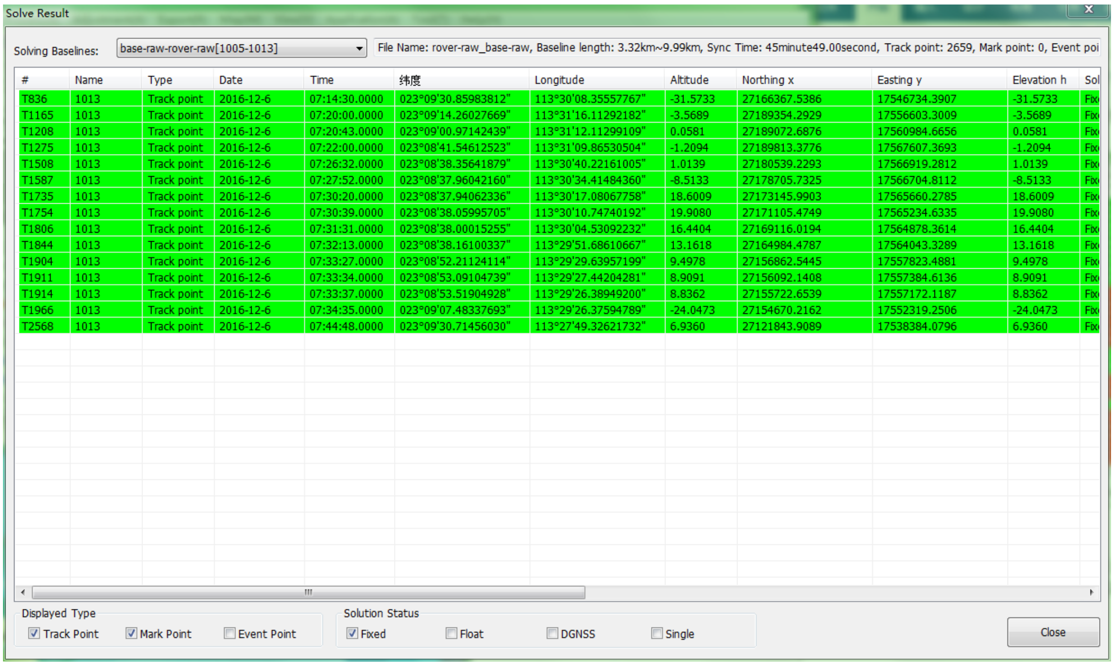


Figure 2-19

6) Export dynamic solution coordinates

Click [Export] - [Dynamic solution coordinates] as shown in Figure 2-20, choose file type, point type and solution status, then click [Export]. Select the file storage location, and the dynamic solution coordinates could be exported successfully.

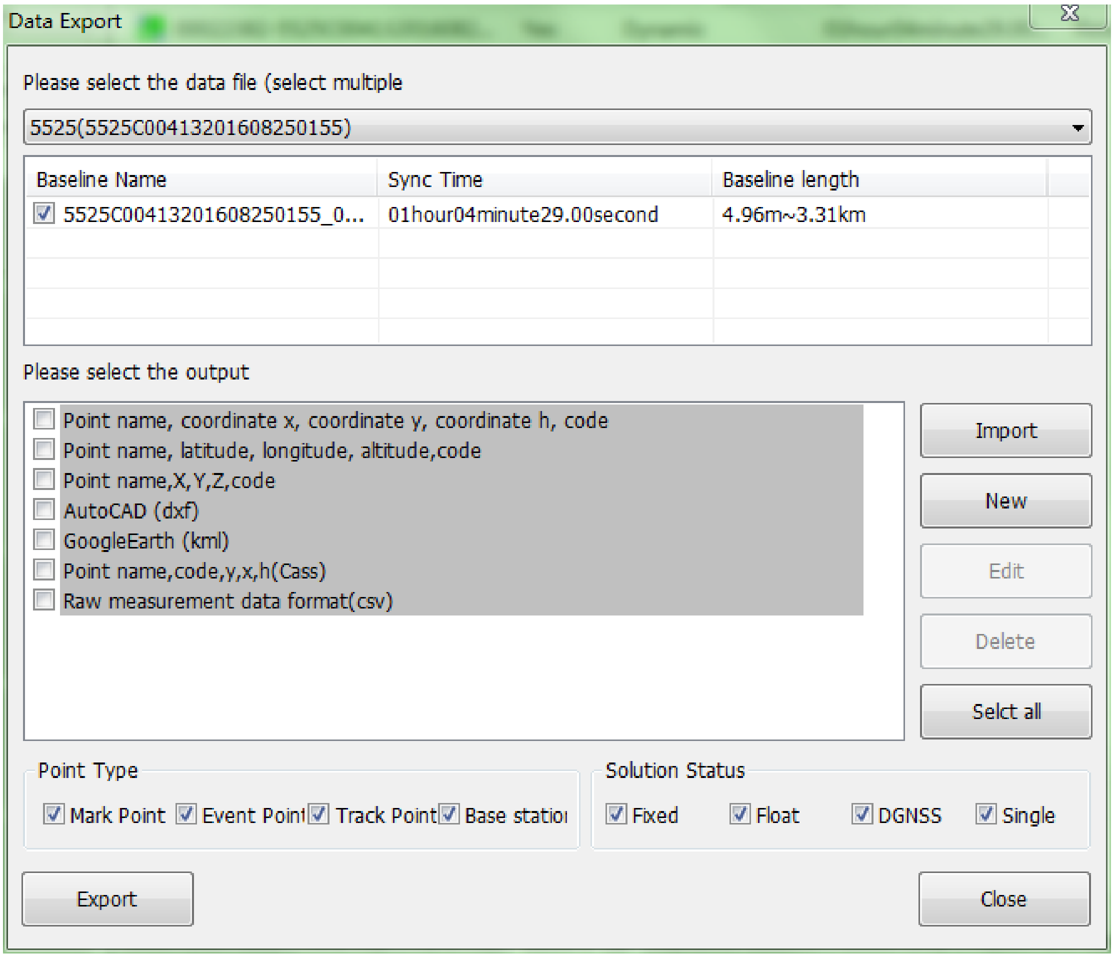

Data Export
Please select the data file (select multiple
5525(5525C00413201608250155)
Baseline Name
Sync Time
Baseline length
5525C00413201608250155_0...
01hour04minute29.00second
4.96m~3.31km
Please select the output
Point name, coordinate x, coordinate y, coordinate h, code
Point name, latitude, longitude, altitude,code
Point name,X,Y,Z,code
AutoCAD (dxf)
GoogleEarth (kml)
Point name,code,y,x,h(Cass)
Raw measurement data format(csv)
Import
New
Edit
Delete
Selct all
Point Type
Mark Point
Event Point
Track Point
Base statio
Solution Status
Fixed
Float
DGNSS
Single
Export
Close

Figure 2-20

Chapter 3 GEOSolution

GEOSolution is a professional processing software in GPS industry. Using management of establishing project file, it needs to create or open a project before data processing. The software can process data collected by third-party receivers with the aid of RINEX format data input, including the post-processing of mixed operation data from different kinds of GPS receivers.

3.1 The Main Function

1) It can deal with the observation data in the standard RINEX data format, which is advantageous to process the observation data collected by the mixed operation of different receivers.
2) It can download the observation data of IGS and CORS.
3) It can process static baseline, dynamic baseline and perform network adjustment.
4) It can export dynamic/static baseline processing results and network adjustment results.
5) All baselines can be fully automatically processed and can be individually handled manually.

3.2 Main Interface of Software

Run GEOSolution as shown in Figure 3-1. The main interface consists of a Title Bar, Menu Bar, Tool Bar, Navigation Bar, Workspace, Information Bar and Status Bar.

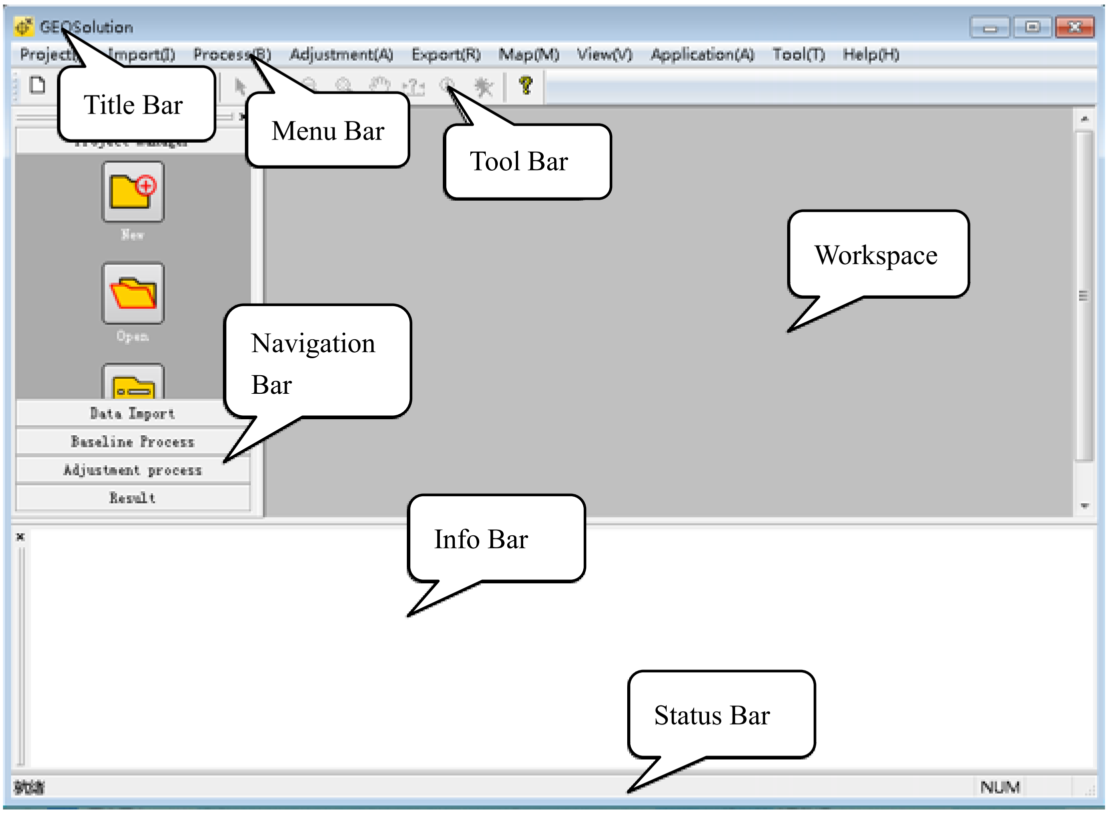


Figure 3-1

Title Bar: The initial purpose of the Title Bar is to help you quickly determine the current application class. It can provide some basic program control for you, such as restore, move, size, maximize, minimize, and close. If a project is open currently, the project save path will be displayed.

Menu Bar: The drop-down menu is an important part of any Windows application window, for providing commands of building projects, baseline solutions, network adjustment, data management, view management, etc.

Toolbar: It provides some common shortcut commands, including creating new projects, open projects, import observation data, baseline solutions, network adjustment, and the operation commands in the map of peace surface.

Navigation Bar: It stores most of the common quick commands, including project management, baseline solutions, network adjustment, and a series of commands of exporting results.

Workspace: The workspace is a major area of work for the user, usually including various diagrams related to the project.

Information Bar: It exports various status information in the processing.

Status Bar: It displays some prompt information for the current operation.

3.3 Menu Bar

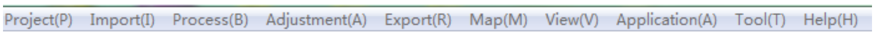


Figure 3-2

The Menu Bar contains the various functional menus of the software, namely, Project, Import, Process, Adjustment, Export, Map, View, Application, Tool, Help. The various functions are described in detail below.

3.3.1 Project

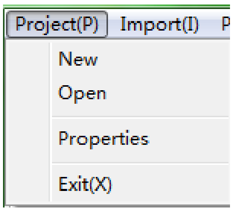


Figure 3-3

1) New

   Creating new project.

2) Open

   Open an existed project.

3) Attributes

   Check the attribute information of the project, and the attributes information can be modified after clicking open.

4) Exit

   Close the current project file and exit the software.

3.3.2 Import

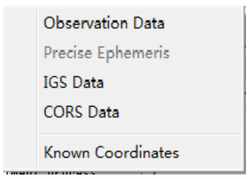


Figure 3-4

1) Observation Data

Add an observation file for the newly established project or opened project file to import *.dat and standard RINEX observation files.

2) Precise Ephemeris

Add a Precise Ephemeris file for the newly established project or opened project file to improve the precision of long baseline solution.

3) IGS Data

Add IGS station data for the newly established project or opened project file to improve the precision of solution.

4) CORS Data

Add CORS station data for the newly established project or opened project file to improve the precision of solution.

5) Known coordinate

In the case of observation data import, left-click on the known coordinates, and after adding the known coordinates to the newly established project or opened project, it will be displayed as the green solid triangle in the plane map. The known coordinates that added will be used in the horizontal surface network adjustment or vertical control.

3.3.3 Process

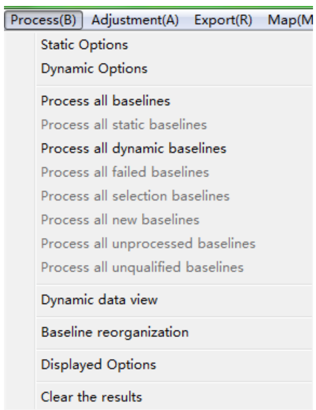


Figure 3-5

Static Options

Before the static baseline solution, ready to set the baseline processing condition, click the [Static Options] and the static solution setting dialog box is shown in Figure 3-6. The meaning of each setting item is as follows:

Basic Settings

- Solution Mode

  The general software uses the automatic solution model in initial solution. There are seven solution modes: automatic, L1, IonoFree, L2, L1L2, LN and LW.

  If user does not want to adopt the automatic mode, L1 solution model would be adopted in short baseline solution, IonoFree mode in long baseline solution, and the positioning precision can be improved by the natural LN mode.

- Ephemeris Type

  It can choose broadcast ephemeris or precision ephemeris to process the project. Generally, using precise ephemeris can improve solution precision of long baseline, and short baseline using the broadcast ephemeris can meet the requirements.

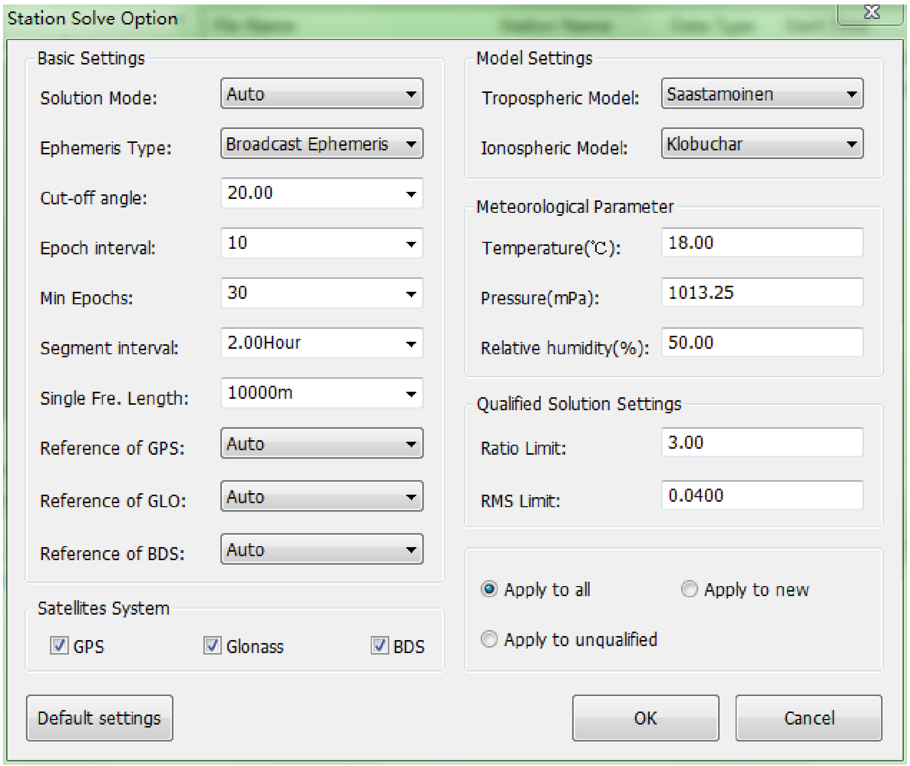


Figure 3-6

- Elevation mask angle

  Elevation mask angle is the mask angle of satellite elevation angle, which is generally used to prevent the satellite data of low altitude from participating in the baseline solution. The schematic diagram of mask angle is shown in Figure. 3-7.

  Due to the atmosphere's influence on low altitude satellite signal is more complex, and more difficult to use model to correct. What's more, due to the signal in low altitude is vulnerable to the influence of various factors such as multipath, electromagnetic wave, the signal quality is usually low. Therefore, usually it must eliminate them in data processing.

  From the angle of atmospheric refraction, the mask angle can be reduced in the case of short distance observations. For long distance observations, the mask angle should be increased, because the shorter the distance, the more easily the atmospheric refraction effect will cancel each other out. Of course, the setting of mask angle also needs to refer to the surrounding environment. The default mask angle of the software is 20 degrees.

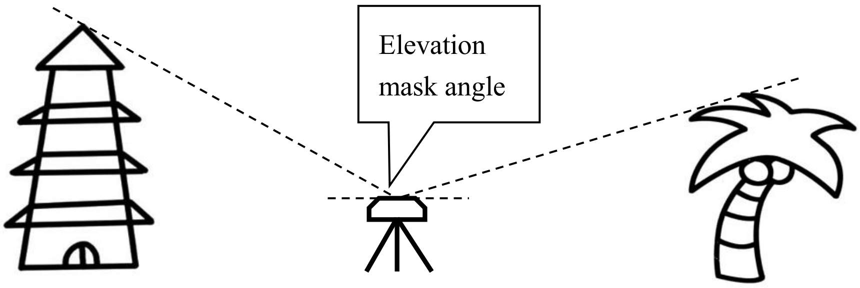


Figure 3-7

- Epoch Interval

  The epoch interval is the time interval at which the software extracts data from the original observation data when the baseline is processed. For short baseline, it is appropriate to reduce the epoch interval. For a long baseline, it is appropriate to increase the epoch interval.

  For example, two receivers are set to collect a set of data every 1 second in static observation, but in the case of indoor processing, such high density observational data usually can’t significantly improve the precision of the baseline, but greatly increases the time of baseline processing. Therefore, to improve the speed of baseline processing, users can appropriately increase the epoch interval of data processing.

The default epoch interval of the software is 10 seconds.

- Min Epoch

  Because in observation, the receiver must observe the continuous carrier phase. For example, if successive cycle slips occur in a piece of data, the quality of this data is usually poor and often affects the quality of the baseline processing. Therefore, the data should usually be excluded. Hence, in baseline processing, the software will remove the data segments that its consecutive observation epoch does not exceed the min epoch.

  The default min epoch of the software is 30 seconds.

- Segment Interval

  It will be divided into several time segments to process when the baseline data observation time segment exceeds the setting value. When you set the segment interval, you can set it to any value, or you can select it in the drop-down box (option 2, 4, 6).

  The default segment interval of the software is 2 hours.

- Single Fre. Length: When the single frequency baseline length is greater than the set value, if it does not fix the ambiguity and the baseline solution is failed.

  The default single frequency baseline length of the software is 10000 meters.

- Reference GPS

  The double differential observed value forms when the single differential observed value is processing between the satellites. Therefore, in order to facilitate the processing, the software adopts to select the reference satellite in forming double differential observed value.

  The default setting is automatic mode. At that time, the software will select the satellite that with maximum observed data and the bigger elevation angle as a reference satellite. However, due to the influence of observation conditions, such a choice may not be the most reasonable. When choosing an inappropriate reference satellite, it will affect the baseline processing results. At this point, user is required to reset the reference satellite according to the condition of the observed data.

- Satellite System Settings

GEOSolution data processing software supports arbitrary combination of GPS, GLONASS and BDS (BEIDOU) satellite system for solution.

Model Settings

In general, there is no need to modify the troposphere and ionosphere model Settings. When using the medium or long baseline, it can be set according to the actual situation to improve the precision of the solution. There are two troposphere models to choose: the Saastamoinen model and the Hopfield model. The ionosphere can choose the Klobuchar model or directly choose none model.

Meteorological parameter

In general, no modification of meteorological parameter Settings is required. According to the actual situation and specific requirements of the project to modify if needed.

Qualified Solution Settings

- Ratio Limit

Ratio is the ratio between the second smallest mean square error and the smallest root mean square error produced when the search algorithm is used to determine the integer value of the parameter of unknown number in the whole cycle.

It reflects the reliability of the determined parameter of unknown of the whole cycle. The higher the value, the higher the reliability. When the processing value is less than the set value, the baseline solution fails.

The default Ratio limit of the software is 3.00.

- RMS Limit

  RMS is the Root Mean Square, which is used to determine the quality of the observed data. The smaller the RMS, the better the observed data quality; Conversely, the worse the observed data quality is.

  The default RMS limit of the software is 0.04.

1) Dynamic Solve Option

   As shown in Figure 3-8, the dynamic option setting contains four aspects of the settings, such as solution parameters, measurement errors, noise processing, and satellite systems.

   Generally, only need to modify several settings of parameters that are following, according to the specific requirements and the actual situation of project to set the rest of the settings of parameters, or to maintain the default settings can be.

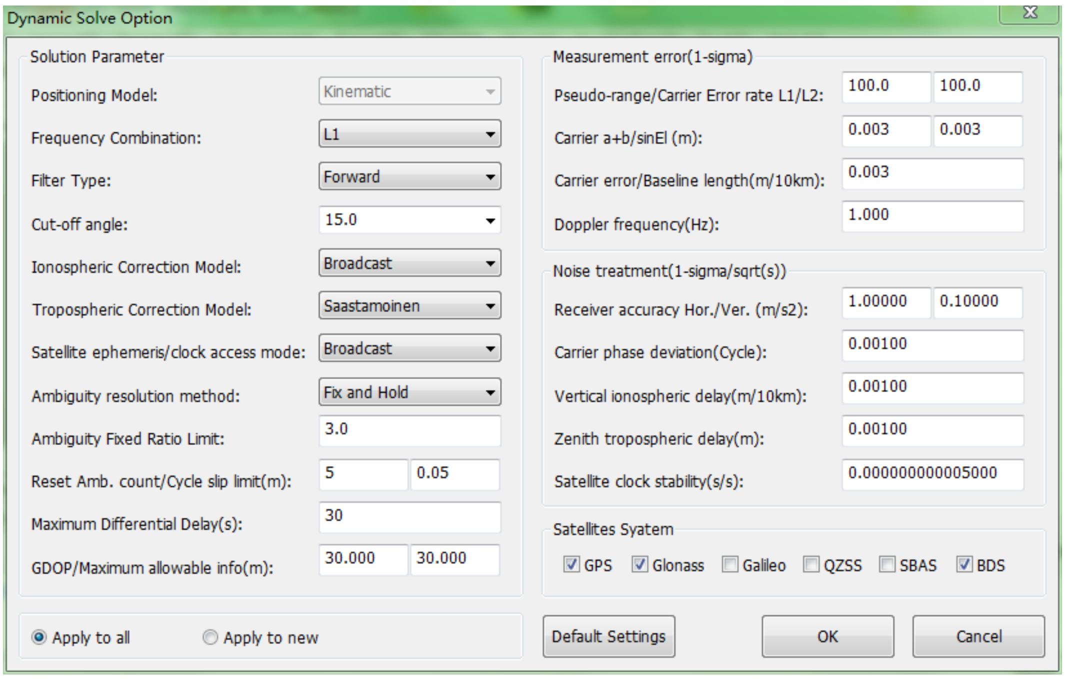


Figure 3-8

- Mask angle: The mask angle of satellite elevation angle, which is generally used to limit the satellite data of low altitude, so that it will not participate in the baseline solution. The default mask angle of the software is 15 degrees.
- Ambiguity fixed Ratio limit value: This value reflects the reliability of the

parameter of unknown number of the whole cycle, when the Ratio value of the solution is less than the set limit value, the baseline solution is failed.

The default Ratio limit of software is 3.0.

- Reset ambiguity count/cycle slips limit value: Because in the observation process, the receiver must observe the continuous carrier phase, for example, if successive cycle slips occur in a piece of data, the quality of this data is usually poor. Therefore, when the time of cycle slips exceeds the limit value of the cycle slips, it will reset ambiguity count as set value.
- Maximum differential delay: To judge the quality of observational data, when the differential delay value is greater than the set value, the data quality is poor and needs to be eliminated.
- GDOP/ Maximum allowable info threshold: Used to judge the quality of geometric combination of space satellites.

2) Baseline Solution

According to the baseline situation, it can be divided into processing all baselines, processing all static baselines, processing all dynamic baselines, processing all failure baselines, processing all chosen baselines, processing all newly increased baselines, processing all unsolved baselines, processing all unqualified baselines.

3) Dynamic Data Viewing

The dynamic data view interface, shown in Figure 3-9, allows users to view the solution results of all dynamic baselines in this interface. The display solution results include: Point Name, Type, Date, time, Latitude, Longitude, Altitude, Northing x, Easting y, Elevation h, Solution status, Satellite number, Standard residual (N), Standard residual(E), Standard residual (U), Differential delay, Ratio, Antenna height, Base station ID, Base station distance, Device Serial Number, File Name. In addition, you can select the display content, and the options available have [display type] and [solution status].

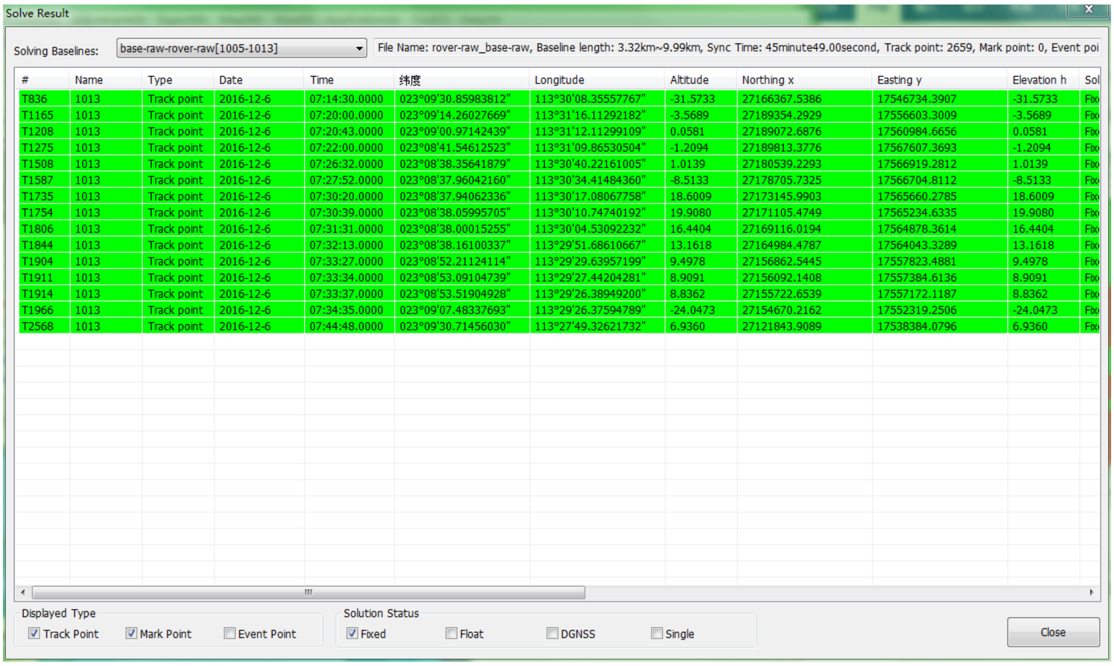


Figure 3-9

4) Baseline Restructuring

Cancel the results of all baselines solution.

After processing of baselines in the project, if need to modify the solution setting and solve baselines again, after modifying solution settings parameters, left-click [Baseline restructuring] and cancel all the results of the baselines, then process the baselines again. At this point, it will process based on the new solution parameters setting. Otherwise, the baseline solution is based on the original solution settings.

5) Show Option

Set up the display information of the plane map, including the display of the Station Point File, Point Type, Solution Mode and Display Map, as shown in Figure 3-10.

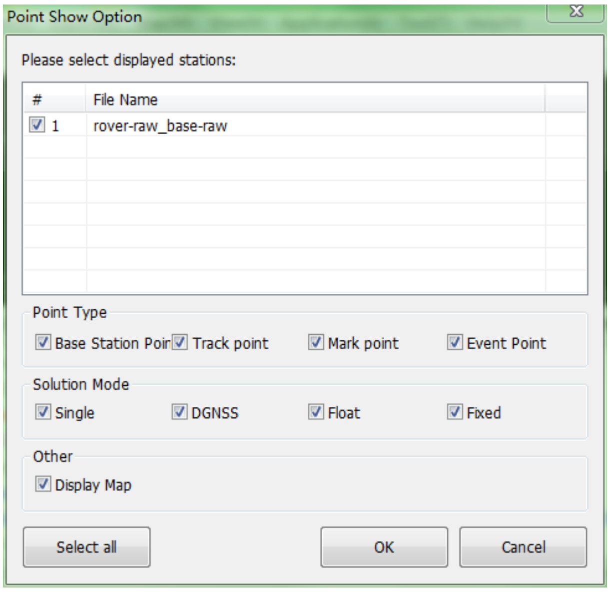
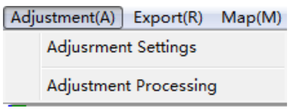


Figure 3-10

6) Delete the Solution

Cancel all baseline solutions.

3.3.4 Adjustment



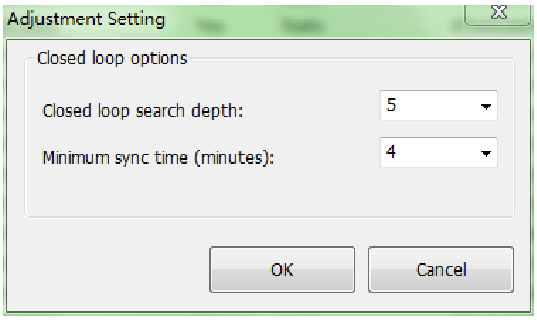


Figure 3-11 Figure 3-12

1) Adjustment Setting (show in Figure 3-12)

Closed loop search depth: For adjust the number of sides of closed loop, for example, set the closed loop search depth to 3, so the number of baseline vectors that make up a closed loop cannot exceed 3.

Minimum sync time: The baseline will not participate in the solution when the synchronous observation time is less than the set synchronization time value.

2) Adjustment Processing

GEOSolution bases on adjustment settings and control network level settings to perform network adjustment solution. The network adjustment can be divided into three-dimensional adjustment, horizontal adjustment and vertical control according to the situation of the input known point.

3) Export Adjustment

After adjustment processing, click [Export] – [Export Static Results], choose the adjustment report as file type, select the file save path, as shown in Figure 3-13. Click [Export], and it will export the adjustment report.

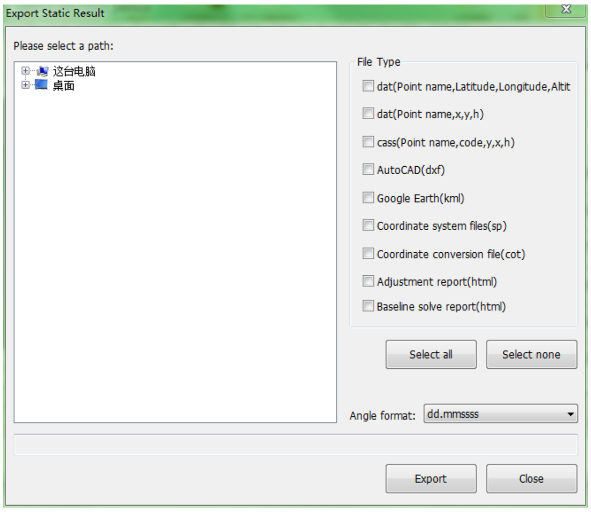


Figure 3-13

3.3.5 Export

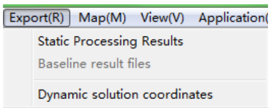


Figure 3-14

1) Static Processing Results

Static Solution results pop-up box as shown in Figure 3-15, users can export and save the static processing result file as various file type for facilitating following work. Export file type supports single and multiple selections.

File types are divided into: dat (point name, latitude, longitude and elevation), dat (point name, coordinates x, coordinate y, coordinate h), cass (point name, code, coordinates y, coordinates x, coordinates h), AutoCAD (dxf), Google Earth (kml), coordinate system files (sp), coordinate transformation file (cot), adjustment report (html), baseline solution report (html).

Users can set their own path to save the static result file.

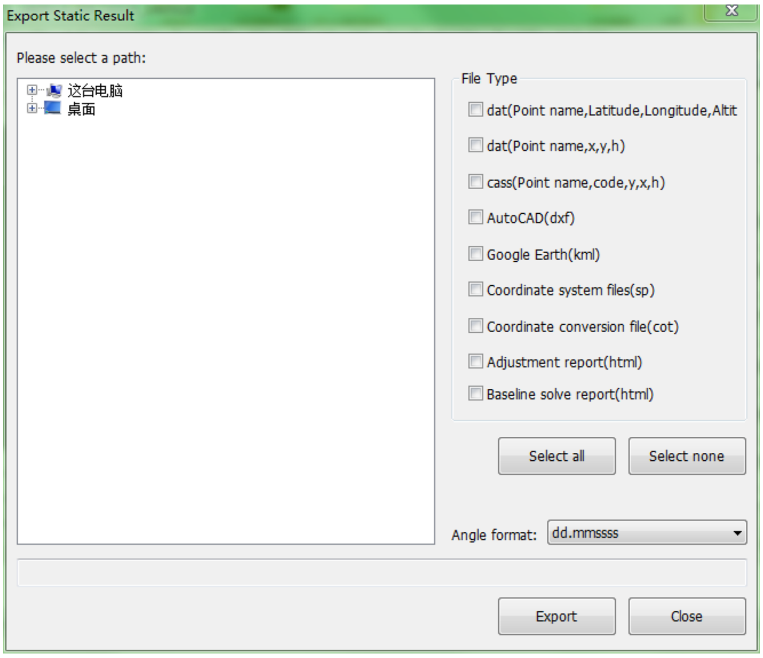


Figure 3-15

2) Baseline Result File

The pop-up box of baseline results file as shown in Figure 3-16, users can export and save the baseline results file as various file type for facilitating later. The export file type is divided into all baselines and qualified baselines.

The export format is divided into: PowerAdj3.0 Trimble, SOUTH, TGO, TGPPS Ski Pro and GeoElectron. Users can set their own path to save the baseline results file.

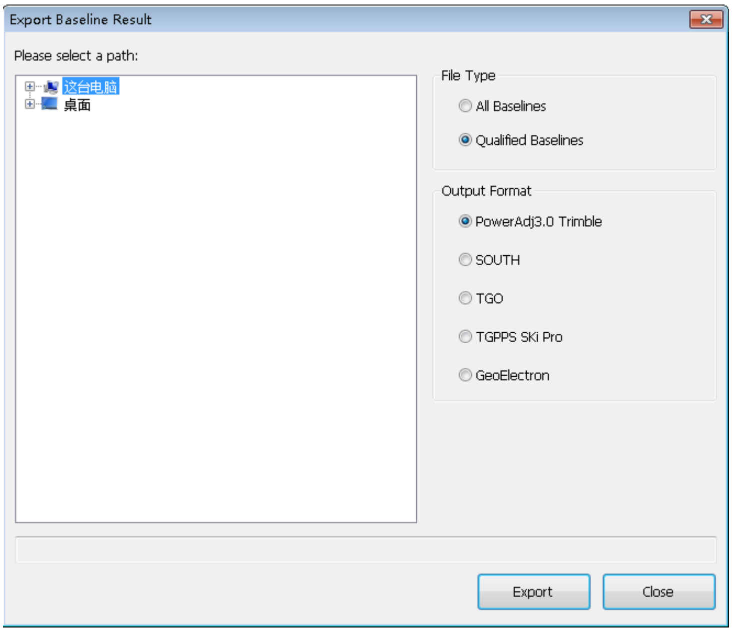


Figure 3-16

3) Dynamic Solution Coordinate

The pop-up box of dynamic solution coordinate as shown in Figure 3-17, user can export and save all or part of the dynamic solution coordinates according to the project management and analysis needs.

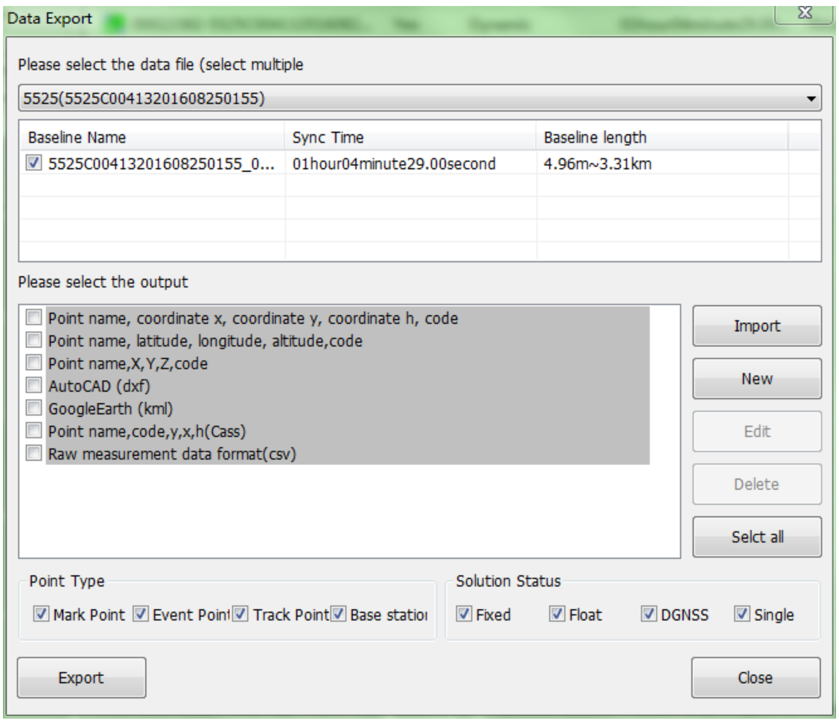


Figure 3-17

Operation step: select data file —> select baseline —>set output type —>set the point type and solution status of export data —> export.

Click [Import] on the right to import the saved output type into the project and display it in the list on the left.

Click [New] on the right to pop-up the [Custom] Output type setting box as shown in Figure 3-18.

Select the content the user wants to display, click [Add], and repeat until the user add all the displayed content they need. The display contains the following: Point name, date, time, latitude, longitude, elevation, coordinate X, coordinate Y, coordinate Z, North coordinate X, East coordinate Y, Elevation H, Solution Status, number of satellite, HRMS, VRMS, differential delay, Ratio, base station distance, covariance.

Below the pop-up settings box, you can set a custom format's separator symbol, angle format, extension name, and whether to write a file header, or keep the software defaults.

Click [OK] to complete the settings of custom format.

For new custom output types, the software provides an [Edit] and [Delete] operation. For the seven types of export that the software comes with, the software does not provide [Edit] and [Delete] operations.

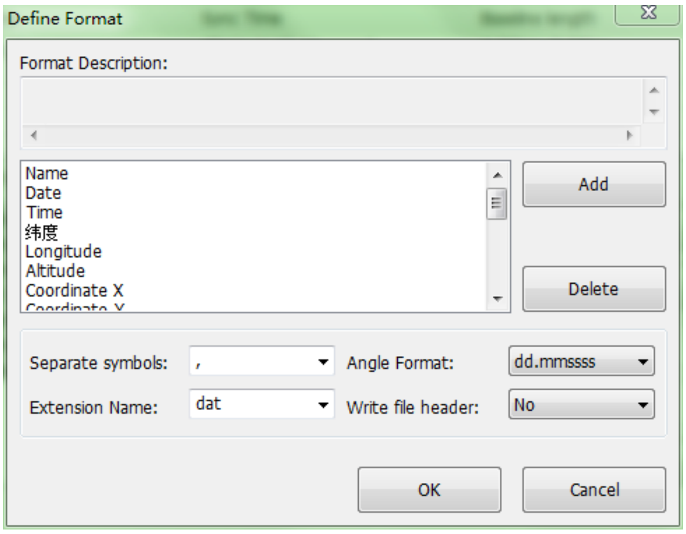


Figure 3-18

3.3.6 Map

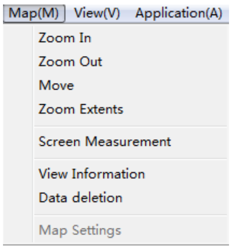


Figure 3-19

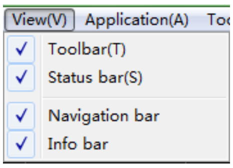


Figure 3-20

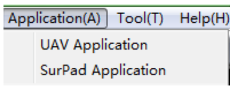


Figure 3-21

The map Menu Bar is designed specifically for planimetric maps, which contains a series of operation commands for planimetric map. Zoom In, Zoom Out, Move, Zoom Extents, Screen Measurement, View Information, Data deletion, map settings, as shown in Figure 3-19.

The meaning of the operation instructions can be referred to Toolbar introduction in section 3.4.

3.3.7 View

Toolbar, Status Bar, Navigation Bar and Information Bar can be set in view Menu Bar whether to be displayed in the main interface to facilitates user, as shown in Figure 3-20.

3.3.8 Application

The application Menu mainly includes [UAV Application] and [SurPad Application], as shown in Figure 3-21.

1) UAV Application

The UAV application is mainly to import and export UAV observation data, as shown in Figure 3-22.

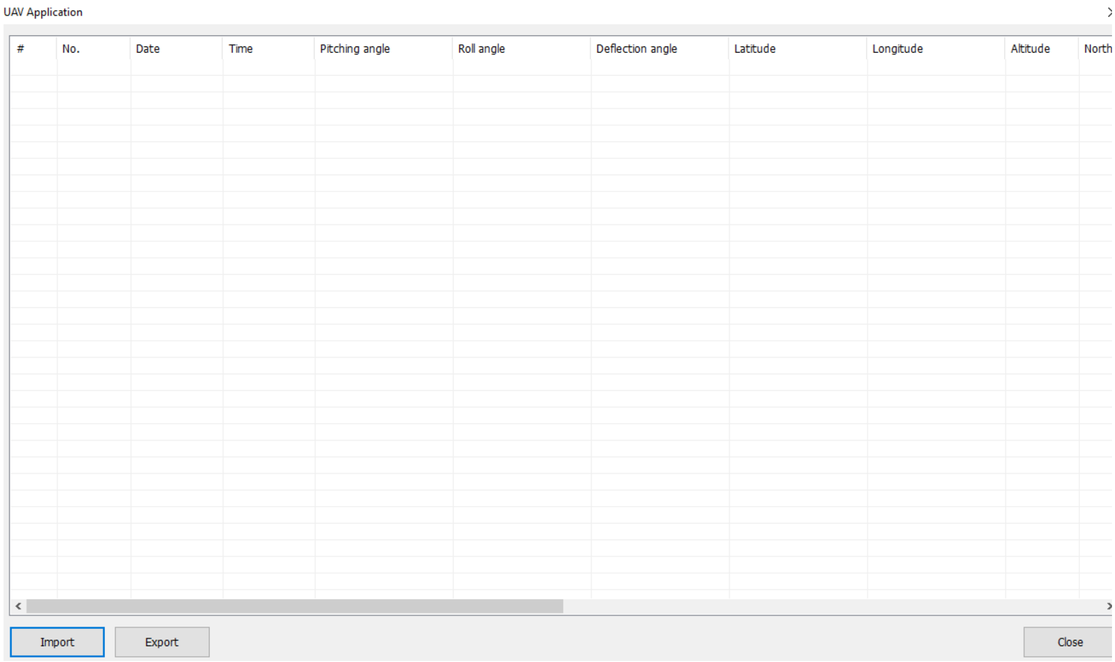


Figure 3-22

2)SurPad Application

Surpad application is to import the data collected by the Surpad software to calibrate the precision of the data in the baseline solution, and the data imported by the Surpad application will replace the low precision part of the original observation data. Click [Open Project], as shown in Figure 3-23, open the *.GSW file, as shown in Figure 3-24, select the data file, and the data import success as shown in Figure 3-25. Select a point, click [Detailed Info], as shown in Figure 3-26, to view real-time positioning information of this point. Click [Start processing], as shown in Figure 3-27, the imported project data will be compared with the imported observation data, and will automatically replace the low precision observation data.

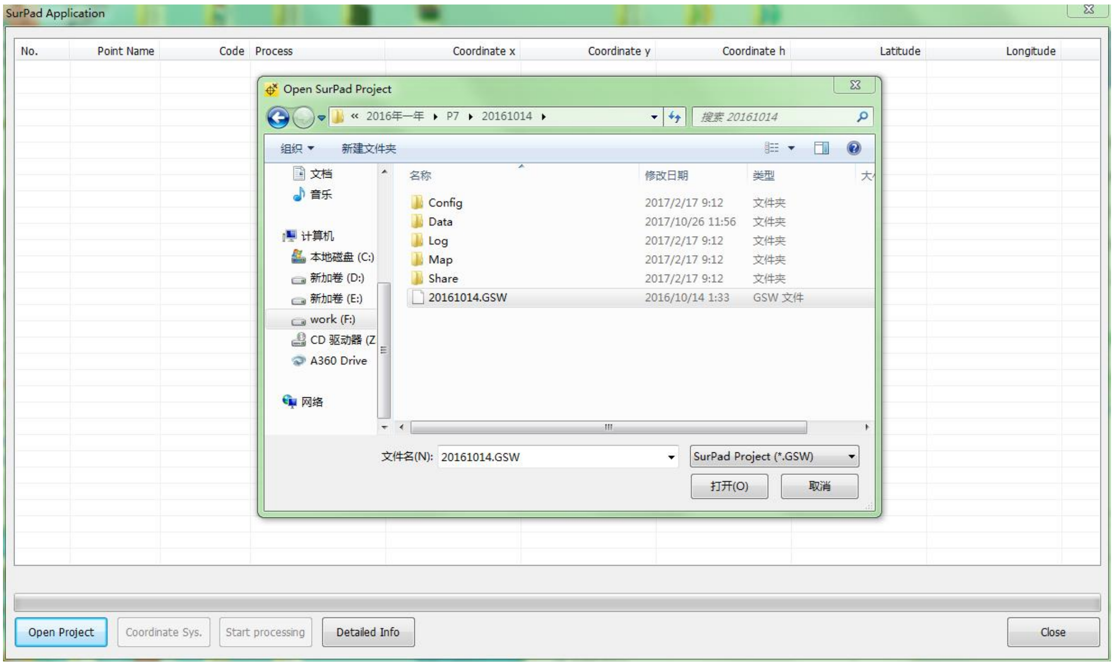


Figure 3-23

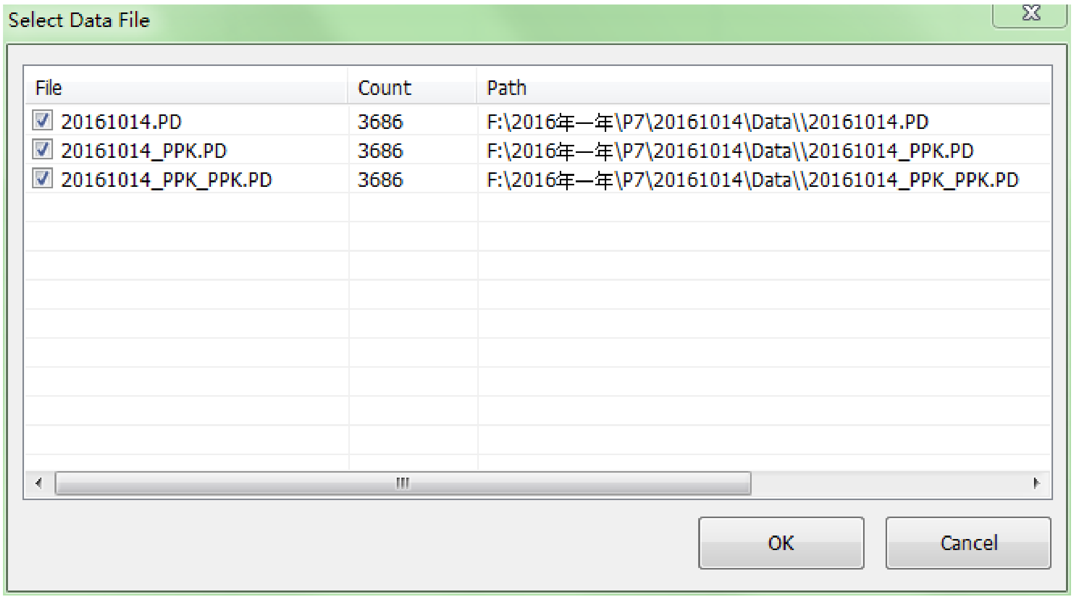


Figure 3-24

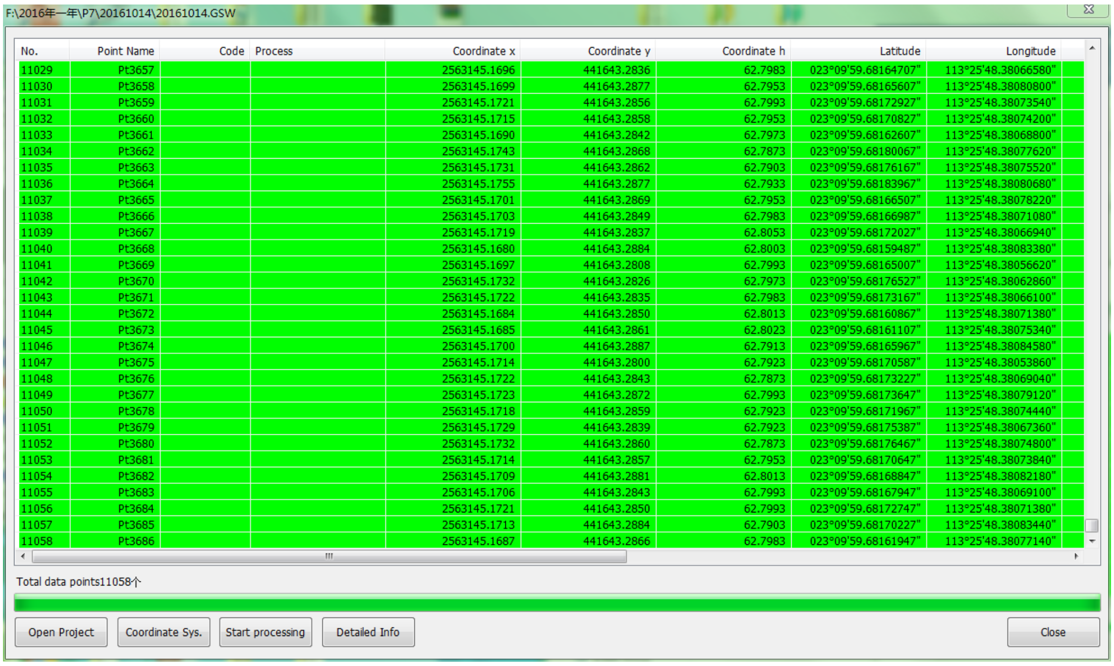


Figure 3-25

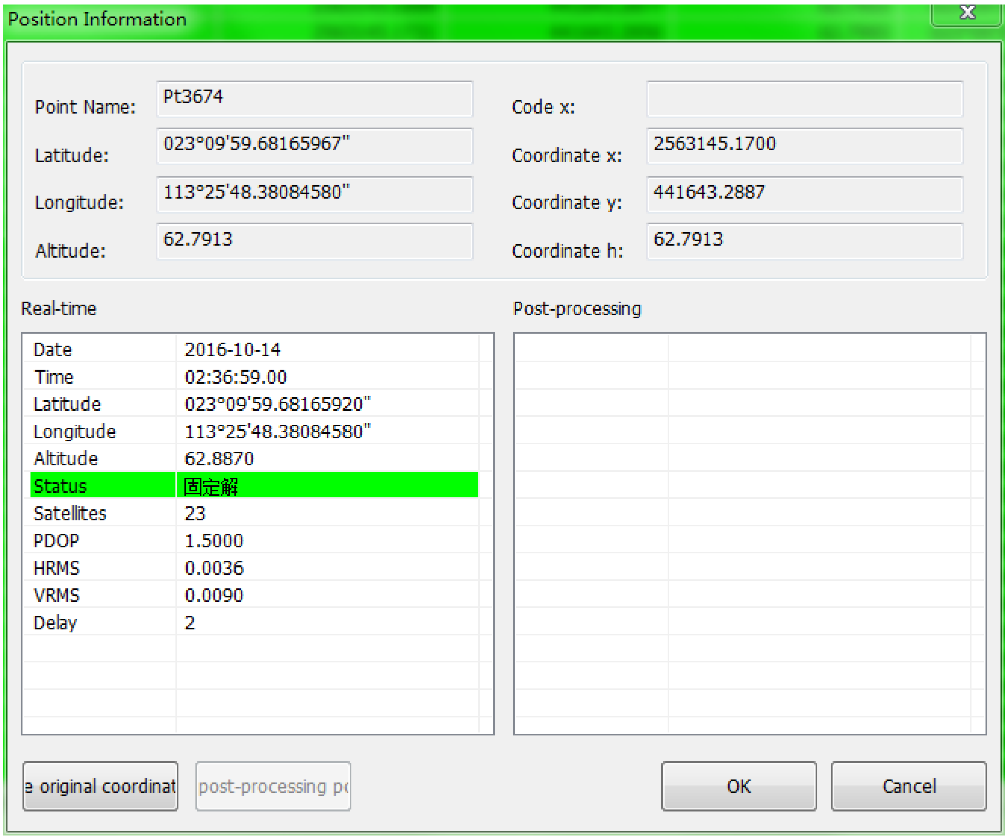


Figure 3-26

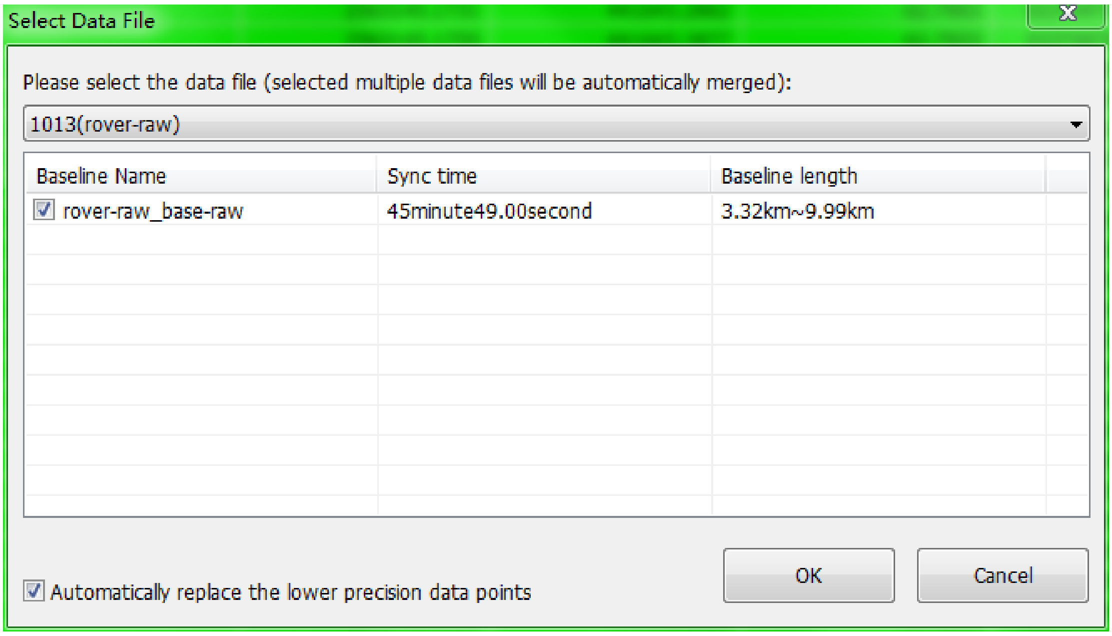


Figure 3-27

3.3.9 Tool

The tool menu mainly includes the [RINEX Converter] and the [Observation Files Merge] two tools, as shown in Figure 3-28.

1) RINEX Converter Tool

Enter the RINEX Converter Tool, which can convert data files in any format, as shown in Figure 3-29. Detailed explanation of RINEX data can be queried in appendix 2.

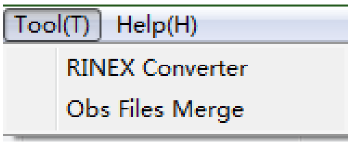


Figure 3-28

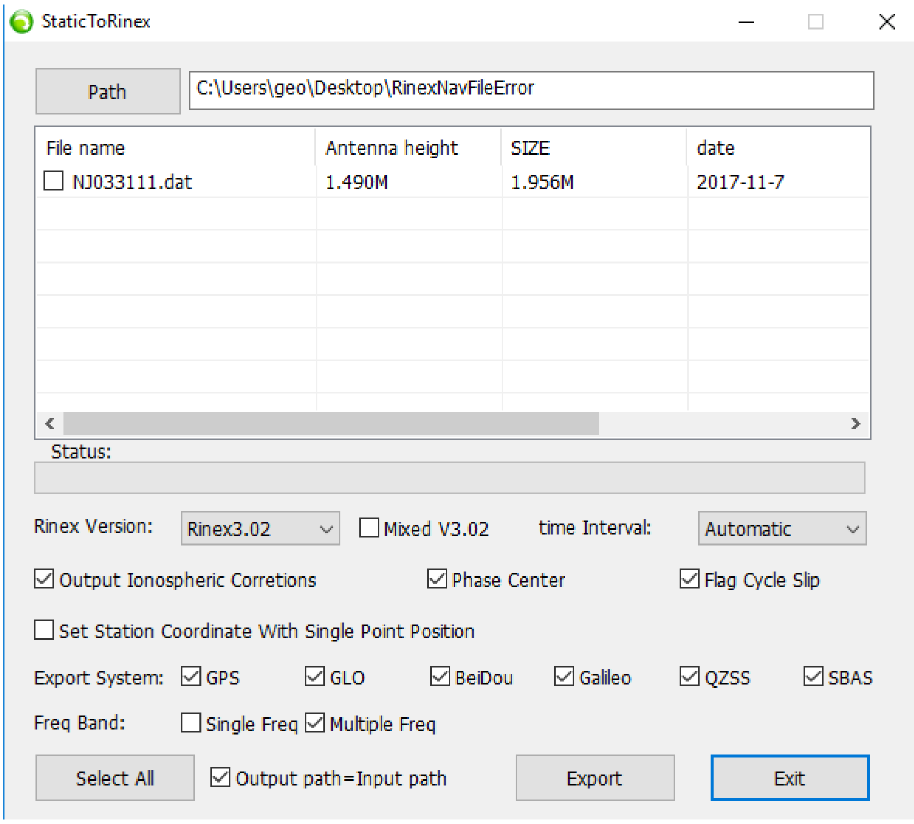


Figure 3-29

2) Observation files Merge

Enter the Observation Merge tool, which can merge multiple observational files, as shown in Figure 3-30. Click [Add] to import the observation data files, click [Delete to delete a single file, click [Clear] to delete all the files in the list, and click [Merge] to merge all the files in the list and export to the user's own optional path.

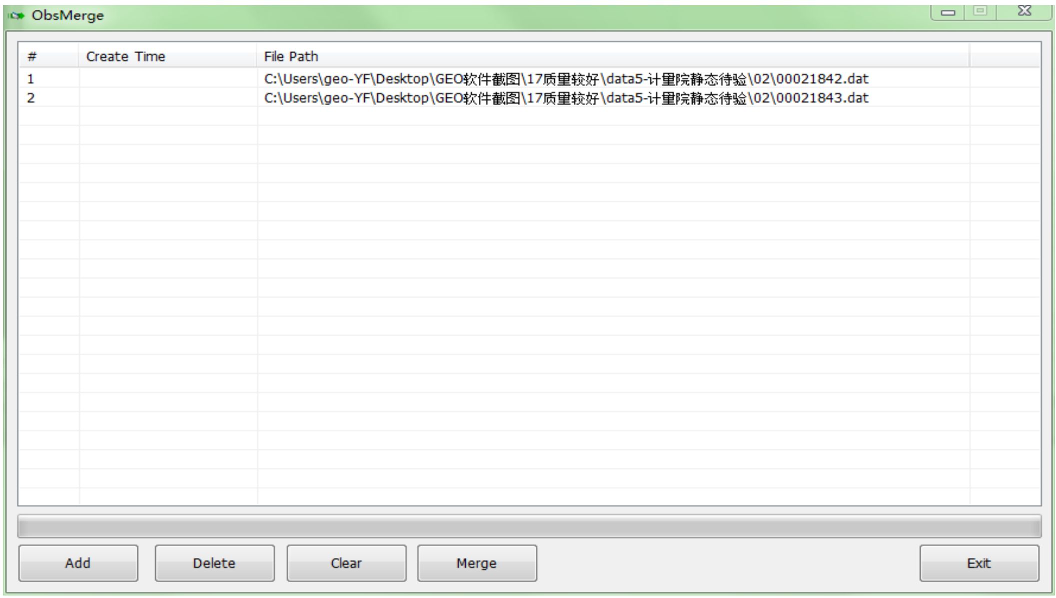


Figure 3-30

3.3.10 Help

The Help menu, shown in Figure 3-31, contains two items: Register and About GEOSolution.

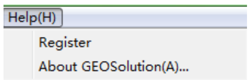


Figure 3-31

1) Register

As shown in Figure 3-32, enter the registration code then clicking [Register], user can use the full function of the software after successful registration. Click [Auto Get] when have no registration code and then user can use the software for free in 7 days.

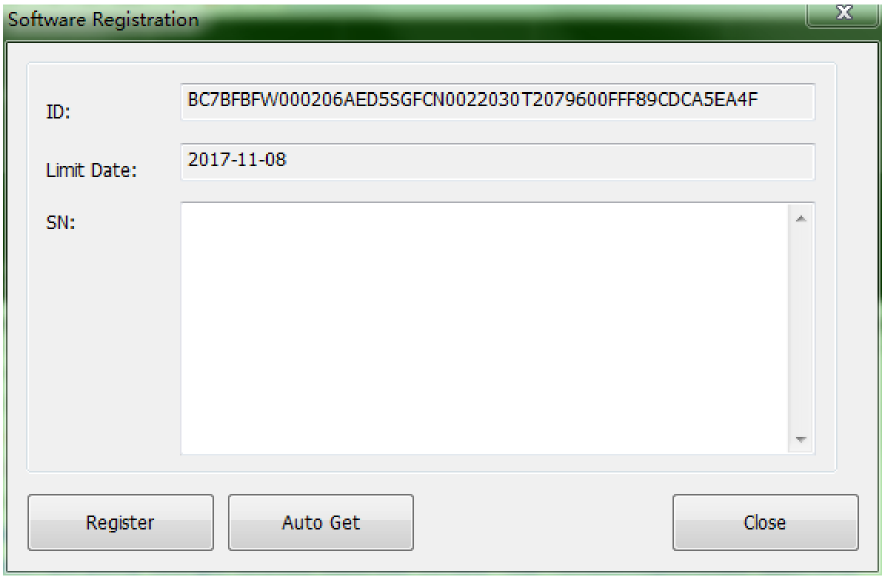


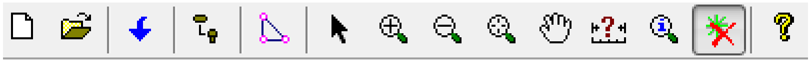
Figure 3-32

2) About GEOSolution

Click [About GEOSolution], as shown in Figure 3-33, to see the version and service time of the GEOSolution.

Figure 3-33

3.4 Toolbar



There are shortcut keys of part of operation commands added to the Toolbar, and the meanings of shortcut keys are as follows:

 New Project Key

 Open Project Key

 Import Observation Data Key

 Baseline Solution key (Default all baselines)

 Net Adjustment Key

 Selection Key, to choose the stations and baselines in the map

 Zoom in key, to zoom in the plane map to display

 Zoom out key, to zoom out the plane map to display

 Zoom the plane map extents to fit the screen.

Move key, to move the plane map

 Screen Measurement Key

 Viewing Key, to view to station points and baselines in the map

 Delete Key, to delete the station points and baselines

 Software Version Viewing Key

3.5 Workspace

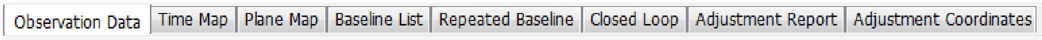


Figure 3-34

The workspace is the main area of the user's work, which contains eight options, namely Observation Data, Time Map, Plane Map, Baseline List, Repeated Baseline, Closed Loop, Adjustment Report, Adjustment Coordinate. The eight-options display different content. The options are free to switch between, easy to operate and view the information.

3.5.1 Observation Data

In the list of observation data files in the workspace, displays detailed information about each observation data file, including file name, station name, data type, start time, end time, antenna height, method of measurement, height of measurement, antenna type, data version, device serial number, and full path of saved file.

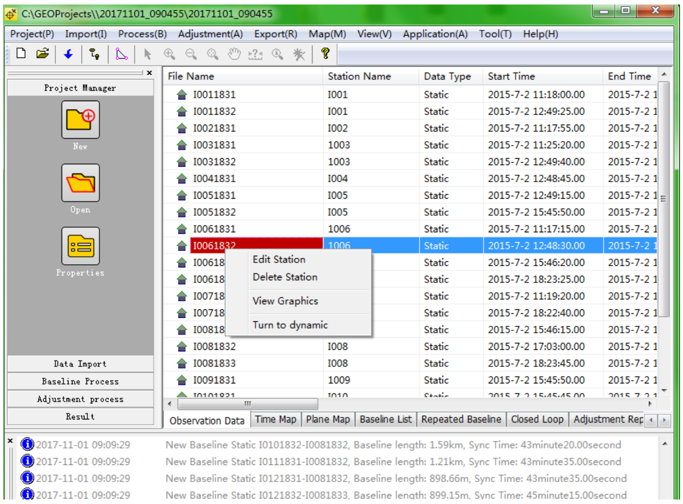


Figure 3-35

Select any one of the target files in the file list, right-click, and pop-up the Drop-down box, as shown in Figure 3-35.

[View Graphics]: As shown in Figure 3-36, you can view the tracking status of satellite data in the observation file, in which the interrupt part indicates conditions that the receiver has lost satellite's track and other conditions.

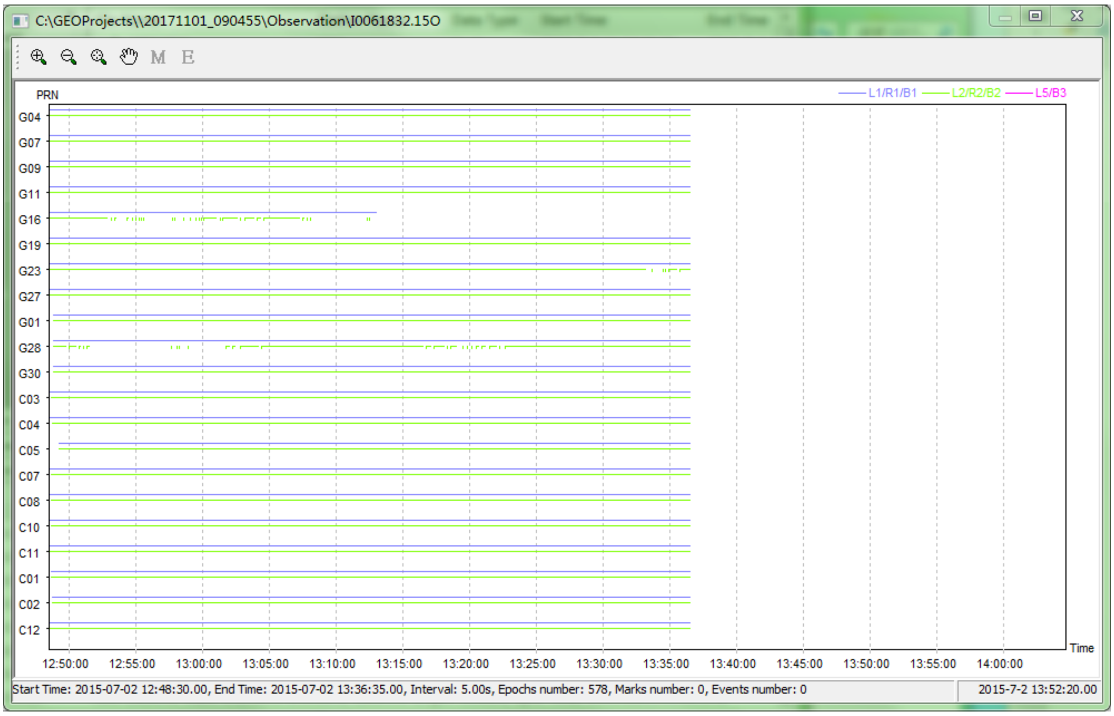


Figure 3-36

[Edit Station]: Left click “Edit Station”, the pop-up dialog box is shown in Figure 3-37, which contains information such as station settings, antenna parameters, antenna height, etc. In the pop-up dialog box, you can modify the parameters of station name, antenna type, and antenna height.

[Delete Station]: you can remove the observation file from the selected station from the list.

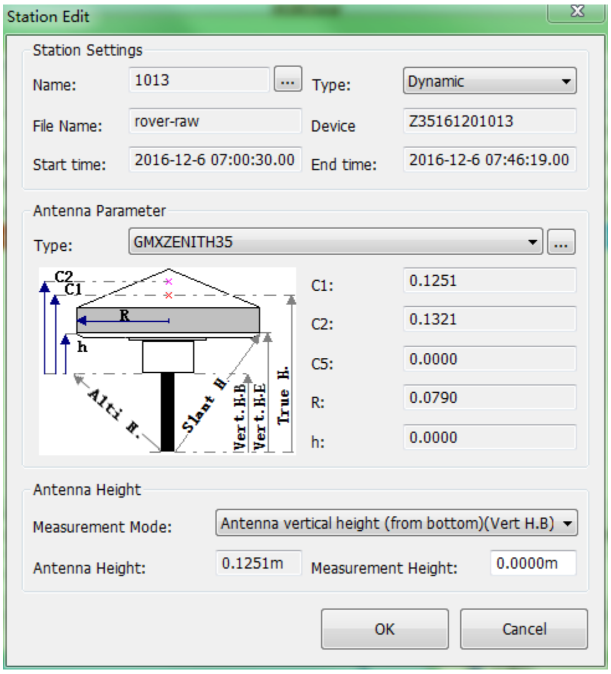


Figure 3-37

[Turn to Dynamic]: The selected observation file data type can be changed from static to dynamic.

3.5.2 Time Map

As shown in Figure 3-38, the observation time of each station is shown separately according to the type of the station (dynamic, Static), because the precondition of the baseline solution is that there must be synchronized observation data between stations, that is, the common observation time. The user can visually observe whether there is a common observation time between the station and the station through time map, whether the data of the observation station can be baseline processed.

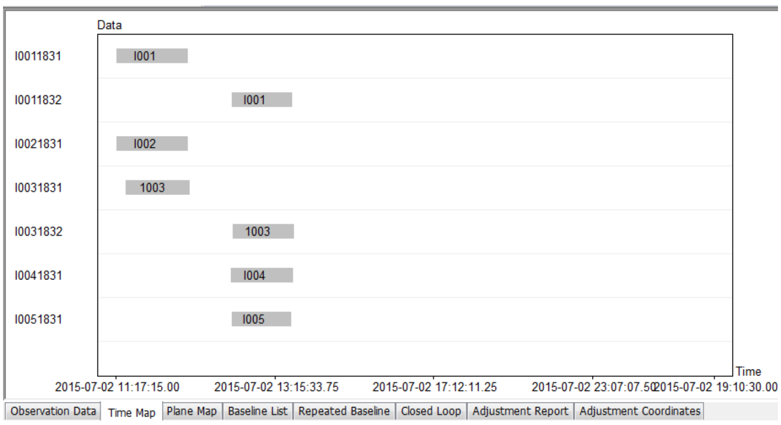


Figure 3-38

3.5.3 Plane Map

The plane map mainly shows the project's auxiliary information such as the station, baseline information and scale, grid reference line and so on.

You can view and modify the station and baseline information by using shortcut keys .

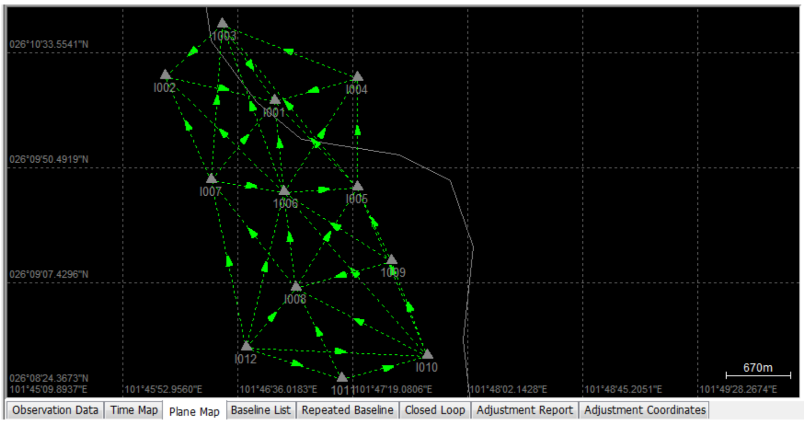


Figure 3-39

Station: The triangle represents the observation station, the gray triangle represents the general observation station, the green triangle indicates that the observation station is a known point.

Baseline: Line segments with arrows represent baselines. The gray baseline indicates that the baselines have not been processed or processed fail, and the green baseline indicates that the baselines have been successfully processed.

Error ellipses: After completion of network adjustment, the error ellipse of the baseline will be shown in blue, which can be used to judge the solution quality of the baseline.

3.5.4 Baseline List

It displays the details of all the processed baseline in list format, includes whether baselines are enabled, baseline name, baseline type, sync time, solution status, variance ratio, mean error, horizontal component, vertical component, x increment, y increment, z increment, baseline length, relative error, azimuth angle, horizontal distance, elevation difference, start point x, start point Y, Start point Z, end point x, end point y, end point Z.

In the baseline list, the green part is the baselines of successful solution, the red part is the baselines of the failed solution, and the blue part is the new added baselines. The user can modify the parameters of solution setting and process the failed baselines again.

Select any one of the baselines, right-click and the pop-up menu as shown in Figure 3-40. The related operation of baseline can be processed through the pop-up menu, including baseline information, solution settings, processing again, delete baseline, enable baseline, disable baseline, end point exchange.

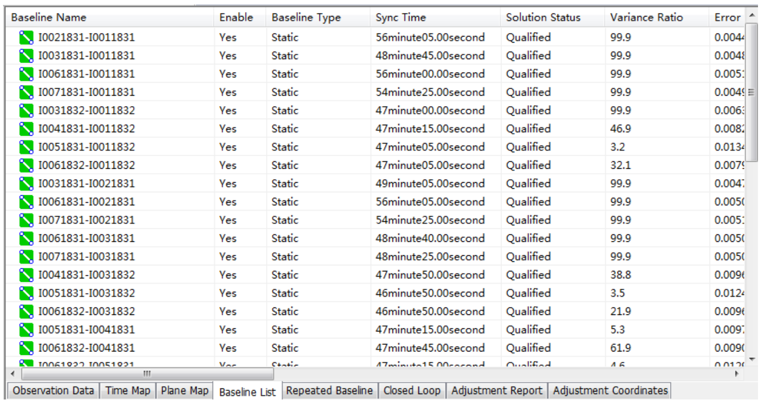


Figure 3-40

[Baseline Information]: View the detail information of selected baseline.

[Solution Settings]: Modify the condition of baseline solution, and process the baselines according to the new solution settings.

[Reprocess]: Reprocess the selected baselines according to the original solution settings.

[Delete baseline]: Delete the selected baselines from the baseline list.

[Enable Baseline]: Re-enable the disable baselines, that is, these baselines can be processed again in data processing, such as net adjustment.

[Disable Baseline]: Disable the selected baselines, and these baselines can’t be processed again in data processing, such as net adjustment.

[Terminal Point Exchange]: To exchange the start point and end point of the selected baseline vector, such as: baseline vector I002-I001 change to I001-I002.

Double-click the selected baseline after processing the baseline can view the baseline vector’s detail information of solution.

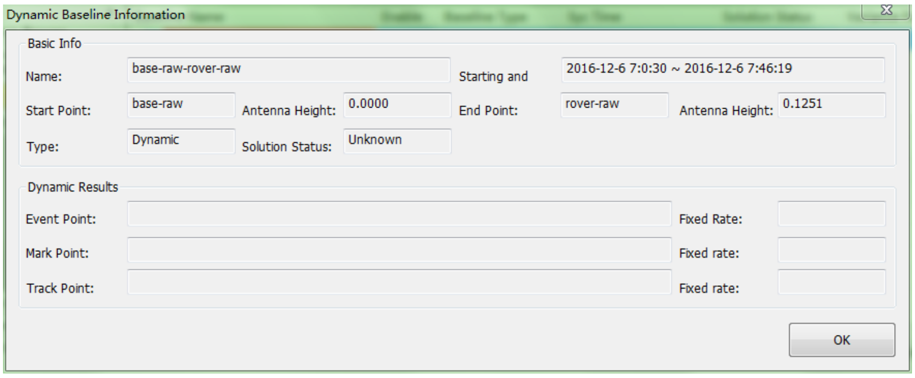
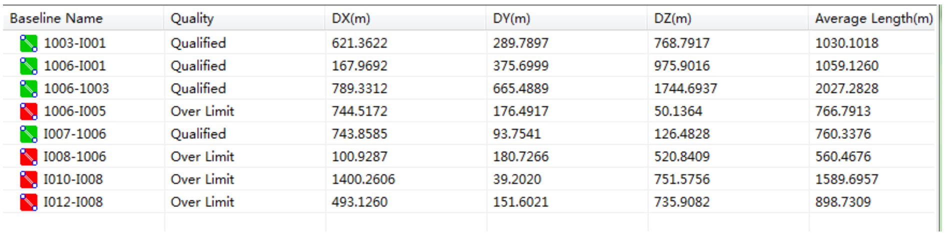


Figure 3-41

3.5.5 Repeated Baseline

Click [Repeated Baseline], as shown in Figure 3-42. Workspace will display the related information of repeated baseline, including baseline name, quality, DX (m), DY (m), DZ (m), average length, relative error, length difference, length difference limit. When the length difference is less than the limit, the repeated baseline is qualified.



Baseline Name	Quality	DX(m)	DY(m)	DZ(m)	Average Length(m)
1003-I001	Qualified	621.3622	289.7897	768.7917	1030.1018
1006-I001	Qualified	167.9692	375.6999	975.9016	1059.1260
1006-1003	Qualified	789.3312	665.4889	1744.6937	2027.2828
1006-I005	Over Limit	744.5172	176.4917	50.1364	766.7913
I007-1006	Qualified	743.8585	93.7541	126.4828	760.3376
I008-1006	Over Limit	100.9287	180.7266	520.8409	560.4676
I010-I008	Over Limit	1400.2606	39.2020	751.5756	1589.6957
I012-I008	Over Limit	493.1260	151.6021	735.9082	898.7309

Figure 3-42

Double-click the repeated baseline, the pop-up dialog is shown in Figure 3-43, and the basic information of the repeated baseline and the detailed solution result of the two baselines will be display.

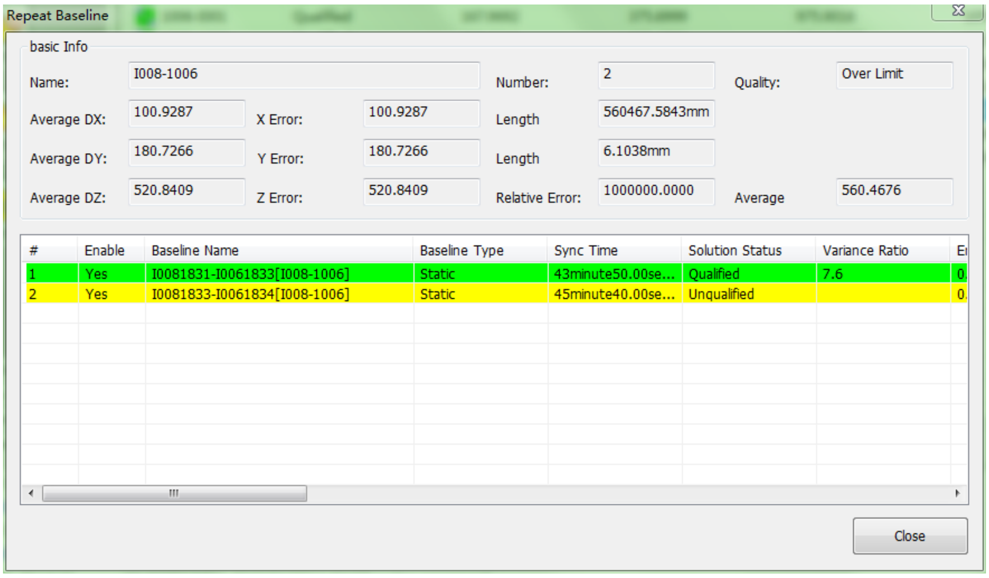


Figure 3-43

3.5.6 Closed loop

Closed loop is divided into two kinds, one is synchronous closed loop, the other is asynchronous closed loop.

Synchronous Closed Loop: It is a closed loop formed by baseline vectors that are obtained by three or more GPS receivers' synchronous observation.

Asynchronous Closed Loop: The closed loop is constituted by a set of baseline vectors (three or more baseline vectors) and any one of the baseline vectors cannot be represented by other baseline vectors of the same group.

Click [Closed Loop], as shown in Figure 3-44, workspace will display the relate information of closed loop, include the station name, Quality, observation time, Total length of loops, X Closure error (mm), Y Closure error (mm), Z Closure error (mm), Closure Error of Side (mm), Relative Error (ppm), Component difference (mm), Closure error (mm), the loop line.

The quality of the closed loop is qualified when the X Closure Error, Y Closure Error, Z Closure Error all are smaller than Component difference and the Closure Error of Side is smaller than closure Error.

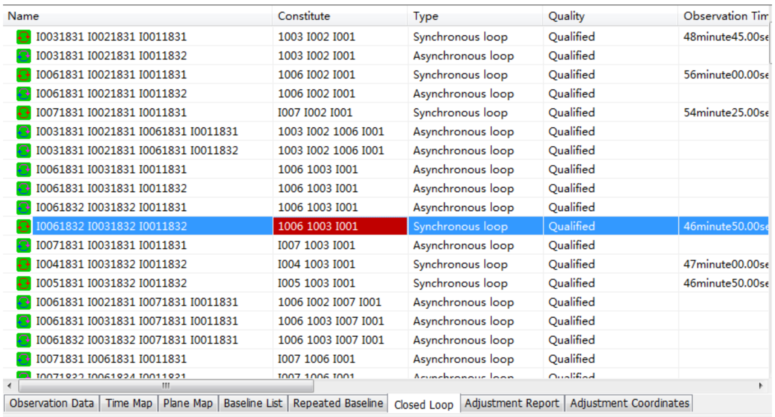


Figure 3-44

Double-click the closed loop, the pop-up dialog is shown in Figure 3-45., and the basic information of the closed loop and the detailed solution results of the closed loop baselines will be displayed.

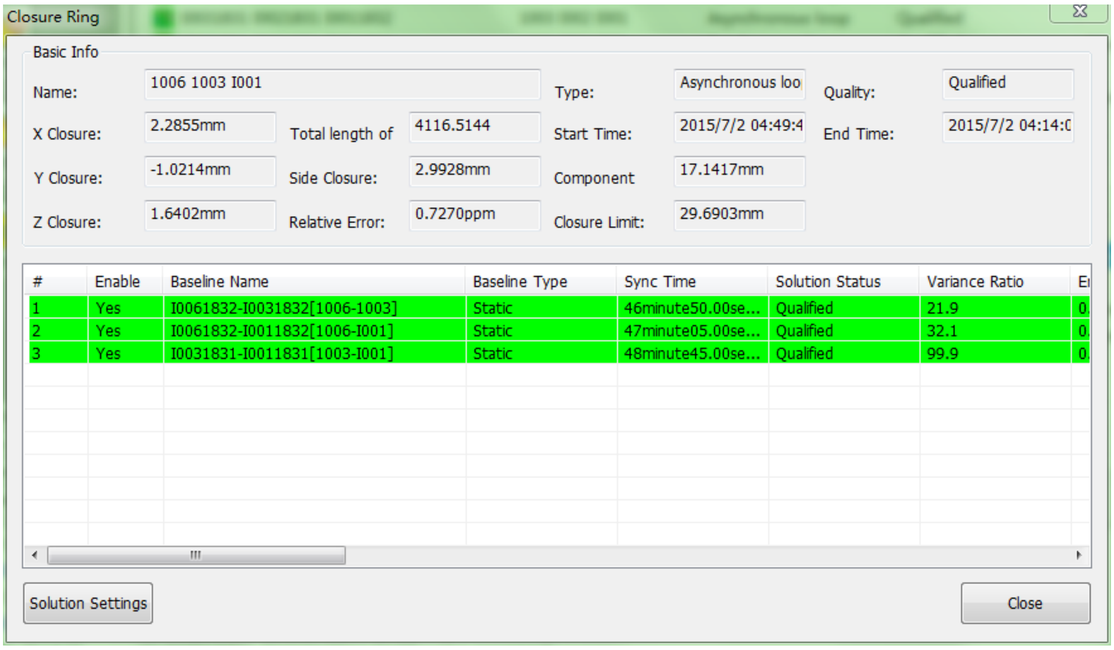
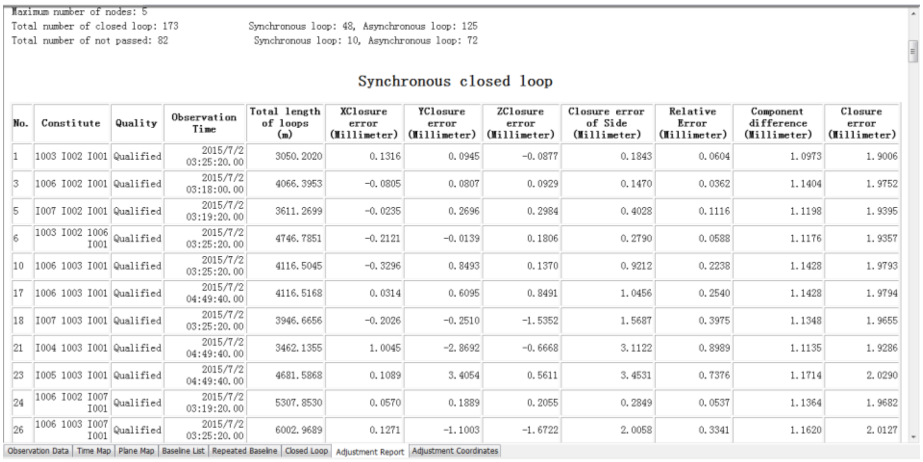


Figure 3-45

3.5.7 Adjustment Report

After the completion of the network adjustment, the workspace will automatically switch to the adjustment report interface, and the adjustment report lists the details of the closed loop, the Known coordinate X, Y, Z increment and correction value of the baseline after net adjustment, the coordinate and point precision of the observation station after adjustment. See Figure 3-46.



Maximum number of nodes: 5
Total number of closed loop: 173 Synchronous loop: 48, Asynchronous loop: 125
Total number of not passed: 82 Synchronous loop: 10, Asynchronous loop: 72

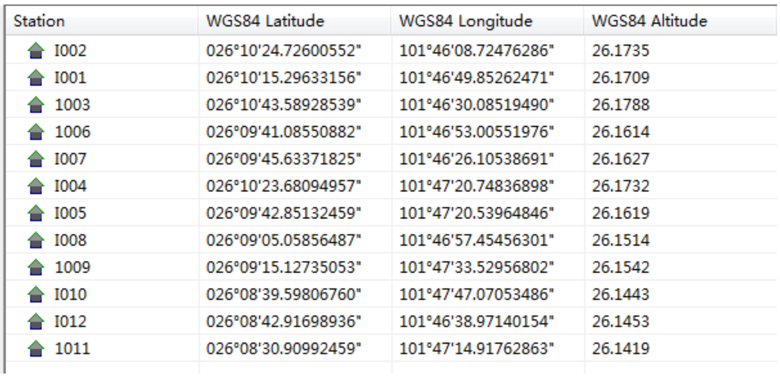
Synchronous closed loop

No.	Constitute	Quality	Observation Time	Total length of loops (m)	XClosure error (Millimeter)	YClosure error (Millimeter)	ZClosure error (Millimeter)	Closure error of Side (Millimeter)	Relative Error (Millimeter)	Component difference (Millimeter)	Closure error (Millimeter)
1	1003 I002 I001	Qualified	2015/7/2 03:25:20.00	3050.2020	0.1316	0.0945	-0.0877	0.1843	0.0604	1.0973	1.9006
3	1006 I002 I001	Qualified	2015/7/2 03:18:00.00	4066.3953	-0.0805	0.0807	0.0929	0.1470	0.0362	1.1404	1.9752
5	I007 I002 I001	Qualified	2015/7/2 03:19:20.00	3611.2699	-0.0235	0.2696	0.2984	0.4028	0.1116	1.1198	1.9395
6	1003 I002 1006 I001	Qualified	2015/7/2 03:25:20.00	4746.7851	-0.2121	-0.0139	0.1806	0.2790	0.0588	1.1176	1.9357
10	1006 1003 I001	Qualified	2015/7/2 03:25:20.00	4116.5045	-0.3296	0.8493	0.1370	0.9212	0.2238	1.1428	1.9793
17	1006 1003 I001	Qualified	2015/7/2 04:49:40.00	4116.5168	0.0314	0.6095	0.8491	1.0456	0.2540	1.1428	1.9794
18	I007 1003 I001	Qualified	2015/7/2 03:25:20.00	3946.6656	-0.2026	-0.2510	-1.5352	1.5687	0.3975	1.1348	1.9655
21	I004 1003 I001	Qualified	2015/7/2 04:49:40.00	3462.1355	1.0045	-2.8692	-0.6668	3.1122	0.8989	1.1135	1.9286
23	I005 1003 I001	Qualified	2015/7/2 04:49:40.00	4681.5868	0.1089	3.4054	0.5611	3.4531	0.7376	1.1714	2.0290
24	1006 I002 I007 I001	Qualified	2015/7/2 03:19:20.00	5307.8530	0.0570	0.1889	0.2055	0.2849	0.0537	1.1364	1.9682
26	1006 1003 I007 I001	Qualified	2015/7/2 03:25:20.00	6002.9689	0.1271	-1.1003	-1.6722	2.0058	0.3341	1.1620	2.0127

Figure 3-46

3.5.8 Adjustment Coordinate

Click the [Adjustment Coordinate], as shown in Figure 3-47. The workspace will switch to the adjustment coordinate of the station. The user can intuitively obtain the adjustment coordinates of the station from the list.



Station	WGS84 Latitude	WGS84 Longitude	WGS84 Altitude
I002	026°10'24.72600552"	101°46'08.72476286"	26.1735
I001	026°10'15.29633156"	101°46'49.85262471"	26.1709
1003	026°10'43.58928539"	101°46'30.08519490"	26.1788
1006	026°09'41.08550882"	101°46'53.00551976"	26.1614
I007	026°09'45.63371825"	101°46'26.10538691"	26.1627
I004	026°10'23.68094957"	101°47'20.74836898"	26.1732
I005	026°09'42.85132459"	101°47'20.53964846"	26.1619
I008	026°09'05.05856487"	101°46'57.45456301"	26.1514
1009	026°09'15.12735053"	101°47'33.52956802"	26.1542
I010	026°08'39.59806760"	101°47'47.07053486"	26.1443
I012	026°08'42.91698936"	101°46'38.97140154"	26.1453
1011	026°08'30.90992459"	101°47'14.91762863"	26.1419

Figure 3-47

Chapter 4 Static baseline solution

In GPS data processing, static baseline vector can be determined by static baseline processing, so as to determine geometrical shape of GOS network.

4.1 New Project

GEOSolution manage data in form of project, so it needs to perform data processing or operation order in project. Hence, before data processing, it needs to create a new project, or open an existed project.

To create a new project needs following steps:

a) Input engineer information. Project name is necessary, while other items are optional.

b) Determine project save path: click Project Path to choose and it will show in the right blank.

c) Set Control Level.

d) Set Coordinate System Parameters.

When a new project is created, its project file naming after Project Name will be generated under the save path, which contains project data, processing results and processing records. To open existed project, choose *.GS file. To transfer project files, copy the project file straightly.

Set project property

Way one: click [Project] in Menu Bar – [Properties]

Way two: click [Project Manager] – [Properties]

Project properties includes four items: Project Info, Project Path, Control Level and Coordinate System.

Project Info contains the project basic information. For Project Name and Project Path, they are determined when the project is created, and only for check but not able to modify after the project is saved. Other information can be modified at any time. As shown in Figure 4-1.

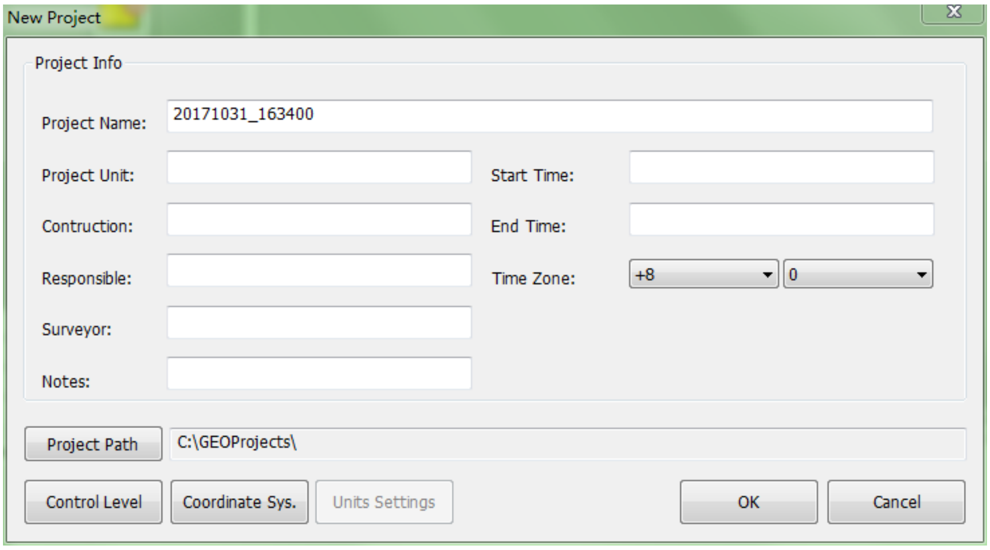


Figure 4-1

[Control Network Level]: Control level is important to provide accordance for many inspections and judgement in data processing. It can choose national normative criterion or user defined level. Click the inverted triangle in Control level blank to choose control level, which includes Specifications for global positioning system (GPS) survey/Version 2009, Technical code for urban surveying using satellite positioning system/Version 2010, Specifications for highway survey/Version 2007 and Specifications for survey engineering of railway/Version 2009. As shown in Figure 4-2.

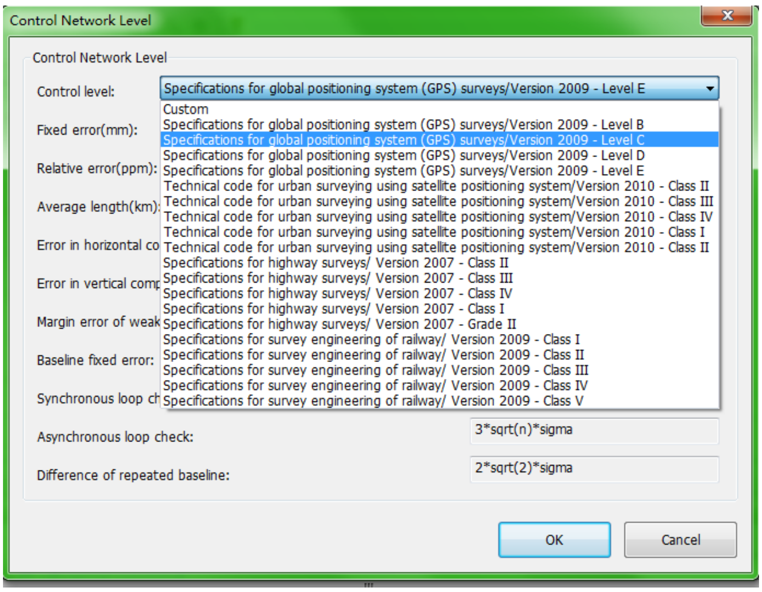


Figure 4-2

[Coordinate System Setting]: Input Coordinate system name, mainly set Ellipsoid Parameter and Projections Parameter, and set other parameters as actual project needed. For Ellipsoid parameter, it can choose built-in ellipsoid parameters like WGS-84 and krassovsky (Beijing54 Using), or choose Define to set Semimajor axis and 1/f, as shown in Figure 4-3. As shown in Figure 4-4, Projections Parameter has six built-in projection modes, namely Gauss Kruger, UTM, Transverse Mercator, Tilt Stereographic, Double Stereographic and Isometric Mercator. The software will automatically calculate measured data to obtain Central Meridian, so Central Meridian directly applying default setting is ok.

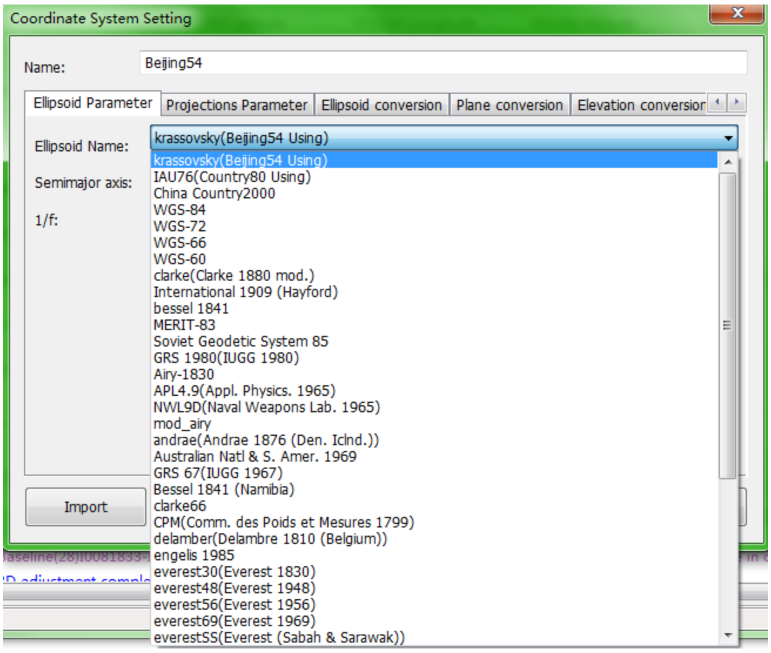


Figure 4-3

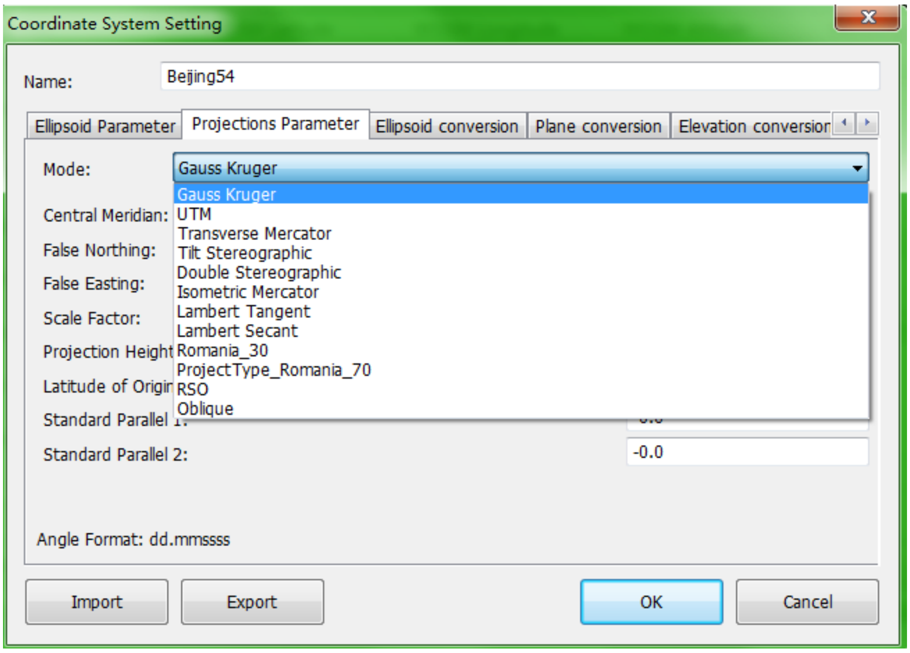


Figure 4-4

4.2 Import Observation Data

GPS receiver exports data in two kinds of formats: ASCII (NMEA 0183) and binary system. Usually, GPS receiver manufacturers use binary system as defined proprietary format, which features high storage efficiency and embrace of various information. However, different GPS receiver manufacturers have different defined proprietary formats. Since data processing software can only recognize limited formats, when a project's raw data is provided by different GPS receiver, data processing analysis is unable to perform.

GEOSolution supports raw data in RINEX format and *.dat format to solve this problem.

4.2.1 Data import

Organize the observation data in advance and then import into GEOSolution.

Way one: click [Import] in Menu Bar – [Observation Data]

Way two: click [Data Import] in Navigation Bar – [Observation Data]

In Import Observation Data interface, find the save path of observation data, as shown in Figure 4-5. In the lower right corner, it can choose document type, and only corresponding documents will show. Choose observation data and click [OK] to import it for following processing.

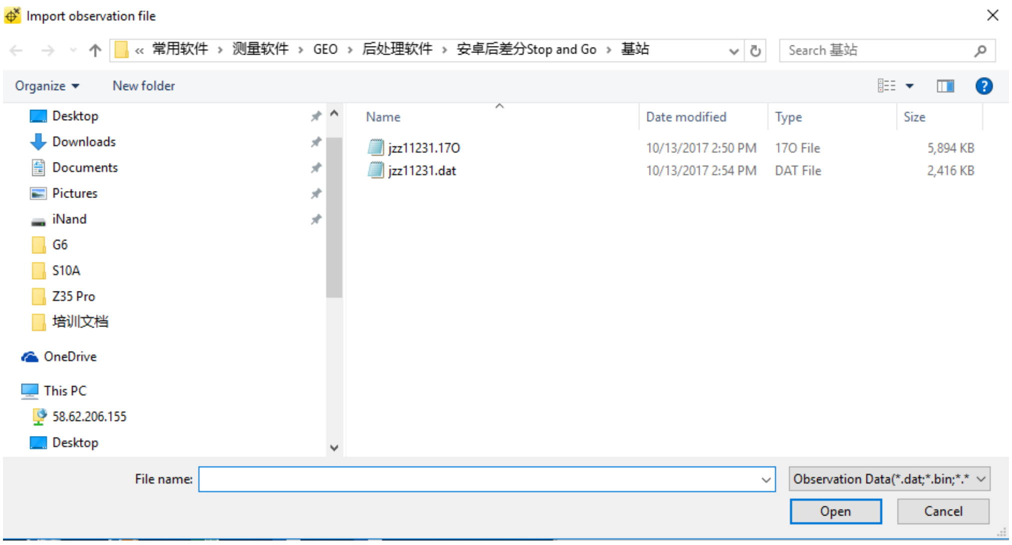


Figure 4-5

While importing the observation file, GEOSolution automatically finds and import relevant ephemeris file. For *.dat file, as observation data and ephemeris data merge in one file, observation file and ephemeris file are imported at the same time. For RINEX file, observation data and ephemeris data save in different files. As a result, it needs to put two files in a same directory, so that the software automatically recognizes ephemeris file with format and import it. Otherwise, ephemeris file needs to be imported additionally.

After importing observation file, the software extract observation stations, and obtain static baselines and dynamic baselines according to their observation time, as shown in Figure 4-6.

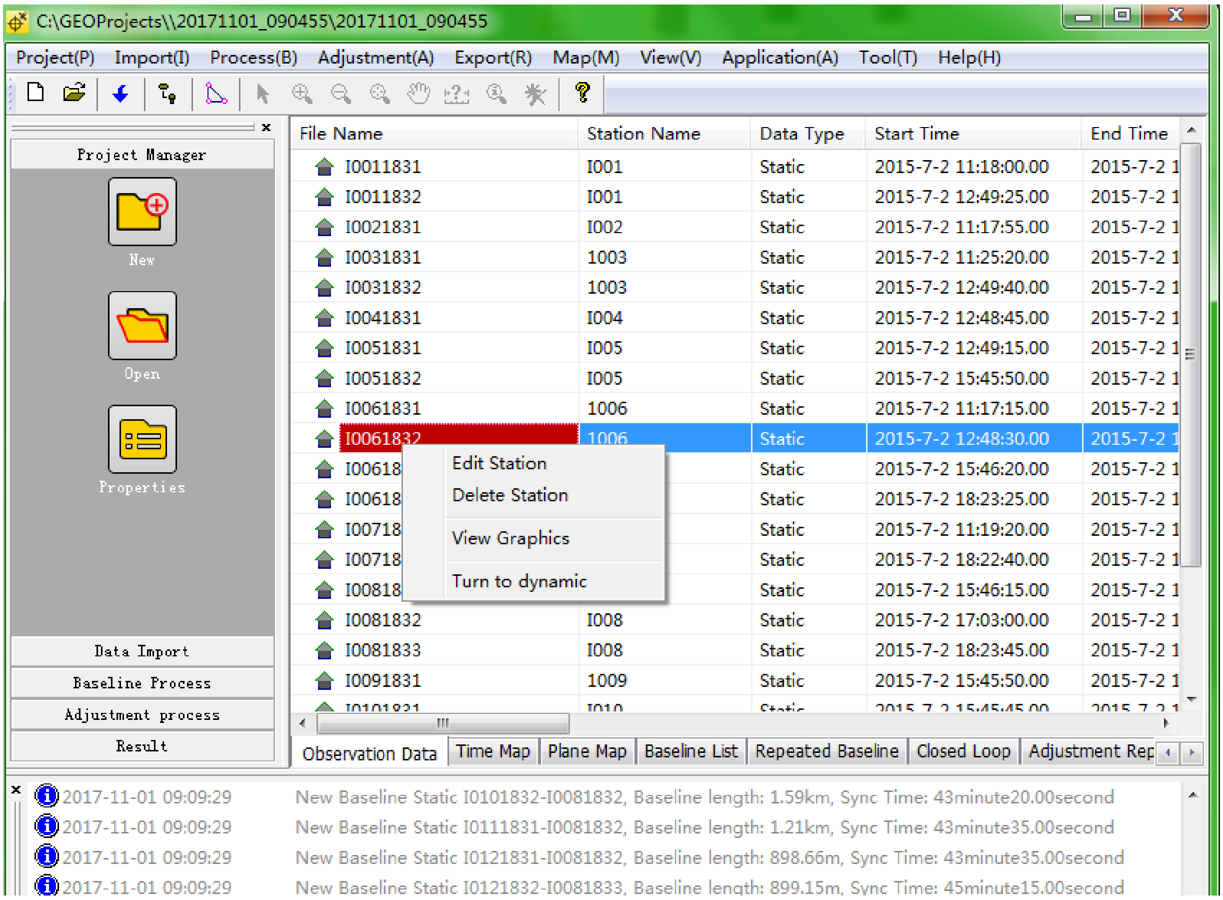


Figure 4-6

Right click target file and it shows [View Graphics], [Edit Station] and [Delete Station] three orders. Find more details in Chapter 3 - 3.5.1.

4.2.2 Observation data content

Observation file mainly saves raw observation data in every epoch that GPS receiver recorded. Each epoch contains observation time, tracking satellite information of every channel, pseudo-range of C/A code, pseudo-range of P1 code, pseudo-range of P2 code, L1 carrier phase and L carrier phase. For GEOSolution, static observation file should at least contain observation time, pseudo-range of C/A code and L1 carrier phase; dynamic observation file should contain at least observation time and pseudo-range of C/A code.

In addition to the above information, observation file also contains point information, initial coordinate and relevant ephemeris information and other information.

4.2.3 Observation data file name

Usually, GEOSolution distinguishes different observation files on the basis of file name. In general, observation file name consists of 8 digits and its extension, such as BJFS1234.dat.

In one project, files sharing a same name are not allowed. For example, in one project, it's not allowed to exist observation files BJFS1234.dat and BJFS1234.16O at the same time.

Naming rule for file name: observation file usually consists of station name, DOY and period number. Station name can be composed of 4 digits or 2 Chinese characters. DOY refers to the observation day of year in sequence. Period number refers to the period in sequence in the observation day, which can be represented by 1, 2, 3, …, 9, A, B, …, Z.

4.2.4 Observation data in RINEX format

RINEX format is a general data interchange format created to uniformly process data that collected by different kinds of receivers. It's put forward by Institute of astronomy, University of Bern in Switzerland. Nowadays, manufacturers, schools and research organizations use it as standard input format in software programming. And current mainstream GPD receivers at home and abroad all support to transfer observation data into RINEX format as well. At present, to meet demand of multisystem and multi-channel observations, RINEX format has developed to 3.X version. Find more detailed description about RINEX 2.X format in relevant content and Appendix 2, description about RINEX 3.X format in official document.

4.3 Static baseline processing setting

Before static baseline processing, it needs to set up static settings. Click [Process] in Menu Bar – [Static Options], or click [Baseline Process] in Navigation Bar – [Static Settings], then pops up a dialog box as shown in Figure 4-7.

Please find Chapter 3-3.3.3 to see specific meanings of every setting parameters in static processing settings as reference to set up the parameters.

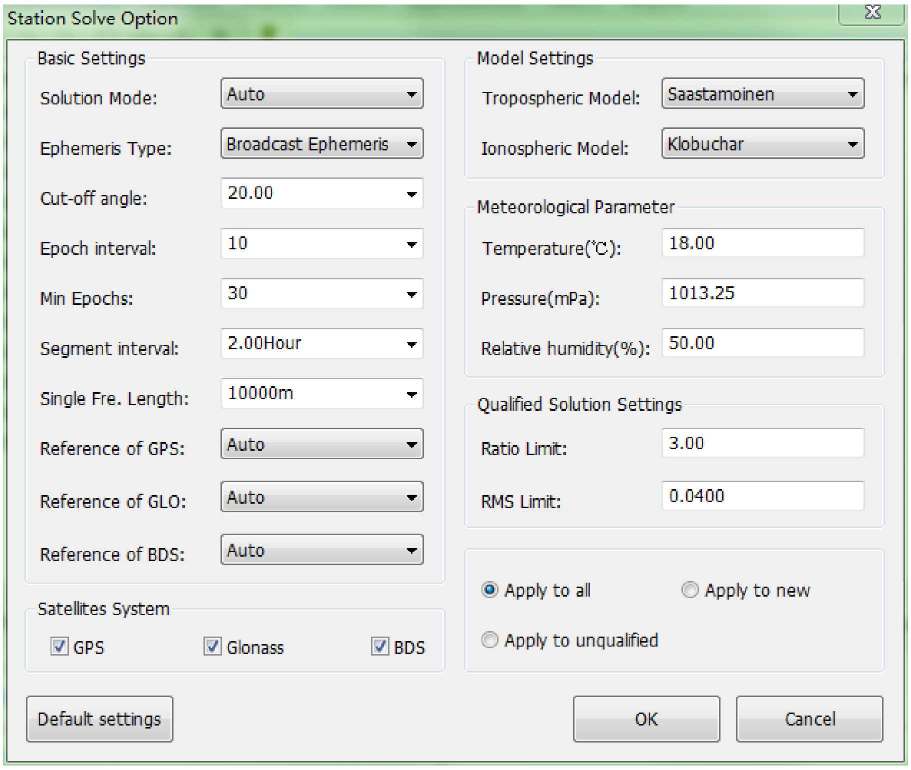


Figure 4-7

4.4 Static baseline solution

Users can perform baseline solution in the following three ways:

Way one: click [Process] in Menu Bar – [Process all baselines]

Way two: click [Baseline Process] in Navigation Bar – [Baseline Process]

Way three: click shortcut key in tool bar

After preparation, to perform [Baseline Process], the program starts to process all baselines one by one in sequence and shows solution information in dialog box, as shown in Figure 4-8.

In dialog box would respectively appear baseline name, processing progress and baseline information of the baseline in progress. It can also click [Cancel] to stop baseline processing while operating.

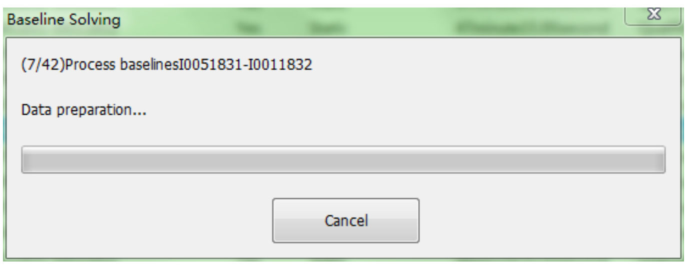
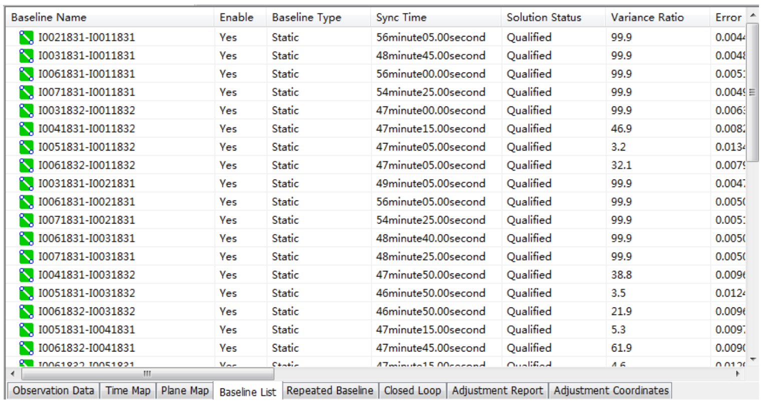


Figure 4-8

After baseline processing, click [Baseline List] to check the result, such as Solution status, Variance Ratio and Error. In the sheet, green area refers to baselines that succeed to process, while red area refers to those failed.

Through user adjusting processing settings, it can reprocess the failed baselines, to qualify all baselines in solution status as far as possible.



Baseline Name	Enable	Baseline Type	Sync Time	Solution Status	Variance Ratio	Error
I0021831-I0011831	Yes	Static	56minute05.00second	Qualified	99.9	0.004
I0031831-I0011831	Yes	Static	48minute45.00second	Qualified	99.9	0.004
I0061831-I0011831	Yes	Static	56minute00.00second	Qualified	99.9	0.005
I0071831-I0011831	Yes	Static	54minute25.00second	Qualified	99.9	0.004
I0031832-I0011832	Yes	Static	47minute00.00second	Qualified	99.9	0.006
I0041831-I0011832	Yes	Static	47minute15.00second	Qualified	46.9	0.008
I0051831-I0011832	Yes	Static	47minute05.00second	Qualified	3.2	0.013
I0061832-I0011832	Yes	Static	47minute05.00second	Qualified	32.1	0.007
I0031831-I0021831	Yes	Static	49minute05.00second	Qualified	99.9	0.004
I0061831-I0021831	Yes	Static	56minute05.00second	Qualified	99.9	0.005
I0071831-I0021831	Yes	Static	54minute25.00second	Qualified	99.9	0.005
I0061831-I0031831	Yes	Static	48minute40.00second	Qualified	99.9	0.005
I0071831-I0031831	Yes	Static	48minute25.00second	Qualified	99.9	0.005
I0041831-I0031832	Yes	Static	47minute50.00second	Qualified	38.8	0.009
I0051831-I0031832	Yes	Static	46minute50.00second	Qualified	3.5	0.012
I0061832-I0031832	Yes	Static	46minute50.00second	Qualified	21.9	0.009
I0051831-I0041831	Yes	Static	47minute15.00second	Qualified	5.3	0.009
I0061832-I0041831	Yes	Static	47minute45.00second	Qualified	61.9	0.009

Figure 4-9

Information Bar shows processing progress, solution status and warning message of every baseline in the project.

After baseline processing, double-click the baseline to view the detailed solution information of the baseline vector, as shown in Figure 4-10.

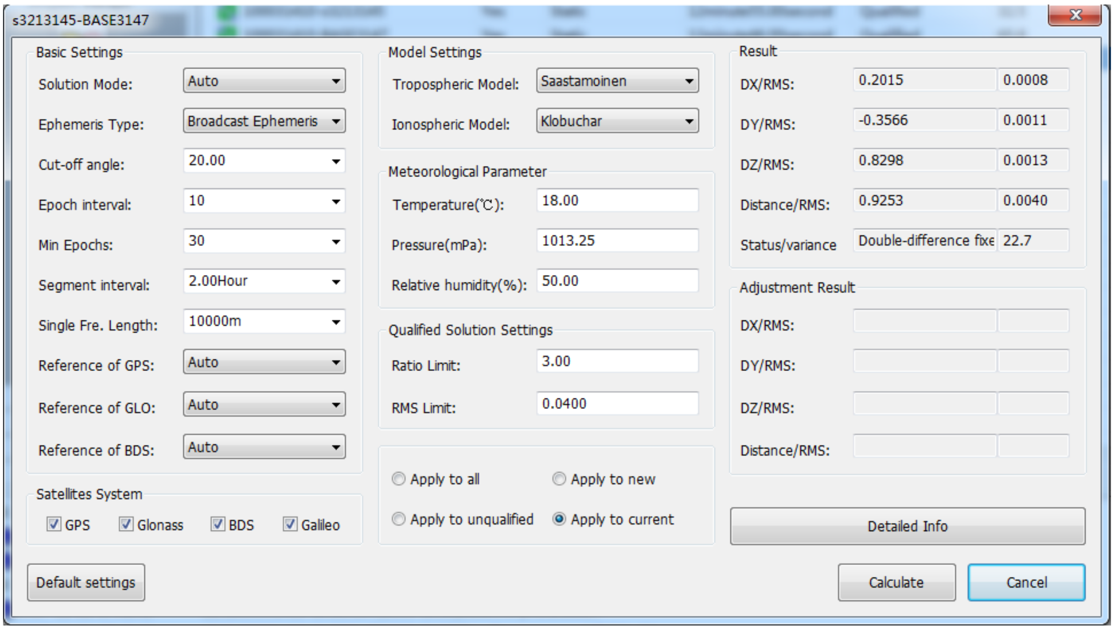


Figure 4-10

4.5 Baseline solution result verification

4.5.1 Baseline quality control

After baseline processing, result quality can be evaluated by RATIO (Variance Ratio) and RMS (Root Mean Square) two quality indicators.

RATIO value (Variance Ratio)

RATIO is the ratio of the second minimum RMS to the minimum RMS after the whole-week ambiguity decomposition. That is:

$$\text{RATIO} = \frac{RMS_{sec}}{RMS_{min}}$$

RATIO reflects the reliability of the uncertain parameters of the whole week. It depends on a variety of factors, such as the quality of the observed values and the conditions of observation.

RATIO is the key value that reflects the quality of the baseline. In general, RATIO should be greater than 3.0.

RMS value (Root Mean Square)

$$\text{RM} = \sqrt{\frac{V^T PV}{n-f}}$$

Of which:

V refers to the residual of the observed value;

P refers to the weight of the observed value;

n-f refers to the total number of observed value minus the number of unknown number.

RMS reflects quality of observed value. The smaller the RMS, the better the quality of observed value. Otherwise, the worse the quality of the observed value. It is unaffected by observational conditions, such as the satellite's distribution.

According to the theory of mathematical Statistics, the probability of observed error being within 1.96 times of RMS is 95%.

4.5.2 Closed Loop verification

Closure error & Loop closure error

Closed loop verification is a powerful method to detect baseline quality.

A closed loop is a closed graph consisting of a number of baseline vectors connected end-to-end.

Closure error of closed loop is the vector sum in the same direction (clockwise or counterclockwise) of the baseline vectors that make up the closed loop.

Closure error of closed loop should be 0 in theory. However, in actual measurement, it allows certain deviations. About the limit error of closed loop please refer to relevant literature.

The closure error of loop can be divided into two kinds as follows:

1) Component Closure Error: the vector sum in the same direction (clockwise or counterclockwise) of the baseline vectors that make up the closed loop.

   i.e.: $\begin{cases} \varepsilon_{\Delta X} = \sum \Delta X \\ \varepsilon_{\Delta Y} = \sum \Delta Y \\ \varepsilon_{\Delta Z} = \sum \Delta Z \end{cases}$

2) Full length relative closure error: The ratio of the root of sum of the square of component closed error to the loop length

   i.e.: $\varepsilon = \frac{\sqrt{\varepsilon_{\Delta X}{}^2 + \varepsilon_{\Delta Y}{}^2 + \varepsilon_{\Delta Z}{}^2}}{\sum S}$

   Of which, $\sum S$ refers to loop length.

Synchronous closed loop

A synchronous closed loop error is a closure error of closed loop consisting of synchronous observation baselines.

Because of the intrinsic connection between synchronous observation baselines, the synchronous closed loop error should always be 0 in theory. If the synchronous closed loop error is over limit, it indicates that there is at least one wrong baseline vector in baselines make up the synchronous closed loop. Whereas, if the synchronous closed loop error is not over limit, it merely indicates that in most situations, static baselines are qualified, not to indicate that all baselines make up the synchronous closed loop are qualified.

Asynchronous closed loop

An asynchronous closed loop is a closed loop that is not entirely composed of synchronous observation baselines. Its closure error names closure error of asynchronous closed loop.

When closure error of asynchronous closed loop meets limit requirement, it indicates that the vectors of baselines make up the asynchronous closed loop are qualified. Whereas, closure error of asynchronous closed loop fails to meet limit requirement, it indicates that at least one baseline vector is unqualified. It can determine the unqualified baseline vector on the basis of multiple adjacent asynchronous loops.

4.5.3 Repeated Baseline

Two same observation stations observe in multiple observation periods (⩾2), and these observed baselines in different periods name repeated baselines. Difference between these baselines is repeated baseline difference.

Repeated baseline difference is an effective indicator to evaluate baseline quality. When it is over limit, it indicates that there must be an unqualified baseline among repeated baselines.

4.6 Factors influencing baseline solution result and coping method

4.6.1 Influence factors

The main factors influencing baseline solution result are as follows:

1) The starting point coordinates set in baseline solution are not accurate. Inaccurate starting point coordinates would result in a deviation in the scale and direction of the baseline.
2) Insufficient observation time of satellites would result in uncertain ambiguity of whole cycles of these satellites. When observation time of satellites is insufficient, the ambiguity of whole cycles of the satellite can’t be determined. In baseline solution, for participating satellites, if their ambiguities of whole cycles are uncertain, it would influence the final baseline solution result.
3) There are excessive cycle slips in certain periods in the whole observation time, which results in imperfect repair of cycle slips.
4) The multipath effect is strong in observation time and corrections of

observation values are generally large.

5) The influence of the troposphere or ionospheric refraction is too strong.
6) The influence of electromagnetic wave is too strong.
7) Receiver issue results in poor data quality. For instance, the phase measurement accuracy of receiver reduces, or the clock of receiver is inaccurate.

4.6.2 Coping method

1) Coping method for inaccurate starting point coordinate

To solve the problem of inaccurate starting point coordinate, it can choose the point with higher coordinate accuracy as starting point in baseline solution. A starting point with higher coordinate accuracy can be obtained by single point positioning in relatively long time or joint measurement with point with more accurate WGS-84 coordinate. The problem also can be solved by another method. In the baseline solution of the entire network, the starting coordinates of all baselines are derived from a coordinate, so that the solution results share certain system deviation, which then can be solved through importing system parameters in GPS network adjustment.

2) Coping method for insufficient observation time

If the observation time of one satellite is insufficient, its observation data should be deleted to prohibit it from baseline solution, so as to ensure the quality of baseline solution.

3) Coping method for excessive cycle slips

If multiple satellites occur cycle slips frequently during a same period of time, it can delete the period occurring cycle slips frequently to improve the quality of baseline solution. If only certain satellites occur cycle slips frequently, it can delete the observation value of the satellites occurring cycle slips frequently to improve the quality of baseline solution.

4) Coping method for multipath effect

Multipath error: signal once reflected by certain object surface together with signal directly from satellite is received by receiver, then this signal superimposition and interference would result in deviation in observation value.

A simple and effective method for this problem is choosing a proper observation station to avoid signal reflector in observation data collection. Or it can solve through deleting the periods or satellites with strong multipath effect.

5) Coping method for strong influence of the troposphere or ionospheric refraction

For strong influence of the troposphere or ionospheric refraction, it can be solved by following ways:

a. Raise elevation mask angle to remove observation data of low elevation angle, which is susceptible to influence of the troposphere or ionospheric refraction. However, this method has certain blindness because signal in low elevation angle is not necessarily affected much by the troposphere or ionospheric refraction.
b. Correspondingly use models to correct delay of the troposphere and ionospheric refraction.

Chapter 5 Network Adjustment

GPS data processing includes baseline solution and network adjustment. Baseline vectors from baseline solution merely can determine graphical shape of GPS network. Hence, after baseline solution, it needs to furtherly verify baseline solution result and optimize baseline vectors, which then needs to convert to national coordinate or local coordinate as needed. And that's what exactly network adjustment performs.

5.1 Functions and basic steps of Network Adjustment

GEOSolution can perform 3D adjustment, 2D adjustment and Elevation adjustment.

To perform network adjustment in GEOSolution, basic steps are as follows:

1) Early preparation (done by user): It needs to complete baseline solution, set up control level and coordinate system, and load known point.
2) Calculation of network adjustment (automatically done by software)
3) Quality analysis and control of calculation result (handled by user)

GEOSolution merely perform calculation of network adjustment. The most important is user's participation and ultimate correct judgement. The process generally repeats till it obtains a proper result.

5.1.1 Early preparation before network adjustment

Before network adjustment, it needs to complete baseline solution and solution status should be "Succeed". Baselines that fail to process do not participate in network adjustment.

Control Level Setting

Before network adjustment, it should check if the control network level is correct. Control level is important to provide accordance for many inspections and judgement in network adjustment. Without setting control level, network adjustment would fail. As shown in Figure 5-1, GEOSolution provides several control level parameters, namely Specifications for global positioning system (GPS) survey/Version 2009, Technical code for urban surveying using satellite positioning system/Version 2010, Specifications for highway survey/Version 2007 and Specifications for survey engineering of railway/Version 2009. If the project has other requirements in control level parameters, it can choose [user define] to set up Fixed error, Relative error, Average length, Error in horizontal component, Error in vertical component and Margin error of weakest baseline.

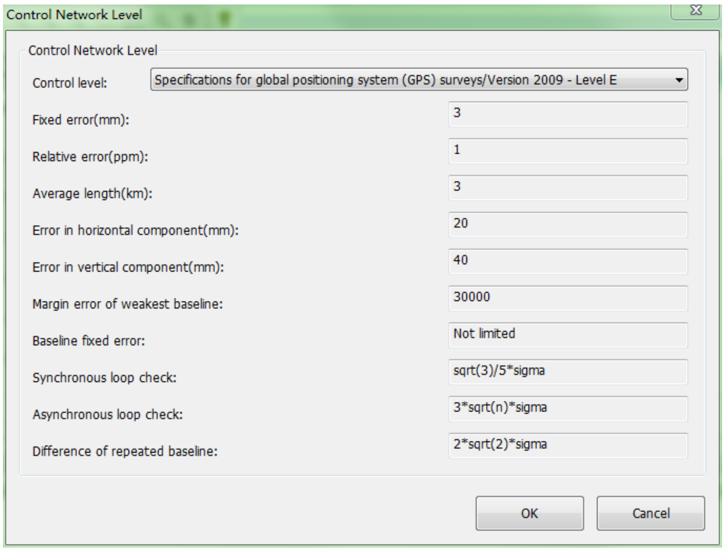


Figure 5-1

If control level is not set up before network adjustment, the baseline vectors succeed to process cannot pass network inspection, resulting in networking failure and then network adjustment fails. Warning window pops up as shown in Figure 5-2.

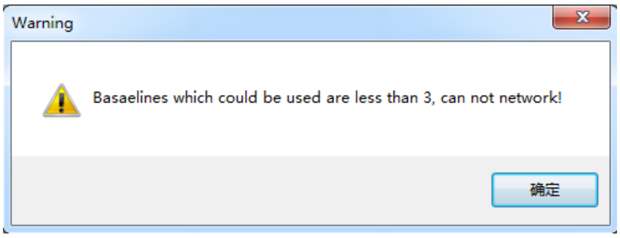


Figure 5-2

Coordinate System Setting

Before network adjustment, it should check if coordinate system setting is correct. In general, it mainly sets up Ellipsoid Parameter and Projections Parameter. Other parameters are set as needed or keep default setting, as shown in Figure 5-3. For instance, Chinese users generally apply krassovsky (Beijing54 Using) as ellipsoid parameter and Gauss Kruger as projections parameter.

GEOSolution has built-in common ellipsoid parameter and projections parameter and it would automatically calculate measured data to obtain Central Meridian. Since it has set up the control level and coordinate system in project creation, setting up these two items again is merely for further confirmation.

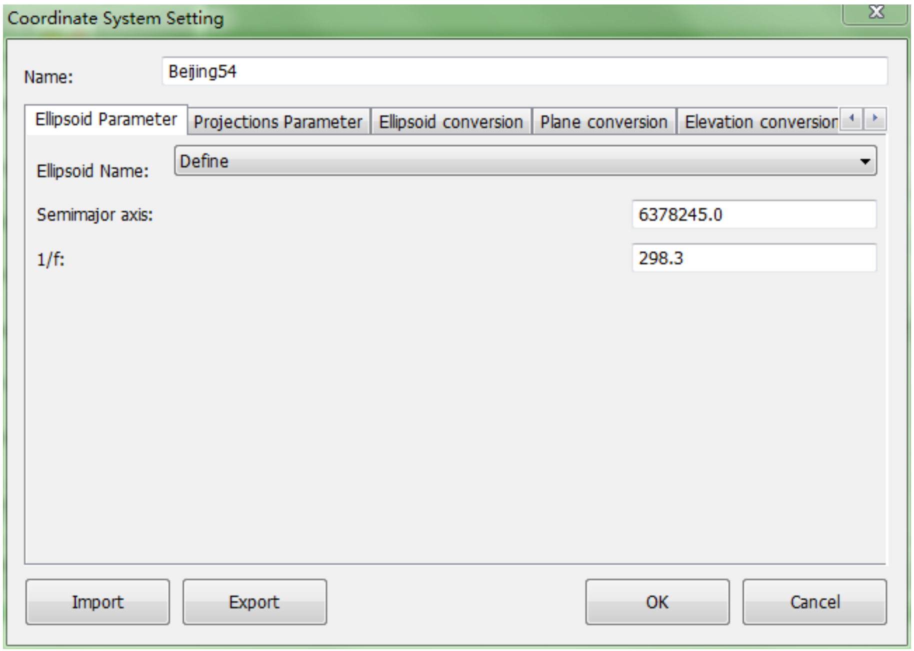


Figure 5-3

5.1.2 Network Adjustment Setting

Way one: click [Adjustment] in Menu Bar– [Adjustment Setting]

Way two: click [Adjustment Process] – [Option Settings]

It needs to set up calculation parameters of adjustment before network adjustment calculation, so as to determine the conditions that constitute a closed loop.

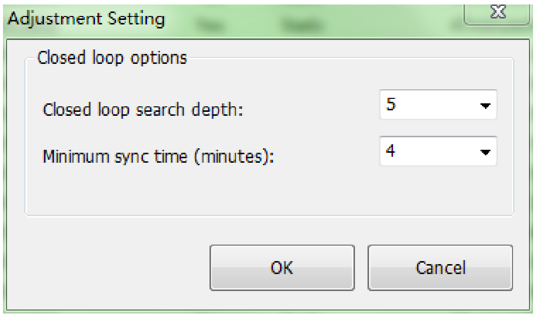


Figure 5-4

Closed loop search depth: to adjust edge number of closed loop. For instance, set closed loop search depth as 4, then in network adjustment closed loop with three sides and four sides would be included and maximum edge number of closed loop is four.

Minimum sync time: baselines whose observation time is shorter than minimum sync time has been set would not be included in network adjustment.

5.1.3 Import Known Coordinates

It needs to import known coordinates before network adjustment, or GEOSolution would automatically choose one station point as known point to perform 3D adjustment.

Import known coordinates:

1) Click [Import] in Menu Bar – [Known Coordinates], or click [Data Import] in Navigation Bar – [Known Points]
2) Click [Add] as shown in Figure 5-5. Input known coordinates and tick options as actually needed.
3) Or directly import the known coordinates have been saved into project through [Import]

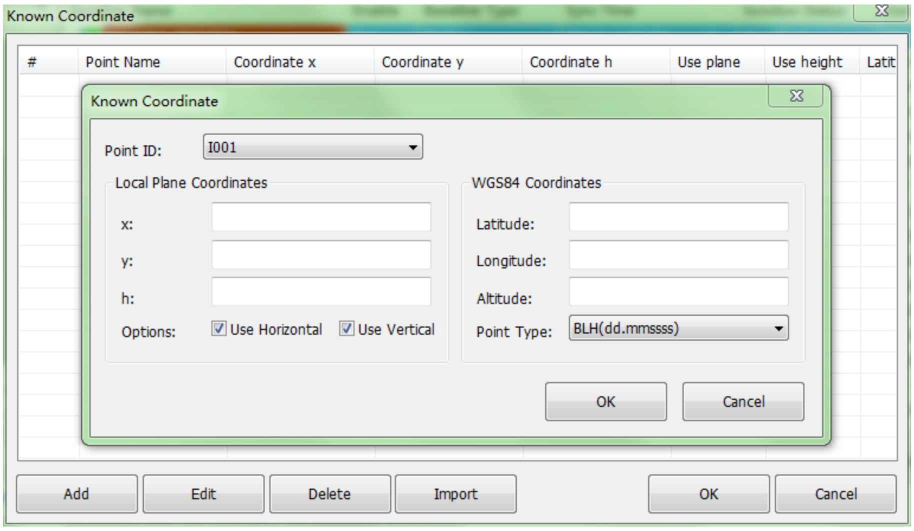


Figure 5-5

In known coordinate management, it would list the information of known coordinates. And it can edit and delete the known coordinates as well.

5.2 Perform Network Adjustment

Click [Adjustment] in Menu Bar – [Adjustment Processing], or click [Adjustment Process] in Navigation Bar – [Adjustment Process] to perform network adjustment. GEOSolution would perform all possible adjustments (3D adjustment, 2D adjustment and Elevation adjustment) directly based on current setting, and show the processing progresses and results in Information Bar. After network adjustment, it would create a network adjustment report and automatically jump to the report interface. According to the network adjustment report, users can judge if the network adjustment meets the project demands. If the result fails, it needs to re-perform network adjustment until the result reaches the project standard.

5.2.1 Extract baseline vector network

First step for network adjustment is to extract the baseline vector network. The principles of baseline vector network constitution are as follows:

1) The baseline exists in current project and is not deleted.
2) The baseline succeeds to process and its solution status shows "Qualified" in Baseline List.
3) The baseline is not disabled.
4) The baseline meets requirements of control level.

Any baseline meets above conditions would be automatically included to form baseline vector network in the first step of network adjustment.

5.2.2 Connection inspection of baseline vector network

Performing network adjustment without connection would cause network adjustment cannot converge. GEOSolution would automatically perform connection inspection of baseline vector network before network adjustment. If network is not connected, warning window would pop up as shown in Figure 5-6.

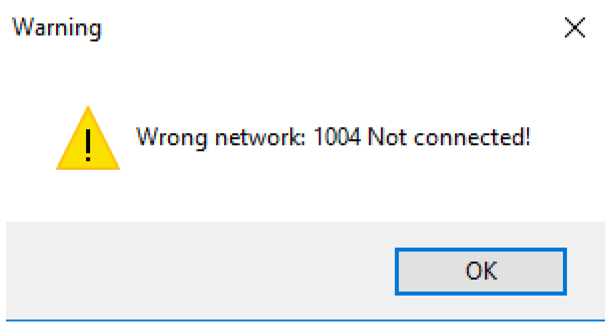


Figure 5-6

If appears above warning, please check the information of baselines that constitute baseline vector network, such as baseline vector and observation station name. Inspection steps are as follows:

1. Check if network is divided into several parts, and if there is isolated station point or baseline. If positive, it must delete the isolated point or perform network adjustment in blocks.

2. Check if any important baseline fails to process or be disabled in network adjustment. If positive, the baseline needs to reprocess or even re-observe.

3. Check if one station has two different names in network, reflecting in network graph that these two stations locate very close to each other. These two points observe in the same location in different periods, so between them cannot form any baseline, which makes network unconnected. Solution is to correct the wrong station name in observation data properties.

5.2.3 Adjustment Report

The results of net adjustment are reflected in the adjustment report. Take 3D adjustment as example, its adjustment result is as shown in Figure 5-7. It can click [Export] in Menu Bar – tick [Adjustment report] or click [Result] in Navigation Bar – [Static result file] – tick [Adjustment report] to export and save adjustment report. In this way, it provides convenience for network adjustment analysis, and avoids losing the result.

Report_Adjust_20...1201_161553.html

3D adjustment result

TD

Adjustment Type	WGS84Adjustment of classical free network in coordinate system
Mean error of unit weight	2.0415m

Baseline and correction

No.	Constitute	ΔX	ΔY	ΔZ	ΔXCorrection (Millimeter)	ΔYCorrection (Millimeter)	ΔZCorrection (Millimeter)	Relative Error (Millimeter)	Distance after adjustment (m)
1	IP142241-DHZ2241	-4976.5988	707.9003	-4065.9146	-0.0003	0.4279	0.3491	7469177	6465.2392
2	NIP122241-DHZ2241	-4069.2464	-309.7030	-1338.1021	0.1413	1.2892	-0.4305	4374787	4294.7874
3	WLS2241-DHZ2241	-9350.4043	-1270.3484	-2058.3448	-0.2360	-2.0185	-0.2479	10679571	9658.1902
4	NIP122241-IP142241	907.3537	-1017.6044	2727.8109	-1.2174	2.0123	0.8971	3140072	3049.5508
5	WLS2241-IP142241	-4373.8063	-1978.2502	2007.5693	0.6398	-0.8783	-0.0587	5780567	5203.2671
6	WLS2241-NIP122241	-5281.1572	-960.6524	-720.2434	-1.0004	3.7669	0.9090	5368571	5415.9235

Figure 5-7

Chapter 6 Dynamic baseline solution

Dynamic data processing is post-differential data processing. Post-differential is different from RTK in that RTK obtains the observation result immediately in the field while post-differential cannot obtain the result until indoor processing.

Dynamic GPS data processing process dynamic baseline, which includes two kinds of data files, base data file and rover data file.

6.1 Early preparation for dynamic baseline solution

In dynamic baseline solution, to create new project and import observation file, its operation steps are the same as that of static data solution. Please refer to section 4.1 and 4.2. Please notice that observation data imported in dynamic baseline solution should include base and rover two kinds of data files.

Click [Process] in Menu Bar – [Dynamic Options] or click [Baseline Process] in Navigation Bar – [Dynamic Settings] to set up dynamic solution parameters, as shown in Figure 6-1. Generally, it merely needs to set up Cut-off angle, Ratio Limit, Reset Amb. Count/Cycle slip limit, Maximum Differential Delay and GDOP/Maximum allowable info. Other items can remain default settings, or set up as actual project needed.

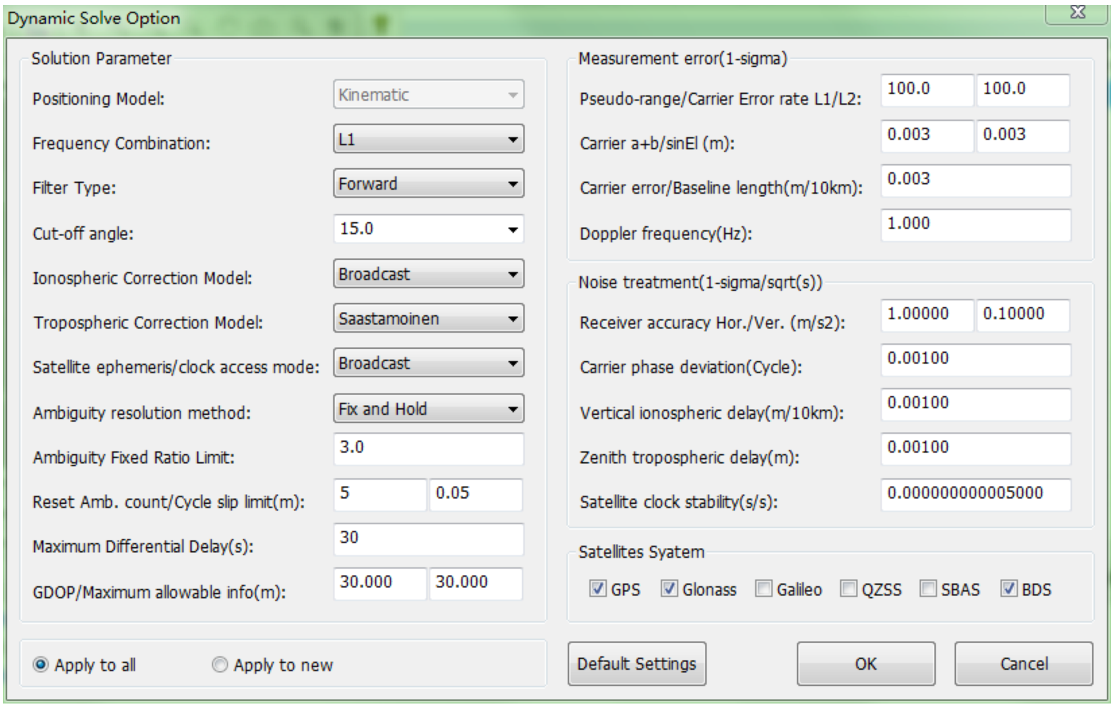


Figure 6-1

After importing observation data, Baseline List lists all possible baselines.

Choose any baseline in Baseline List and right-click to show option Bar. In option bar, it includes Baseline Info, Processing settings, Reprocess, Delete baselines, Enable baselines, Disable baselines, and Endpoint exchange. Detailed description for operation order please refer to section 3.5.4 Baseline List.

6.2 Perform Dynamic Baseline Solution

GEOSolution can perform dynamic baseline solution in several ways as follows:

Way one: click [Process] in Menu Bar – [Process all baselines], or click [Baseline Process] in Navigation Bar – [Baseline Process] to process all baselines. A dialog box would pop up to respectively show baseline name, processing progress and baseline information of the baseline in progress. The processing progress and baseline information of all baselines would also show in Information Bar.

Way two: in Baseline List right-click a dynamic baseline, click [Reprocess] in drop-down box to complete single dynamic baseline solution, and repeat the operation till all dynamic baseline solution finish.

Way three: in Baseline List right-click a dynamic baseline, click [Reprocess] in drop-down box, tick [Apply to all] and click [Calculate], and then it would automatically complete all dynamic baseline solution; or not tick [Apply to all] and click [Calculate] to complete single dynamic baseline solution, and then repeat the operation till all dynamic baseline solution finish.

6.3 Baseline solution result

After baseline processing, in Plane Map baseline succeeded to process shows in green and baselines failed to process show in gray. Also, the Plane Map shows trajectory of station point. Trajectory dot shows green in fixed solution, yellow in float, and red in single. Baseline List would also show all baseline solution result. Green area refers to baselines that succeed to process, while red area refers to those failed.

For baseline fails to process, it can reprocess through modifying process settings.

If the baseline keeps fail, it can disable the baseline.

After dynamic baseline solution, it can view and download the solution result.

1) View dynamic baseline solution result

   Operation: click [Process] in Menu Bar – [Dynamic data view], or click [Result] in Navigation Bar – [View dynamic data].

   In [Solve Result] window, choose Solving Baselines, choose Displayed Type and Solution Status, then it shows the dynamic baseline solution result, as shown in Figure 6-2. In the upper right of the window, it shows basic information of the baseline, including File Name, Baseline length, Sync Time, Track point, Mark point and Event point. Green area refers to points in fixed solution, yellow to points in float solution and red to points in single solution.

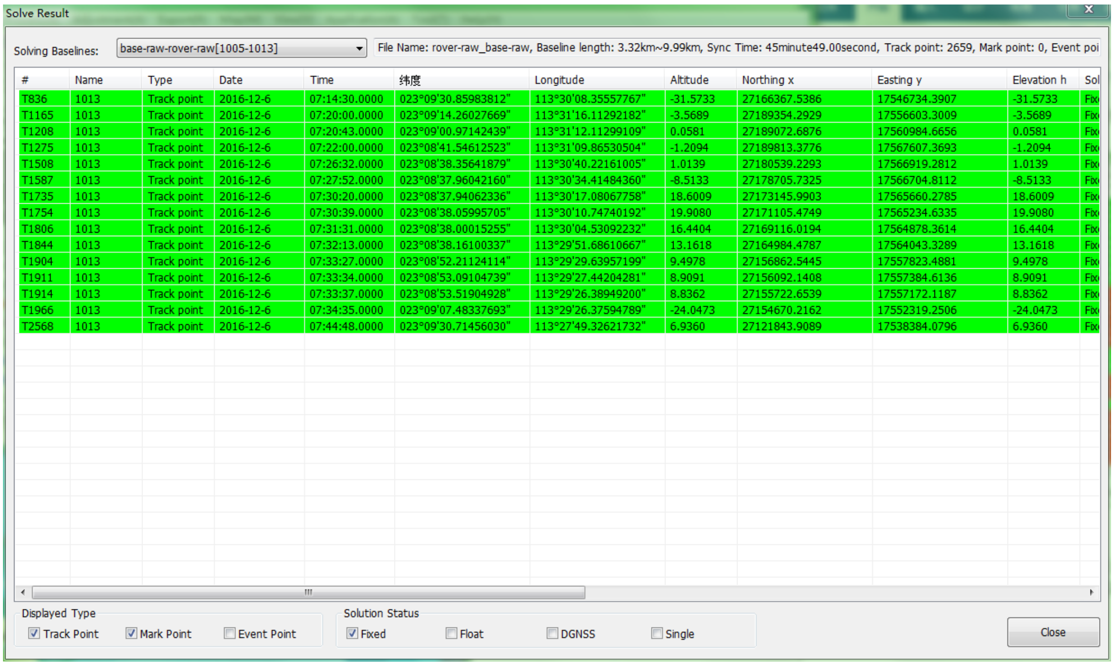


Figure 6-2

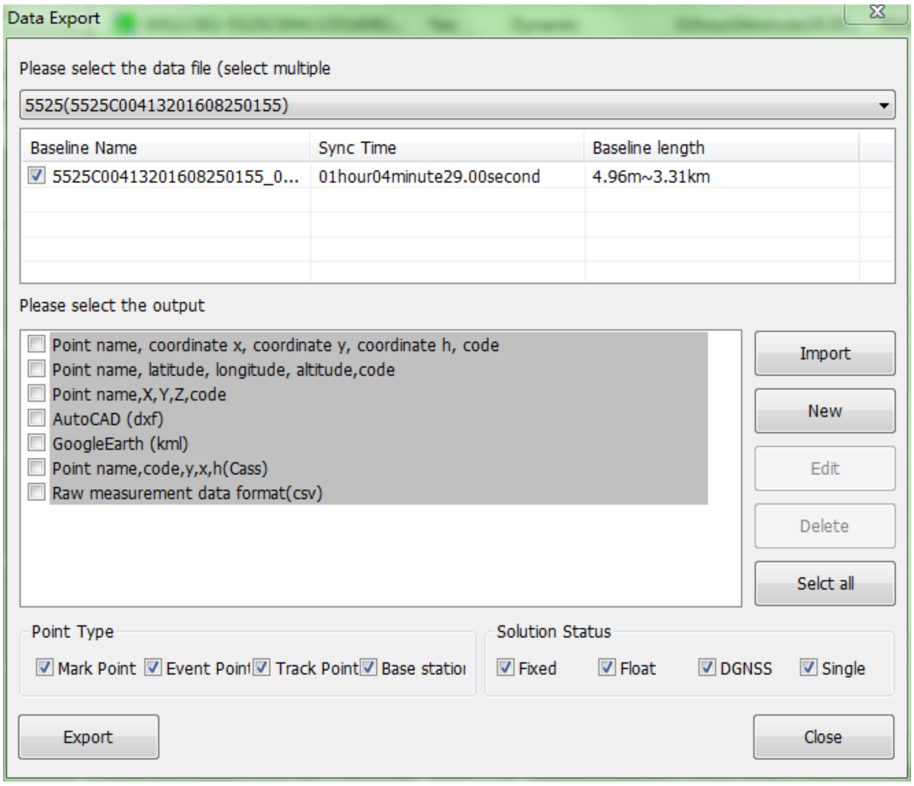


Figure 6-3

2) Download dynamic baseline solution result

Operation: click [Export] in Menu Bar – [Dynamic solution coordinates], or click [Result] in Navigation Bar – [Dynamic coordinate file].

To download dynamic coordinate file, it pops up a window, as shown in Figure 6-3. Firstly, select data file, and then select the baseline and output data type. Click [Export] and choose save path to export dynamic baseline solution coordinates.

If the output type needed does not show in the select list, it can set up the output type as needed, through creating [New] to set the defined format, or modifying the existed user-defined format by [Edit] or [Delete].

It comes the end of completed dynamic baseline solution after early preparation, baseline solution, and view and export of result.

Appendix 1 Glossary

IGS

International GPS Service for Geodynamics. Based on GPS continuously operating stations with global foundation, IGS is a model of network of GPS continuously operating station and comprehensive service system. It's made freely accessible to global users with all kinds of GPS information, such as GPS precise ephemeris, rapid ephemeris, forecasting ephemeris, coordinates and movement rates of IGS stations, phase and pseudo range of GPS signal received by IGS stations, and earth rotation rate. It supports tremendous scientific projects in geodesic and geodynamics, including ionosphere, meteorology, reference frame, precise time transmission, high-resolution projections of earth rotation rate and its variant, and crustal movement. France's DORIS and German's PRARE are considering establishing similar international organization, striving to make this kind of space-based geodetic surveying system more efficient, more automated, more precise and more reliable.

Ambiguity

An unknown value, the integer cycle value of carrier phase measured between satellite and receiver.

Baseline

Connection line between two observation points where simultaneously receive GPS signal and collect observation data.

Broadcast ephemeris

Satellite orbit parameter demodulated from telegraph text sent by satellite.

SNR (Signal-to-noise ratio)

Ratio of signal power to noise power at one endpoint.

Cycle slip

A phenomenon that with interference, cycle loop jumps several cycles from a balance point to a new balance point and stabilize on it, which cause incorrect integer cycle in phase.

Carrier

A radio wave having at least one characteristic (such as frequency, amplitude, or phase) that can be varied from a known reference value by modulation.

C/A Code

GPS rough observed/captured code, a 1023-bit pseudo-random binary code in double phase modulation. It repeats every 1023 bits and modulates at a 1MHz rate.

Difference measurement

GPS measurement with cross satellites, cross receivers and cross epochs. It can be divided into the following three kinds:

SD (Single Difference) Measurement (cross receivers): instantaneous effect rate of signal phase obtained by two receivers simultaneously observing one satellite.

DD (Double Difference) Measurement (cross receivers and cross satellites): the difference of one satellite's SD to the reference satellite's SD.

TD (Triple Difference) Measurement (cross receivers, cross satellites and cross epochs): the difference of the DD in an epoch to the DD in last epoch.

Differential positioning

Method to determine relative coordinates of two or more receivers through simultaneously tracking a same GPS signal.

Geometric Dilution Precision

A term to specify additional multiplicative effect of navigation satellite geometry on positional measurement precision in dynamic positioning, defined as:

$$DOP = \sqrt{tr(Q^T Q)^{-1}}$$

Of which, Q is the matrix of instant dynamic position solution (depends on positions of receiver and satellite). There are a number of standard terminologies in GPS as shown in following table:

Name	Description
GDOP (Geometric Dilution of Precision)	Four-dimensional geometry factor
PDOP (Position (3D) Dilution of Precision)	Three-dimensional geometry factor
HDOP (Horizontal Dilution of Precision)	Two-dimensional geometry factor

VDOP (Vertical Dilution of Precision)	Vertical geometry factor
TDOP (Time Dilution of Precision)	Time geometry factor (1:40000)
HTDOP (Horizontal and Time Dilution of Precision)	Horizontal and Time geometry factor

Dynamic positioning

Method to determine the time-varying coordinate of moving receiver. Each observation result is obtained by real-time calculation of single data sampling.

Eccentricity

$$e = \sqrt{\frac{a^2 - b^2}{b^2}}$$

Of which, a and b respectively refer to semi-major axis and semi-minor axis.

Ellipsoid

In geodesy, it is a mathematically defined surface generates when it is rotated about its minor axis. The semi-major axis of the ellipse, a, is identified as the equatorial radius of the ellipsoid: the semi-minor axis of the ellipse, b, is identified with the polar distances (from the center). These two lengths completely specify the shape of the ellipsoid but in practice geodesy publications classify reference ellipsoids by giving the semi-major axis and the inverse flattening, 1/f. The flattening, f, is simply a measure of how much the symmetry axis is compressed relative to the equatorial radius:

$$f = \frac{1}{a}(a - b)$$

Ephemeris

A set of numerical parameters that can be used to determine a satellite's time-varying position.

Flattening

$$f = \frac{1}{a}(a - b) = 1 - \sqrt{(1 - e^2)}$$

of which, a and b respectively refer to semi-major axis and semi-minor axis, and e refers to eccentricity ratio.

Geoid

The surface of the oceans that is extended through the continents, to whom the force of gravity acts perpendicular everywhere.

Ionosphere delay

Delay occurred when electric waves pass through the ionosphere (inhomogeneous dispersive medium). Phase delay depends on electron content and it affects carrier signal, while group delay depends on ionospheric dispersion and it affects signal modulation code. Phase delay and group delay share the same amplitude but with opposite signs.

L-band

Radio frequency range of 390-1550MHz.

Multipath error

The positioning error occurs when GPS signals arrive at an antenna having traversed different paths.

Observation session

The period when two or more receivers simultaneously collect GPS data.

Pseudo range

Distance calculated by time offset used to align the GPS copy code in receiver with the received GPS code multiplying velocity of light. The time offset is the difference between the time signal be received (receiver time series) and the time signal transmit (satellites time series).

Receiver channel

RF channel, mixed frequency channel and intermediate frequency channel of GPS receivers, which can receive and track two kinds of carrier signals.

Satellite configuration

Satellite configuration for a specific user or a group of users at a certain time.

Static positioning

Point measurement that not considering the receiver movement.

Universal time

Universal time: the mean solar time on the Prime Meridian at Greenwich, London, UK.

UT: acronym for Universal Time.

UT0 is Universal Time determined by observing the diurnal motion of stars. The relationship between Universal Time and Solar Time is: solar day-sidereal day=$3^{m}56.555^{n}$.

UT1 is UT0 after polar motion correction.

UT2 is a smoothed version of UT1, filtering out periodic seasonal variations.

UTC (Universal Time Coordinated) is an atomic timescale that approximates UT2.

Interval

The process of taking a continuous change value at periodic intervals.

Observation condition

In GPS measurement, observation condition refers to the geometry and trajectory of satellite constellation.

Appendix RINEX data format

RINEX file type

Six different types of data files are defined in the second edition of the RINEX format for respectively storing different types of data, namely observation data file for GPS observation value, navigation message file for GPS satellite navigation messages, meteorological data file for meteorological data measured in station, GLONASS navigation message file for GLONASS satellite navigation messages, Geostationary satellite (GEO) navigation messages file for GEO satellite navigation messages from a geostationary satellite equipped with a similar GPS signal generator in an enhanced system, and satellite and receiver file for time information of satellite and receiver.

RINEX naming rule

RINEX format has special naming rules for data files, so that user can easily distinguish the attribution, type and time of recorded data of the data files through the file name. According to the rule, the data file in RINEX format is named with 8.3 naming method. A completed file name consists of two parts: 8-digit main target name to represent file attribution, and 3-digit extension to represent file type, its specific form as follows:

ssssdddf.yyt

of which:

ssss: measurement station code in 4 digits.

ddd: DOY in the first record in the document.

f: file sequence number (FSN) in one day, sometimes names period number. The value is from 0-9, A-Z. When it is 0, it means that the file contains all data in that day. Notice that the FSN is based on the synchronous observation period of the whole project in one day instead of observation period of one receiver in one day. For instance, at one day, a project uses four receivers to observe. In the first period, four receivers all participate in observation, then in that period the FSNs of the data files in four receivers are 1. In the second period, only three receivers participate in observation, then in that period the FSNs of the data files in three receivers are 2. In the third period, four receivers all participate in observation again, then in that period the FSNs of the data files in four receivers including the one didn't participate in the second observation are 3.

yy: year.

t: file type, one among the follows:

O——observation file;

N——GPS navigation message file;

M——meteorological data file;

G——GLONASS navigation message file;

H——GEO navigation messages file

C——clock file.

Take BJFS0010.17O for example, it is the observation data file of whole-day data for point BJFS in Jan 1st, 2017 (DOY is 1). And BJFS0010.17N is its corresponding navigation message file.

Observation data file

It includes file header and data record. In Table 1 list the file headers of this file and in Table 2 list the data record. Here merely introduce a couple of terms.

Time: measuring time is the time when the signal arrives at the receiver. It is GPS time instead of UTC time. The pseudo ranges and phases of all tracking satellites are observed at that time.

Pseudo range: pseudo range is the distance calculated by time offset used to align the GPS copy code in receiver with the received GPS code multiplying velocity of light. There are three pseudo-range observations in RINEX: C1 is C/A code in L1; P1 is P code in L1; and P2 is P code in L2. Due to AS policy, plenty of receivers cannot receive P code in L2, so the delay of Y2-Y1 calculated by relevant technology is used for instead to eliminate influence of ionosphere. In this case, in RINEX it adopts P2 code composited by C/A code and the delay of Y2-Y1.

Phase: phase is the small value of integer cycle in beat frequency in actual L1 and L2. When using square technology to extract phase, if it is small value of half cycle, it must transfer to that of integer cycle.

Doppler: using specific processing software in receiver, it can record value of Doppler, D1, D2, Hz as units.

Table 1 Header description for GPS observation data file

Header label (column 61~80)	Description	Format
RINEX VERSION/TYPE	Version number of RINEX format (2.10 in this version) File type (“O” in this file) Satellite system where observation data from: (space or “G” for GPS, “R” for GLONASS, “S” for synchronous satellite signal payload, “T” for NNSS Meridian Satellite, “M” for combined system)	F9.2，11X， A1， 19X， A1， 19X
PGM / RUN BY / DATE	Program name that creates the data file Agency name that creates the data file	A20， A20，

	Date when data file is created	A20
COMMENT	Comment line	A60
MARKER NAME	Name of antenna mark (point name)	A60
MARKER NUMBER	Number of antenna mark (point number)	A20
OBSERVER / AGENCY	Observer name/Observation agency name	A20，A40
REC # / TYPE / VERS	SN, type and version (internal software version) of receiver	3A20
ANT # / TYPE	SN and type of antenna	2A20
APPROX POSITION XYZ	Approximate position of mark (WGS84)	3F14.4
ANTENNA:DELTA H/E/N	Antenna height(H): higher than the lower surface height of marked antenna Antenna center offset in east and north	3F14.4
WAVELENGTH FACT L1/2	Wavelength factor of L1 and L2 1: ambiguity of whole cycle 2: ambiguity of half cycle 0: L1 single frequency Tracking satellite number (maximum as 7, more than 7 repeats record) PRN: satellite number	2I6 I6 7(3X，A1，I2)
#/TYPES OF OBSERV	The number of different observed value types stored in the file. Observed value type list: Description: in RINEX 2.10 define the following observed value types: L1, L2: phases observed value in L1 and L2; C1: pseudo range measured by C/A code in L1;	I6 9(3X，A1，I2) 6X，9(4X，A2)

	P1, P2: pseudo ranges measured by P code in L1 and L2; D1, D2: Doppler frequencies in L1 and L2; T1, T2: Doppler integrations in 150(T1) of Meridian Satellite and 400MHz (T2) signal; S1, S2: initial signal strength of phase observed value in L1, L2 given by receiver or SNR value. Units of observed value: Cycle for carrier phase; Meter(m) for pseudo range; Hz for Doppler; Cycle for Meridian Satellite; SNR depends on receiver.	
INTERVAL	Epoch interval of observed value, second as unit.	F10.3
TIME OF FIRST OBS	The first recorded moment in the data file (year, month, day, hour, minute, second). Time system: GPS for GPS time, GLO for UTC time Description: in GPS/GLONASS file it must include the time system field. Default field for pure GPS file is GPS, and for pure GLONASS file is GLO.	5I6，F13.7 5X，A3
TIME OF LAST OBS	The last recorded moment in the data file (year, month, day, hour, minute, second). Time system: same as TIME OF FIRST OBS	5I6，F13.7 5X，A3
LEAP SECONDS	Leap seconds from Jan 6th, 2017 in GPD/GLONASS file.	I6

#OF SATELLITES	The number of satellites have observed value storied in file	I6
PRN/# OF OBS	The PRN (satellite number) involved by every observation values indicated in #/TYPES OF OBSERV record and the number of their observed value If types of observed value are over 9, then use a continuous line. Description: there is a record for each satellite in observation data file.	3X，A1，I2，9I6 6X，9I6
END OF HEADER	The last record in header	60X

Notes:

The above introduction formats are RINEX2.10:

In introduction of RINEX format, data types used are as follows:

X——space

A——alphabet

I——integral

F——float

D——double

Table 2 Observed value format description for GPS observation data file

Observed value record	Description	Format
EPOCH/SAT OR EVENT FLAG	Observed epoch: Year (2 digits, add 0 in the front as needed), month, day, hour, minute, second Epoch symbol: 0 for normal; 1 for a power failure occurred between the previous one and the current one; >1 for event symbol	1X，I2.2 4(1X，I2) F11.7 2X，I1 I3

	Satellite number observed in current epoch Satellite PRN list (satellite number with satellite system identifier) observed in current epoch Deviation of receiver clock (s as unit) If satellites are over 12, then use a continuous line. If epoch symbol is 2-5, it indicates that: 2: antenna starts moving; 3: new station is set (dynamic data ends); 4: following is information similar to header, describing certain special conditions in observation; 5: external event. "satellite number in current epoch" describes the following record number, i.e., how many lines in the following used to describe event. Maximum is 999. For a time that does not specify a moment in the epoch, the epoch field can be empty. Description: if epoch field is 6, it indicates in the following is record of cycle slips detected and repaired. This item is optional.	I2(A1，I2) F12.9 32X 12(A1，I2) [2X，I1] [I3]
OBSERVATIONS	Observed value LLI (Loss of Lock Indicator) Signal strength	m(F14.3，I1，I1)

Navigation message file

Satellite ephemeris is broadcast navigation message from satellites, which is the essential data of ground location calculation. In navigation message, it includes satellite's orbital elements and satellite clock parameter and other information. To speed up ground location calculation, broadcast navigation message is sent by satellite once per second and updated once per hour. Hence, every observation merely needs to record a set of broadcast navigation message. In Table 3 and Table 4 respectively are header description of navigation message file and record format description of navigation message file.

Table 3 Header description of GPS navigation message file

Header label (column 61-80)	Description	Format
RINEX VERSION / TYPE	Version number of RINEX format File type (N)	F9.2，11X A1，19X
PGM / RUN BY / DATE	Program name that creates the data file Agency name that creates the data file Date when data file is created	A20 A20 A20
COMMENT	Comment line	A60
ION ALPHA	Ionospheric parameter A0~A3 in ephemeris	2X， 4D12.4
ION BETA	Ionospheric parameter B0~B3 in ephemeris	2X， 4D12.4
DELTA-UTC：A0，A1，T，W	Ephemeris parameters used to calculate UTC time: A0, A1: multinomial coefficient T: reference moment of UTC data W: Reference cycle of UTC, as continuous counting	3X， 2D19.12 I9 I9
LEAP SECONDS	Time difference caused by leap seconds	I6

END OF HEADER	The last record in header	60X

Table 4 Observed value format description for GPS navigation message file

Observed value record	Description	Format
PRN number/ Epoch/ Satellite clock	PRN number of satellite Epoch: TOC (reference moment of satellite clock) Year (2 digits, add 0 in the front as needed) month, day, hour, minute second Deviation of satellite clock (s) Drifting of satellite clock (s/s) Drift speed of satellite clock (s/s^2)	I2 1X，I2.2 4(1X, I2) F5.1 3D19.12
Broadcast channel-1	IODE (Issue of Data，Ephemeris/Released time of data, epoch) C_{rs}(m) $\triangle n$(rad/s) M_0(rad)	3X， 4D19.12
Broadcast channe-2	C_{us}(rad) e orbital eccentricity C_{us}(radians) sqrt(A)(m1/2)	3X， 4D19.12
Broadcast channe-3	TOE reference of ephemeris time (the number of seconds in the GPS cycle) C_{ic}(rad) Ω (rad)(OMEGA) C_{is}(rad)	3X， 4D19.12
Broadcast	i_0(rad)	3X，

channe-4	C_{rc}(m) w(rad) Ω (rad/s) (OMEGA DOT)	4D19.12
Broadcast channe-5	i(rad/s) (IDOT) Code in L_2 GPS cycle number (together with TOE indicates time). It is continuous counting, not remainder of 1024. L_2 P-code data symbol	3X， 4D19.12
Broadcast channe-6	Satellite accuracy(m) Satellite state TGD(sec) AODC of IODC	3X， 4D19.12
Broadcast channe-7	Released time of message (second in GPS cycle as unit, calculated by Z in transition word (HOW)) Fitting range(h), as 0 if unknown	3X， 4D19.12