



A NovAtel Precise Positioning Product

**GrafNav / GrafNet
GrafNav Static**

User Manual

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Foreword

GrafNav / GrafNet® is a Windows®-based suite of programs that provide GNSS (Global Navigation Satellite System) data post-processing. Whether you have bought GrafNav / GrafNet or GrafNav Static, this manual will help you install and navigate your software.

Scope

This manual contains information on the installation and operation of Waypoint's GrafNav / GrafNet and GrafNav Static software packages. This information allows you to effectively navigate and post-process GNSS data. It is beyond the scope of this manual to provide details on service or repair. See *Customer Service* below for customer support.

How to use this manual

This manual is based on the menus in the interface of the GrafNav / GrafNet or GrafNav Static software. It is intended to be used in conjunction with the corresponding version of Waypoint's GrafNav / GrafNet or GrafNav Static software.

Although previous experience with Windows is not necessary to use Waypoint software packages, familiarity with certain actions that are customary in Windows will assist in using the program. This manual has been written with the expectation that you already have a basic familiarity with Windows.

Conventions

This manual covers the full performance capabilities of GrafNav / GrafNet GNSS data post-processing software. The conventions include the following:



This is a note box that contains important information before you use a command or log, or to give additional information afterwards.

The term "master" refers to the reference station and the base station.

The term "remote" refers to a rover station.

Customer Service

If the software was purchased through a vendor, contact them for support. Otherwise, for software updates and customer service, contact Waypoint using the following methods:

Call: 1-800-NovAtel (1-800-668-2835) for North American access
1-403-295-4900 for International access

Email: support@novatel.com

Web: www.novatel.com/support/info/view/software

Chapter 1 Introduction and Installation

1.1 Waypoint Products Group Software Overview

NovAtel's Waypoint Products Group offers GNSS post-processing software packages including GrafNav (a static/kinematic baseline processor) and GrafNet (a static baseline processor and network adjustment package). Both of these products have a Windows based Graphical User Interface (GUI) and use the same precise GNSS processing engine. This processing engine has undergone years of development effort and has been optimized to give the highest precision with the least amount of operator intervention.

This chapter contains a description of the hardware requirements and installation instructions. This chapter also provides an overview of the product packages (see *Table 2: Product Capabilities* on page 24).

1.2 Installation

Waypoint software supports software-based licensing only. Installation instructions are provided in the following sections.

1.2.1 What You Need To Start

1.2.1.1 Activation ID

A license is required to convert raw GNSS data¹, use the Download Service Utility and to process GNSS data. The license will be delivered electronically by either NovAtel Order Management or Support staff.

1.2.1.2 Installation file

The latest software installation files can be found at the following password protected website:

www.novatel.com/waypoint-installation-files-8-70

The password to this website should have been provided with your software license. If not, contact NovAtel Support at support@novatel.com with your activation ID.

See *Prerequisites* below for the hardware requirements.

1.2.2 Prerequisites

Only a user with administrator privileges can successfully install all of the components required to run Waypoint software. To run Waypoint software packages, your personal computer must meet or exceed this minimum configuration:

1.2.2.1 Operating System

Windows 7, 8, 8.1 or 10.

1.2.3 How to install Waypoint software

Administrator privileges are required to successfully install all components of Waypoint software.



It is recommended that a license be returned prior to any significant computer maintenance or changes

¹No license is required to convert NovAtel data to Waypoint format.



(i.e. upgrading of the operating system, motherboard replacements etc.).

1. If you have a previous version of Waypoint software installed, we do not recommend uninstalling it prior to installing a new version. This is because any user created content such as favourites, processing profiles, customized grids or conversions etc. can be copied over to the new version. This is only possible if the new version is installed prior to uninstalling the old version.

Each major version of Waypoint software will install to a separate default installation directory and will thus not overwrite or remove content from a previous major version.

All installation files are provided on both an FTP site and a password protected website. Contact support@novatel.com with your software activation ID for login instructions if required.

2. Launch the setup and follow the on-screen instructions.
3. If you are upgrading from a previous major version, such as 8.60, you will need to upgrade your license.

For upgrade instructions, see *How to Activate Your License* below or *How to Manually Activate/Return Your License* on the next page.

4. See *Copy User Files* on page 22 for instructions on how to copy user created content from previous major versions.

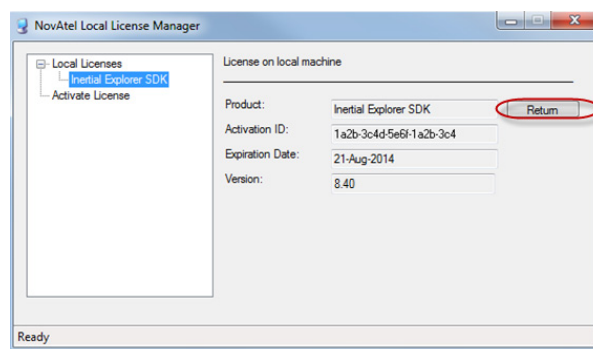
1.2.4 How to Activate Your License

This section applies to customers who wish to activate a new license or upgrade an existing license in order to use Waypoint software.

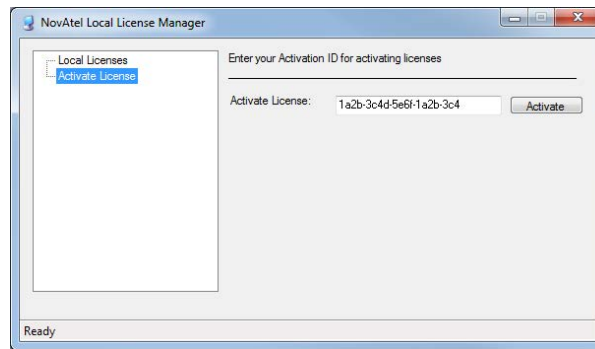


This procedure requires an Internet connection. If you do not have an Internet connection, go to *How to Manually Activate/Return Your License* on the next page.

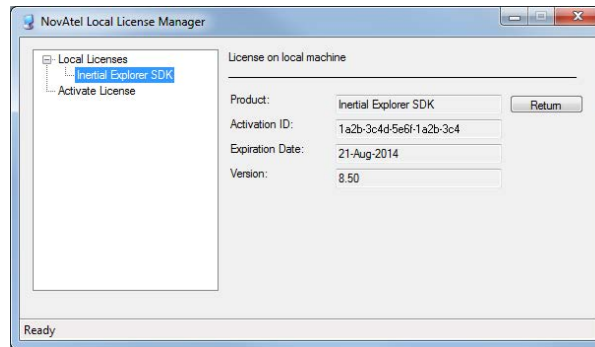
1. Install the Waypoint software that you intend to use. Contact support@novatel.com with your activation ID if you need help locating the setup file.
2. From the Start menu, navigate to the *Utilities* folder within the software's program group and open the *Local License Manager*.
Alternatively, you can navigate to the software's installation folder on your computer and open the *LLMForm.exe* file.
3. If you are upgrading an existing license, you will first need to return the original license. Do this by selecting your existing license under *Local Licenses* and then clicking the *Return* button.



4. Copy the alpha-numeric Activation ID that was provided to you by Customer Support and paste it into the box under the *Activate License* branch.



5. After the Activation ID has been entered, click the *Activate* button.
6. If the license was successfully activated, you will see it appear under the Local Licenses branch. Click on the license to see the relevant information.



If you have activated a term license, then the expiration date will be displayed here.

If the activation fails, contact Customer Support (support@novatel.com).

1.2.5 How to Manually Activate/Return Your License

This section describes how to activate and/or return a license when no Internet connection is available or you are unable to access NovAtel's license server.



If you are upgrading an existing license, your original license will need to be returned prior to activating the upgrade (see the manual return instructions first).

1.2.5.1 Manual Activation Process

1. Open a console window and navigate to the software's installation folder (e.g. C:\NovAtel\InertialExplorer870\bin).

2. Enter the following command to generate a Manual Activation Request.

```
LLMForm -am ActivationID OutputFile
```

Where:

ActivationID is the alpha-numeric Activation ID provided to you by Customer Support

OutputFile is the output XML file that will contain the request

Sample usage:

```
LLMForm -am 1a2b-3cf4-5e6f-1a2b-3c4d-5e6 c:\temp\activate_req.xml
```

3. Using your activation ID, login to the FlexNet customer portal here: <https://license.novatel.com/flexnet/operationsportal/showActivationIdLogon.do>.
4. Select *Manual Activation* under *Offline Operations*.
5. Select *Choose File* and browse to the request XML file you generated in step 2 and then select *Submit*.
6. A response will be generated and displayed to the screen. Select *Save* and a *responseXML.xml* file will be saved to the Windows default download directory. Optionally, move this file to the same directory as the activation request.
7. To process this response, navigate back to the installation directory and enter the following command:

```
LLMForm -p InputFile
```

Where:

InputFile is the full name and path of the *responseXML.xml* file generated from the FlexNet customer portal

Sample usage:

```
LLMForm -p c:\temp\responseXML.xml
```

8. If this is the first manual activation on a machine, the license will not be activated on the machine at this point, because the first response file is simply a configuration response. You will need to repeat step 1 - 7 in order to re-submit the request and complete the activation.
9. The license should now be activated. To check, enter the following command:

```
LLMForm -v
```

Alternately, open the Local License Manager and look under the Local Licenses branch.

1.2.5.2 Manual Return Process

1. Open a console window and navigate to the software's installation folder (e.g. C:\NovAtel\InertialExplorer870\bin).
2. Enter the following command to generate a Manual Return Request:

```
LLMForm -rm ActivationID OutputFile
```

Where:

ActivationID is the alpha-numeric Activation ID provided to you by NovAtel Order Management or Customer Support

OutputFile is the output XML file that will contain the request

Sample usage:

```
LLMForm -rm 1a2b-3cf4-5e6f-1a2b-3c4d-5e6 c:\temp\return_req.xml
```

3. Using your activation ID, login to the customer FlexNet portal here: <https://license.novatel.com/flexnet/operationsportal/showActivationIdLogon.do>
4. Select *Manual Return* under *Offline Operations*.
5. Select *Choose File* and browse to the manual return request file generated in step 2 and then select *Submit*.
6. A response will be generated and displayed to the screen. Select *Save To File* and a *responseXML.xml* file will be saved to the default Windows download directory. Optionally, move this file to a temporary directory or to the root of your hard drive.
7. To process this response, navigate back to the installation directory and enter the following command:

```
LLMForm -p InputFile
```

Where:

InputFile is the full name and path of the *responseXML.xml* file generated through the FlexNet customer portal

Sample usage:

```
llmform -p c:\temp\responseXML.xml
```

8. The license should now be returned. To check, open the Local License Manager and look under the Local Licenses branch to ensure that the license is no longer listed.

1.3 Processing Modes and Solutions

1.3.1 Processing Modes

The following are the types of processing modes:

1.3.1.1 Static Mode

Static processing involves the determination of a single coordinate for an entire static session. There are two types of static solutions supported by GrafNav: float and fixed solutions.

1.3.1.2 Kinematic Mode

When processing kinematic data, it is of interest to optimize the entire trajectory. This is in contrast to static processing, which solves one coordinate for the entire session.

In order to quickly achieve cm-level accuracy in kinematic processing environments, ARTK is used to resolve integer carrier phase ambiguities.

1.3.2 Processing Solutions

1.3.2.1 ARTK solution

AdVance RTK® is NovAtel's industry leading RTK engine which provides rapid centimetre level positioning. ARTK is used in Waypoint products to resolve integer carrier phase ambiguities.

With short baseline lengths (several kilometres), open sky conditions and dual frequency data, ARTK often requires only several seconds of data to fix ambiguities. Although ARTK needs at least 5 satellites to resolve, in practice it is most robust when 7 or more satellites are available. ARTK may resolve at baseline lengths as long as 70 km, however it is most reliable at distances of 30 km and less provided dual frequency data.

1.3.2.2 Fixed static solution

The fixed static solution uses ARTK with static constraints to resolve integer carrier phase ambiguities. New ambiguities are automatically fixed whenever there is a change in satellite geometry (i.e. a new satellite rises or

a satellite drops out). A history of ARTK solutions over the static session is kept and GrafNav/GrafNet allows you to choose which is accepted as the final solution based on estimated error, lowest RMS, highest reliability, or an average of all fixes.

1.3.2.3 Float solution

Float solutions, unlike fixed static and ARTK solutions, do not resolve carrier phase ambiguities as integer values. As such, they are associated with lower accuracy applications than fixed solutions. Provided good data, float solutions improve with time and can still achieve centimetre-level accuracy, depending on factors such as baseline length, number of satellites and geometry, raw measurement data quality, etc.

1.4 Overview of the Waypoint Products

1.4.1 Inertial Explorer

Inertial Explorer shares a similar interface with GrafNav and provides both GNSS and INS processing capabilities. Inertial Explorer is powerful and feature rich, including support for both loosely and tightly coupled processing, multi-pass processing, a backsmoother, automatic processing profile detection and many other features. See www.novatel.com/products/software/inertial-explorer/ for more information.

1.4.2 GrafNav

GrafNav is a kinematic and static GNSS post-processing package. Included with GrafNav is a Precise Point Positioning (PPP) module, support for multi-base applications, and support for moving base applications. See *GrafNav and GrafNav Static Overview* on page 24 for more information.

1.4.3 GrafNet

GrafNet is a batch static baseline processor and network adjustment package. It is often used to check or establish base station coordinates for later use within GrafNav or to survey static networks. See *GrafNet Overview* on page 85 for more information.

1.4.4 GrafNav Static

A GrafNav Static license allows a user to process GNSS data within either GrafNav or GrafNet, however only static data will be processed. See *GrafNav and GrafNav Static Overview* on page 24 for more information.

1.4.5 Moving Baseline Features

GrafNav includes a moving baseline module that processes GNSS data between two moving antennas. Heading can also be computed if the two antennas are mounted on the same vehicle

1.4.5.1 Relative Processing

All of the same advanced GrafNav processing features including ARTK, a robust Kalman filter, and forward/reverse processing are also supported in moving base processing. The only restriction is that only one base station can be used when processing the relative vector.

For applications where both antennas are mounted on the same vehicle, the surveyed distance between the antennas can be entered to assist ambiguity resolution. Heading can also be computed for these applications.

1.4.5.2 Relative Vector Output

After processing, the included Export Wizard profiles are available to output the relative vector in local level or ECEF format.

1.4.5.3 Relative Velocity

In addition to relative position information, GrafNav uses Doppler measurements to compute instantaneous relative velocity between two moving antennas.

1.5 Software Utilities

The following utilities are installed automatically and can be accessed from *Start | Programs | Waypoint GPS 8.70 | Utilities*.

1.5.1 Concatenate, Slice and Resample

This utility is most often used for combining multiple GPB files together and resampling GPB files to higher intervals. There are many other uses of this utility however and a full description can be found in *Concatenate, Slice and Resample Files* on page 124.

1.5.2 Copy User Files



Prior to version 8.70, the CopyUser utility could be used to migrate any user created content from a previous version to the current version. This utility has been discontinued in 8.70. See the following for instructions on copying user created content from previous software versions to 8.70.

User created content from previous versions of Waypoint software can be found in the *User* directory of the previous software version. To find this directory, open the previous version of software and navigate to *Settings | Preferences* then select the *Update* tab. The directory listed under the label *All user created or modified profiles, grids, datums, favorites, etc.* is your User directory.

The User directory of your previous version of software may contain files such as:

- User created export profiles (*.prf)
- User created processing profiles (*.DefOpt)
Be sure to check your installation directory for user created processing profiles as well.
- User created datums (user.dtm)
- User created grids (user.grd)
- User created favourite points/coordinates (user.fvt)
- User created plot groups (user.pgr)
- User created download service links (user.xml)
- User created 3rd party IMU conversion profiles (user.cim, Inertial Explorer only)
- User created IMU error models (user.imu, Inertial Explorer only)
- User created vehicle profiles (user.vpf, Inertial Explorer only)

To find your 8.70 User directory, navigate to the installation directory of your 8.70 software and read the *waypoint.settings* file. This is an ASCII file that you can read with any ASCII text editor. Your 8.70 User directory path will be saved in the node labeled *UserDir*. By default UserDir will be in your 8.70 installation directory.

To migrate your old user created content simply copy the files from the User directory of the previous version of software to the User directory of your 8.70 software.

All user files from 8.60 are fully compatible with 8.70 and you can copy them directly from 8.60 to 8.70. Waypoint cannot guarantee 8.70 User file compatibility for older software versions (e.g. the lever arm favourites – user.lvf

– file is not supported in 8.70). If a user file is incompatible with 8.70, you will have to recreate the file using 8.70 utilities.

1.5.3 Download Service Data

This utility allows you to search for freely accessible base station data provided by government organizations. The utility will download, convert, and if necessary resample and concatenate the downloaded data so that it is ready to be used within your project.

The download utility can also be used to obtain precise satellite clock and ephemerides, and alternate broadcast ephemerides.

1.5.4 GPB Viewer

This utility allows you to view converted GNSS data as well as perform certain functions, such as changing the static/kinematic processing flag. See *GPB Viewer Overview* on page 120 for more information.

1.5.5 GNSS Data Converter

This utility converts raw GNSS data files into Waypoint GPB format. The following table shows the supported receivers and formats. See *GNSS Data Converter Overview* on page 125 for more information.

You will also see the Local License Manager utility.

Table 1: Supported Data Formats

Make	Model
NovAtel	All Models
Javad	All Models
Leica	System 500 System 1200 GX1230
NavCom	SF-20x0 SF-30x0 Sapphire
RTCM	3.0
Septentrio	SBF
Ashtech	Real Time B-file
U-Blox	Antaris M-8
RINEX	2.x 3.x

Chapter 2 GrafNav

2.1 GrafNav and GrafNav Static Overview

2.1.1 GrafNav

GrafNav is a full-featured kinematic and static GNSS post-processing package that uses a proprietary GPS, GLONASS, BeiDou, Galileo and QZSS processing engine. It supports single and multi-baseline (MB) processing, moving baseline processing, Precise Point Positioning, and directly supports many different receiver formats. For any receiver formats not currently supported, RINEX files can be imported. See *Table 1: Supported Data Formats* on page 23 for more information.

This chapter describes how to get started with GrafNav and goes through each menu of its interface. Step-by-step instructions for first-time users are also included.

2.1.2 GrafNav Static

GrafNav Static provides the same processing features as GrafNav, but only for static baselines. The following table shows a capability comparison between GrafNav and GrafNav Static.

Table 2: Product Capabilities

Capabilities	GrafNav Static	GrafNav/GrafNet
Float Static	✓	✓
Float Kinematic		✓
Fixed Integer Static (Fixed Solution)	✓	✓
Fixed Integer Kinematic		✓
Dual Frequency	✓	✓
GPS, GLONASS, BeiDou, Galileo and QZSS Support	✓	✓
Multi-Base Processing	✓	✓
PPP	✓ (Static only)	✓
Moving Baseline		✓
Azimuth Determination		✓
Batch Processing ^a	✓ (Static only)	✓
a. For more information about batch processing see <i>WPGCMD</i> on page 149.		

2.2 Start a Project with GrafNav

New users will find it easiest to create a new project with the New Project Wizard. The Wizard takes you through all the steps of creating a GrafNav project, including data conversion and downloading base station data (if needed). The only requirement for using the Wizard is that you have a raw GNSS data file downloaded to your computer. Access the Wizard through *File | New Project | Project Wizard*.

After you have become familiar with the GrafNav interface, you may prefer to create new projects using the *Empty Project* method. When creating an empty project, you need to convert your data using the Raw GNSS conversion utility prior to adding it to the project and download any base station data using the Download Service Utility prior to adding it to the project. See *GNSS Data Converter Overview* on page 125 for a description of the Convert Utility, and *Download Service Data* on page 79 for instructions on the Download Utility.

2.2.1 Install Software

Verify that the installation was successful by ensuring that you have a *Waypoint* program group on your computer and that your license has been successfully activated through the local license manager. If this program group is not there, see *How to install Waypoint software* on page 16 for installation instructions.

2.2.2 Convert Data

Raw GNSS data files must be converted into Waypoint's GPB format. If creating a project through the New Project Wizard, there is no need to convert your data first. If creating an empty project, the Raw GNSS Converter must be used before adding the data to an empty project. See *GNSS Data Converter Overview* on page 125 for a complete description of the *Convert* utility.

2.2.3 Download Service Data

If no data was logged from a reference station, you have the option of downloading free GNSS data from the Internet.

A reference station can also be added directly from a list. See *Download Service Data* on page 79 for these instructions as well as a complete description of the *Download* utility.

2.3 File menu

The following sections provide information about the features available on the File menu.

2.3.1 New Project

To process a survey for the first time, start a new project. When you start a new project, choose between *Project Wizard* and *Empty Project*.

The Project Wizard is recommended for new users as it will guide you through all the steps of getting started, including data conversion and downloading base station data (if needed). After you are more familiar with the tools and workflow, you may prefer to use the *Empty Project* option.

The following sections discuss these options and step-by-step instructions once you have decided on the method for starting your project.

2.3.1.1 Project Wizard

The Project Wizard offers you a guided step-by-step way of creating a project.

How to create a new project using the Project Wizard

1. Create and name the project.
2. Add rover data to the project.



The rover data can be in Waypoint's GPB format, or in the receiver's raw format, in which case the Wizard converts it to GPB for you.

3. Add base station data to the project.



You can add your own local base station data (in raw or GPB format) or you can have the Wizard download free service data.



If you plan to process with PPP, you can skip adding base station data and download the precise satellite clock and orbit files.

2.3.1.2 Empty Project

Creating an empty project is not recommended for new users as all steps involved with project creation must be done manually. Specifically, the remote GNSS data must be converted to GPB format using the GNSS Data Converter utility and any base station service data must be downloaded through the Download Service Data utility.

The Project Wizard is best for new users as it guides you through each step involved with starting a project. Creating an empty project is usually preferred by advanced users. This is because, for someone familiar with Waypoint's workflow, it may be possible to get started more quickly creating an empty project as opposed to stepping through a Wizard.

How to create a new project using Empty Project

Prior to starting the following steps, the Raw GNSS Converter must be used to convert the remote data to GPB format. If required, the Download Service Data Utility must also be used to acquire base station data.

1. Select *File | New Project | Empty Project*.
2. Enter the name and where you would like to save your project.
3. Select *File | Add Master File(s)* to load master files. Select the GPB files collected at the base station(s) and click *Open*.
4. Enter the base station coordinates, datum and antenna information when prompted.
5. Select *File | Add Remote File*. Select the GPB file corresponding to the data that was collected at the remote.
6. Enter the antenna information for the remote when prompted.
7. Select *Process | Process GNSS*.
8. Ensure an appropriate processing profile is selected prior to processing.

2.3.2 Open Project

This option allows you to open existing projects.

2.3.2.1 How to open a project

1. Choose *File | Open Project*. A dialog box appears that asks you to select the name of an existing project (CFG file).
2. Choose the name of the project and click the *OK* button.

2.3.3 Save Project

When this option is selected, all project settings are saved to a GrafNav configuration (.cfg) file. The project is automatically saved when processing and thus accessing the save option from the File menu is not typically

necessary.

2.3.3.1 How to save a project

1. Choose *File | Save Project*.

2.3.4 Save As

Use the *Save As* command under the *File* menu to create a new project that has identical processing options as the current project. This allows you to change the options in the new project and process the data without losing the solution computed by the original configuration.

2.3.4.1 How to save as a project

1. Choose *File | Save As*.
2. Enter the name and where you would like to save your project.



Entering the name of a project that already exists overwrites the file contents.

2.3.5 Add Master File(s)

Up to 32 base stations can be added to a single GrafNav project. We recommend adding additional base station data only if each base station is in a distinctly different project area and is at some point the closest in the trajectory.

All data must be converted to GPB prior to adding as a base station. When adding a base station, take care to verify base station coordinates and datum (and epoch, if necessary) as this is critical to absolute position accuracy.

To add a master file:

1. Select *File | Add Master File(s)*.
2. Select the base Station file(s) from the list of available GPB files. Up to 32 base stations can be added to a project. Click the *Open* button.
3. Enter the coordinates and datum of each base station when prompted.

If you are importing data retrieved from the Download Service Utility, precise coordinates may be accessed through the *Select from Favorites* option under the *Coord. options* pull-down.

If the datum of any coordinate does not match the processing datum, it will be automatically converted prior to processing.

4. Enter or verify the antenna model and height information and click the *OK* button.

Refer to the following links for information about the fields on this dialog.

- *Master Station Position* on the next page
- *Datum Selection* on the next page

The image shows the 'Coordinate/Antenna Settings' dialog box. It has two tabs: 'Master' and 'Remote'. The 'Master' tab is selected. The 'Base Station' section includes a dropdown menu showing '2: PRDS', a text field for 'Name' containing 'PRDS', and a 'Disabled' checkbox. Below this is a 'File' field containing 'C:\Data\Highway_2016_1\prds2440.gpb'. The 'Coordinates' section has fields for 'Latitude' (North, 50, 52, 16.86267), 'Longitude' (West, 114, 17, 36.59725), 'Ellipsoidal height' (1248.050 m), 'Datum' (IGS08), 'Proc Datum' (NAD83(2011)), and 'Epoch' (2016.667 year). There are 'Coord. options' and 'Save to Favorites' buttons. The 'Antenna Height' section includes 'From station file' (AOAD/M_T, NONE), 'View STA File' button, 'Antenna profile' (ASH700700.A), 'Info' button, 'Measured height' (0.100 m), 'ARP to L1 offset' (0.024 m), 'Applied height' (0.124 m), and a 'Measured to' section with radio buttons for 'ARP' (selected) and 'L1 Phase Centre', plus a 'Compute From Slant' button. At the bottom are 'OK' and 'Cancel' buttons.

- *Epoch Selection* below
- *Antenna Height* below
- *Antenna Models* on the next page

2.3.5.1 Master Station Position

When loading a master station, the coordinates that appear in the master coordinate dialog may come from two different sources.

If loading data converted from RINEX, as is the case when obtaining base station data through the Download Service Data Utility, the coordinates that appear initially are scanned from the RINEX header. The coordinates provided in the RINEX header may be precise or approximate, this will depend on the individual RINEX data provider. The RINEX header does not provide any information regarding the datum of the coordinates. As such, the user is required to specify the coordinate datum of each base station loaded.

If loading base station data converted from any other source, the coordinates that appear initially are likely averaged from the unprocessed position records decoded in the raw GNSS data file. The accuracy of this position is typically no better than approximately 2 m horizontal and 5 m vertical. If you select the *OK* button using averaged coordinates, a warning dialog appears to ensure you are aware the coordinates may not be accurate.

Regardless of the source of your base station data, it is important that accurate coordinates are loaded. In differential processing, a vector is solved between the base station antenna and the remote antenna. Any error in the base station position is directly transmitted to the remote position.

To assist in loading precise coordinates, it is recommended that coordinates be selected from the favorites list through the *Select from Favorites* option, which appears under the *Coord. options* pull-down. Coordinates for select base station networks, such as CORS and IGN, are regularly maintained and accessible through Favorites.

The *Compute from PPP* option, which also appears under the *Coord. options* pull-down, can be used to easily check or survey base station data using GrafNav's Precise Point Processor. When using this option, the differences between the loaded and computed coordinates are displayed. Note that PPP accuracy is largely dependent on the length of the survey and the quality of the data.

2.3.5.2 Datum Selection

GrafNav 8.70 distinguishes between base station coordinate datums and the processing datum. Each base station may have a unique coordinate datum. If any base station's coordinate datum is different than the processing datum, it will be automatically converted prior to processing.

2.3.5.3 Epoch Selection

GrafNav allows users to enter the epoch of their base station coordinates for tracking/reporting purposes. This is important as coordinates change over time due to tectonic plate motion, and as such in any precise application both the datum and epoch of the coordinates should be known.

If entering the epoch of a base station coordinate, it is required that all base stations have the same epoch (if using more than one base station).

2.3.5.4 Antenna Height

The antenna height applied at the base station depends on where the base station coordinates are referenced. If the coordinates are referenced to some point below the antenna, the vertical offset between the marker and the Antenna Reference Point (ARP) should be entered for *Measured Height*. In this case, the total applied height would then be the addition of the vertical offset defined by the antenna model and the vertical offset between the ARP and the marker from which the coordinates are referenced.

If the base station coordinates are ARP values, the *Measured height* is by definition zero and the total *Applied height* is only equal to the difference between the ARP and the L1 phase center as defined by the antenna model.

If the base station coordinates are L1 phase center values, choose the *L1 Phase Center* option within the *Measured to* options and zero the *Measured to* height.

2.3.5.5 Antenna Models

The purpose of an antenna model is to:

- Correct for the vertical offset between where GNSS observations are observed (the electronic phase center) and the bottom of the antenna (Antenna Reference Point, or ARP).
- Correct for any difference between the L1 and L2 electronic phase centers, which can be a factor in the success or failure of ambiguity resolution.
- Apply elevation based corrections

GrafNav supports absolute antenna models as provided by the NGS. If the antenna model is not known at your remote, it is recommended that the *Generic* profile be applied, which does not apply any corrections. In that case, the processed positions are referenced to the antenna L1 phase center, or as best can be estimated without applying the antenna model. The correct antenna model should be selected for best results.

When selecting an antenna model, the *ARP to L1 offset* reflects the vertical difference between the L1 phase center and the ARP (which is the bottom of the antenna). This value comes directly from the antenna model and reduces the processed position from the phase center to the ARP. This value should match any diagram that appears directly on your antenna, presuming it is an absolute antenna calibration. Antenna heights can be measured to the antenna reference point, phase center, or computed from a slant measurement.

When loading a base station converted from RINEX, the antenna name and radome (if provided) are scanned from the RINEX header and used to automatically load the appropriate antenna profile. It is good practice to ensure the correct antenna model is loaded prior to processing.

2.3.6 Add Remote File

The remote file contains the raw GNSS measurements that are processed together with data from known base station(s). The remote file must be converted to GPB prior to loading. When adding a remote GPB file, you are prompted to enter the antenna information. See *Antenna Models* above for more information.

2.3.6.1 How to add a remote file

1. Select *File | Add Remote File*.

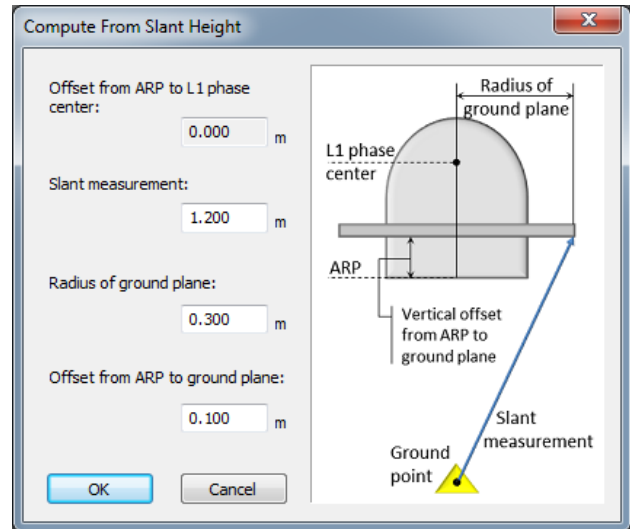
From the list of available GPB files, choose the file collected at the remote station.

2. When prompted, enter the remote station antenna information.

The screenshot shows the 'Coordinate/Antenna Settings' dialog box with the 'Remote' tab selected. The 'Remote file name' field contains the path 'C:\Data\SPAN\WheelSensorDatasets\STIM\Highway_2016_1\SteadyState'. Under 'Antenna Height', the 'From station file' is 'N/A' and the 'Antenna profile' is 'Generic'. The 'Measured height' is '0.000 m', 'ARP to L1 offset' is '0.000 m', and 'Applied height' is '0.000 m'. In the 'Measured to' section, 'L1 Phase Centre' is selected with a radio button. A 'Compute From Slant' button is also present. The dialog has 'OK' and 'Cancel' buttons at the bottom.

2.3.6.2 Compute from Slant

The *Compute from Slant* feature enables the automatic computation of the true vertical *Applied height* required by GrafNav given a slant measurement, the radius of the ground plane edge and the offset from the ARP to the ground plane edge.



2.3.7 Add Precise/Alternate Files

The *Precise Files* dialog primarily facilitates the easy download of precise products. Users can choose between GPS, GPS+GLONASS, and GNSS (sources that provide data for GPS, GLONASS, BeiDou, Galileo and QZSS) sources depending on the signals acquired in data collection.

The *Precise Files* utility also enables a user to add alternate broadcast ephemeris data downloaded through the *Download Service Data* utility. A user may do this to supplement missing broadcast ephemeris data within their project.

2.3.7.1 Broadcast Ephemeris

The ephemeris file contains Keplerian orbital parameters used to compute satellite positions. Presently, the line of sight component of satellite positions can be computed within an accuracy of approximately 2 m (RMS) using the broadcast ephemeris.

Orbital error is largely removed in differential processing, as the line of sight component is heavily correlated at short and medium baseline lengths (< ~100 km). Therefore, the accuracy of the broadcast orbits is completely sufficient for most projects. A discussion on precise orbits is found in the next section.

Generally, the GNSS receiver includes broadcast ephemeris data with its raw data files. The decoder converts these files into EPP format. Receivers typically output ephemerides at startup, as satellites rise into view, or approximately every two hours.

Prior to processing, GrafNav combines all ephemeris information collected at the base station(s) and remote. This minimizes the chance of missing broadcast ephemerides.

In version 8.50 and earlier, if a GPS broadcast ephemeris was missing the satellite could not be used regardless of whether or not a precise ephemeris file had been added to the project. Versions 8.60 and greater are not dependent on the presence of GPS, BeiDou, Galileo and QZSS broadcast ephemerides and any missing broadcast values can be fixed by adding a precise ephemeris to the project. The same is not true for GLONASS, broadcast ephemerides are required regardless of whether a precise ephemeris has been added to the project. The *Download Service Data* utility can be used to download a global broadcast ephemeris file in EPP format as well as to download precise ephemerides.

2.3.7.2 Precise Ephemerides

Precise ephemerides are computed from data collected by ground reference stations around the world. These files are produced by various agencies, including CODE (Center for Orbit Determination), the IGS, and others.

The different precise ephemeris products vary in the rate they provide precise clock corrections, the constellations for which data is provided, and their latency. Presently supported products range in latency from approximately 2 hours to 3 weeks. The difference in accuracy between rapid and final products is marginal, generally within the noise of either differential or PPP kinematic solutions.

Presently, precise ephemerides reduce the line of sight component of satellite position error to approximately 2 cm RMS (as compared with approximately 2 m RMS for broadcast orbits). As orbital error is largely cancelled in differential processing, adding precise ephemerides to a differential project will only produce observable differences where the baseline length is large (150-200 km). For this reason, adding precise orbits to a differential project is generally considered optional.

Precise ephemerides can be downloaded through the Download Service Data utility or directly through the GrafNav interface. Adding a precise ephemeris file will compensate for any missing broadcast ephemeris data for GPS, BeiDou, Galileo and QZSS satellites. A broadcast ephemeris for each GLONASS satellite observed is required regardless of the presence of a precise ephemeris.

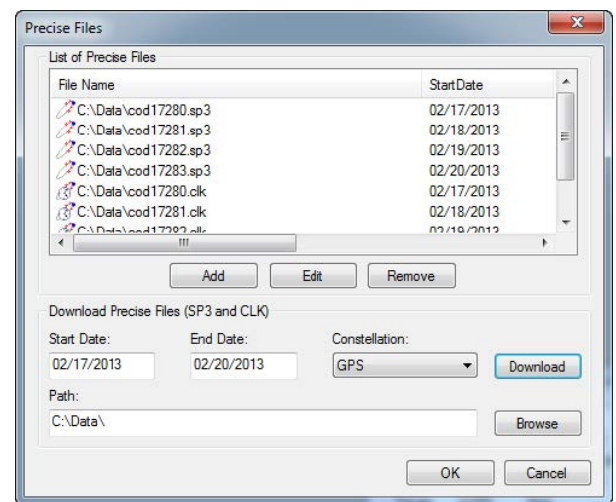
How to download precise ephemeris files

1. Select *File | Add Precise Files*.

The project start and end date are automatically scanned from the GNSS data loaded into the project. This should not need to be set manually.

2. Select *Browse* in order to choose any precise orbits (.sp3) and clock files (.clk) that have previously been downloaded.

If no files have been downloaded, select *Download* after specifying the source to download from under *Constellation*. Note that multiple precise products for the same day cannot be loaded into one project. The precise orbit (.sp3) and clock (.clk) data will automatically be downloaded and added to your project. This requires an internet connection.



If your project includes GLONASS or other constellation data, make the appropriate selection under the "Constellation" pull down menu prior to downloading. The default search location for precise products contains only GPS data.

2.3.7.3 IONEX Files

IONEX (Ionosphere Map Exchange) files contain a model of the TEC (Total Electron Content) of the ionosphere. These files can be applied to assist long distance L1 only processing. As such, these corrections are not applicable to the majority of GrafNav users. These files are ignored if dual frequency ionospheric processing is engaged.

2.3.7.4 Satellite Clock Files

Presently, using the data available in the broadcast ephemeris, satellite clock errors can be predicted within an accuracy of approximately 2 m RMS. Satellite clock error is completely removed in differential processing, as this error is exactly the same at the base and the rover. Thus adding precise clock files to a differential project will have no effect.

Satellite clock files can be downloaded through the Download Service Utility or from *File | Add Precise/Alternate Files*.

2.3.8 Load

The following sections describe the options available from *File | Load*.

2.3.8.1 GNSS Solution

After processing, forward and reverse solutions are automatically combined if available. Thus, the trajectory output to the map window, and all generated plots, are usually relative to a combined forward/reverse solution. The title bar of the map window and plots clearly indicate which solution is loaded.

If the processing results from a particular direction (forward or reverse) are of interest, individual solutions can be loaded using this feature.

2.3.8.2 PPP Solution

GrafNav's differential and PPP trajectory files have, by design, different file extensions. This allows both differential and PPP trajectories to be processed within the same project without overwriting each other. If both types of solutions have been processed, you can control which type of solution is loaded through the *GNSS Solution* and *PPP Solution* options.

2.3.8.3 Any Solution

This option allows any GrafNav readable trajectory to be loaded into a project. The only requirement is that the trajectory cover the same time range as the data within your existing project. An example of when this feature may be used is when loading a real time trajectory produced from the GNSS decoder.

2.3.8.4 Single Point Solution (from .gpb file)

This option ensures the trajectory displayed to the map window reflects the unprocessed positions in the remote GNSS data. This trajectory typically represents the real time solution as computed on board the receiver during data collection.

2.3.8.5 Camera Event Marks

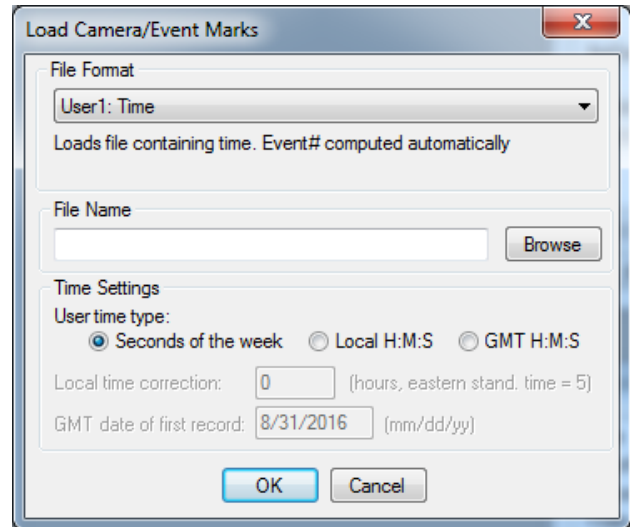
Events from supported GNSS formats are automatically written to a station file (.sta) during conversion of the raw GNSS data to GPB, and automatically loaded into the project and displayed on the map window.

Use the *Load Camera/Event Marks* feature to load external time-tagged events from an ASCII file from one of four supported input formats. When you load events, they must be referenced to GPS time, local H:M:S or GMT H:M:S. The source of the events can come from an aerial camera, sounding equipment or other real-time devices.

How to load camera event marks

1. Under *File*, select *Load | Camera Event Marks*.
2. Choose the file format that matches your input file.
3. Under *File Name*, use the *Browse* button to select the input file.

When features/camera marks have been loaded into a project, they appear as bright blue circles on the map window. If no event marks are present after processing, first check that you have not disabled the display of event marks within the *General* options of the *Display* tab within *Settings | Preferences*. If *Show feature marks* is enabled, it is likely that the time tags are wrong or no event marks have been loaded. To determine what has been loaded, use the *Feature Editor* by selecting *View | Features*.



File Format

STA File

Most supported receiver formats write features/camera marks directly to the station file. The features load when you add the GPB file to the project. In the event you have deleted features using the Feature Editor and you wish to re-load the original station file, use the *File | Load | Station File* feature.

User#

These formats allow you to import the time and name of each event mark. Optional variables include line number (description) and altitude information.

Time settings

User time type:

Seconds of the week – GPS time ranging from 0 to 604800.

Local H:M:S – Local hours, minutes and seconds (HH:MM:SS.SSSS).

GMT H:M:S – GMT hours, minutes and seconds (HH:MM:SS.SSSS).

Local time correction:

This is necessary for both Leica and User# formats using *Local H:M:S*. This is the offset, in hours, from GMT. For the Eastern Standard Time zone, this number is 5. For the Pacific Standard Time zone, this number is 8. During daylight savings time, these numbers are reduced by one. An incorrect entry causes the camera marks to be displayed incorrectly or not be displayed at all.

GMT date of first record:

This is necessary for Leica, Ashtech and User# formats implementing H:M:S time-tagging. Enter the date of the first exposure record in month/day/year format. It is not the date in local time, which may differ towards the end of the day. An invalid date results in the marks not being displayed.

2.3.8.6 Station File (.sta/nst)

GrafNav automatically loads the station file (.sta) associated with the remote GPB file. This file is produced during conversion and contains, among other information, any time tagged events. If properly loaded, these time tagged events are displayed to the map window.

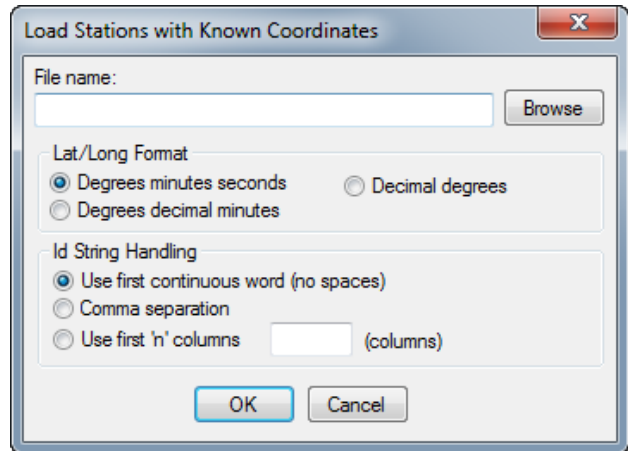
The program automatically loads the STA station file as long as the filename is the same as the remote GPB file. If the station file has a different filename than the GPB file, then load the file through the *File | Load | Station File* feature.

2.3.8.7 Stations with Known Lat/Long

This option allows you to load and display a file that contains stations with known coordinates. The coordinates are displayed with pink triangles.

How to load stations with known latitude and longitude

1. Select *File | Load | Stations with Known Lat/Long*.
2. Use the *Browse* button to locate the input file containing the points with known positions that you wish to display to the map window.
3. Choose the appropriate file format under the *Lat/Long Format*.
4. Choose an option under *Id String Handling* to tell the program how to separate the ID from the coordinates. The first column usually contains the station IDs.



Lat/Long Format

The following are formats that the coordinates from the file can be in:

Degrees Minutes Seconds

For example: 51° 03' 28.3214"

Degrees Decimal Minutes

For Example: 51° 03.4720'

Decimal Degrees

For Example: 51.0579°

Id String Handling

The settings under this option tell the program how to separate the ID from the coordinates.

Use first continuous word (no spaces)

To be used if the station names are separated from their coordinates by a space.

Comma separation

Use this option if commas separate the IDs from the coordinates.

Use first 'n' columns

If you know which column the coordinates start in, you can enter the number for the program to begin at. Each character is a column.

2.3.9 Convert

2.3.9.1 Raw GNSS to GPB

You must convert your raw GNSS data files to GPB prior to adding them to an empty project. It is not necessary to convert your raw GNSS data prior to creating a new project if using the New Project Wizard. See *GNSS Data Converter Overview* on page 125 for more information regarding this utility.

2.3.10 GPB Utilities

The GPB Utilities are available for use with GPB files and includes the following:

2.3.10.1 Concatenate, Slice and Resample

See *Concatenate, Slice and Resample Files* on page 124.

2.3.10.2 View Raw GNSS Data

See *GPB Viewer Overview* on page 120.

2.3.11 Recent projects

Provides a list of recent projects for quick access.

2.3.12 Exit

Exits Waypoint software.

2.4 View Menu

2.4.1 Project Overview

This window provides a summary of the data in the current project. From here, you can view information regarding the base and remote files, including receiver/antenna types, time coverage, data gaps and the constellations present in each file.

2.4.2 GNSS Observations

These options are available via *Master* or *Remote*:

2.4.2.1 View Raw GNSS Data

Opens the master or remote GPB file in the *GPB Viewer*.

2.4.2.2 View Ephemeris File

Opens the master or remote ephemeris file in the internal ASCII viewer.

2.4.2.3 View Station File

Opens the master or remote station file in the internal ASCII viewer.

2.4.2.4 Resample/Fill Gaps using the following options

File Interval

Fills any gaps but does not resample to a higher rate than the file was originally collected at.

Processing Interval

Fills gaps and matches the data rate in accordance with the specified processing interval.

Remote File Times

Produces a new master GPB file with epoch times that match the remote file. Any data gap present in the remote file is also present in the new master GPB file. This method of resampling removes unneeded data logged before, and after, the observation time period at the remote.



Resampling base station data to a lower interval will add noise to the processed trajectory. This noise is negligible if resampling from an original rate of 5 seconds or less, but can add as much as 1-2 cm if resampling from 30 second data. Note, this is often within the noise of a differentially processed trajectory and thus should not be seen as a significant limitation.

2.4.2.5 Disable

Disables the selected master station from being used for processing. You may want to disable individual baselines from a multi-base project when trouble shooting poor multi-base processing results.

2.4.2.6 Remove

Removes the master file completely from the project.

2.4.3 Forward and Reverse Solutions

2.4.3.1 GNSS / PPP Message Log

These files display all messages generated by the processing engine. GrafNav outputs a forward message log (.fml/.fsl) and a reverse message log (.rml/.rsl), depending on the processing mode (differential or PPP). Possible messages reported here are listed below.

Types of messages written to the message log files

- Times at which ARTK was engaged and the reasons for its engagement. These messages are preceded by +++.
- The satellite constellations (GPS/GLONASS/BeiDou/Galileo/QZSS) that will be used in processing and within ARTK
- Any satellites with no ephemeris information.
- The antenna types detected for the base stations and remote files
- The GLONASS fixing receiver type mode
- Base satellite drop outs
- Epochs of less than 4 common satellites between the master and remote.
- Periods of poor satellite geometry.
- The occurrence of cycle slips. This log gives a time and record of these slips that mean problems in kinematic data.
- Data errors that cause filter resets or the rejection of satellites. These messages are preceded by \$\$\$.
- Entering static and kinematic modes.
- Events resulting from significant changes in the satellites' geometry. These include changes in the base satellite and the rising or falling of satellites above or below the elevation mask.
- The omission of satellites, baselines or time periods from processing.

2.4.3.2 GNSS Summary

These summary files (.fss and .rss) display some basic processing settings and the statistics for ARTK fixes and static sessions. Other items reported in this summary are listed below. See *FML*, *RML*, *FSL* and *RSL* Files on page 115 for an example of this summary file.

Static/ARTK summary report items

- Final solutions for all static sessions, as well as the type of solution obtained.
- Time and place at which ARTK engaged successfully, as well as the corresponding statistics. Such information is useful for evaluating whether or not ARTK resolved ambiguities correctly.
- Master station coordinates, antenna summary for base and rover, and the processing mode.
- Satellite usage information pertaining to static sessions.
- Slope, horizontal and corrected ellipsoidal distances for all static sessions.
- Program completion information.

2.4.4 Processing Summary

This file provides a statistical summary of the processing results. It can be used for reporting and quality checking purposes. A list of the items reported in this file include:

- Solution type (forward/reverse/combined)
- Summary of the number of epochs in the remote GPB file processed, missing and epochs with poor measurement residuals
- Summary of measurement RMS values (L1 Phase, C/A code and L1 Doppler)
- Breakdown of quality number percentages
- The RMS of the forward/reverse position separation, including separate statistics where both solutions are fixed
- Percentages of standard deviations that fall within given intervals
- Percentage of epochs with poor satellite geometry ($DD_DOP > 10$).
Note: DD_DOP is approximately equal to $PDOP^2$.
- Baseline distance summary

The *Processing Summary* can be added to the end of an output text file created through the *Export Wizard*. See *Export Wizard* on page 65 for information about the *Export Wizard*.

2.4.5 Features

The *Feature Editor* window lists all of the features loaded into the project. If the data has been processed, a summary of processing quality is also displayed. In addition to viewing features, the feature editor can also be used to:

- Edit Station feature names and time-tags. For camera marks, the line number can be inserted into the *Desc/Info* field.
- Re-number stations and camera event marks.



Changes made to features are saved automatically to an NST file. To revert back to the original station information, use *File | Load | Station File*.

2.4.5.1 Columns on the Features Editor window

The following is a list of the columns displayed on the Features Editor window.

Name

The name of the feature. The symbol next to the name indicates the type of feature loaded. Examples include camera marks and stations. The symbol appears gray if the feature has been disabled.

Time

This is the feature's GPS capture time. To show the time in HH:MM:SS, select *Show HMS*.

Q

Reports GrafNav's computed quality number. Quality numbers range from 1 (best) to 6 (worst).

- 1 represents a fixed integer solution with good satellite geometry
- 2 & 3 represent either fixed integers with marginal geometry or converging float solutions
- 4 & 5 indicate qualities similar to DGPS
- 6 represents a C/A only solution

The quality number is only meant to communicate, at a high level, the overall processed data quality. For more information, access GrafNav's quality control plots.

Std(m)

Combined standard deviation of the north, east and height components, including additive PPM based error.

Fix

Shows the ambiguity status of the feature's solution:

- Y** = fixed integer
- N** = float solution

Azimuth

Azimuth, in degrees-minutes-seconds, from previous feature to current feature.

Dist(m)

Distance, in metres, from previous point to current point.

Dt(s)

Time difference, in seconds, between current and previous point.

Height

Height, in metres, of the feature. This is normally an ellipsoidal height, but if the master station height was entered as orthometric then this height is more orthometric. Use the *Export Wizard* to get the exact orthometric height. For stations, like STA and GIS, with antenna heights, this height is of the monument and not the antenna.

AntHgt

The height of the antenna above the monument. Camera marks do not have an antenna height and so *N/A* is displayed.

Desc/Info

Describes the feature or line information for the camera mark.

2.4.5.2 Buttons on the Features Editor window

The following is a list of the options that are available with the buttons on the right-hand side of the *Features Editor* window.

Add Station

Lets you manually add a station. Also add stations by right-clicking on epochs in the map window.

Remove

Removes the selected stations. Multiple stations can be selected and removed. You might consider disabling a feature instead of deleting it.

Edit

Edits the station name, time-tag, description and remarks.

Select All

Selects all features. Use this prior to *Edit Selected* when you want to apply global edits to all features.

View Info

Shows processing information for any selected feature enabled during processing.

Global Edit

Make changes to multiple selected features. Modifications can be made to the antenna height and time offset.

Re-Number

Re-number a selection of stations. Numbering can be performed starting from the bottom or the top of the list. You can specify the starting number and the increment value. To decrease numbers, use a negative number.

Move to Static

This feature is used to assist in the quality control of surveys where multiple short static sessions are collected in challenging GNSS signal environments. When used, it allows you to see the difference between the forward and reverse solution for each static session in your survey when exporting from the Wizard.

An example of an application that may use the *Move to Static* feature is seismic surveying. Move to Static requires that a station mark be present within each static session.



Edit, *Re-Number* and *Move to Static* work with multiple features selected. To select a continuous block, hold down the *Shift* key while clicking on features. To select individual features, use the *Ctrl* key.

2.4.6 ASCII File(s)

The *View ASCII File(s)* option allows you to view any of the ASCII files generated by the software using GrafNav's ASCII file viewer. Examples of these files include the following:

- Message logs (FML and RML)
- Static summaries (FSS and RSS)
- Station files (STA)
- Ephemeris files (EPP)
- Configuration files (CFG).

2.4.7 Raw GNSS Data

This option launches the GPB Viewer. The GPB viewer allows the viewing and editing of raw GNSS data that has been converted to Waypoint's format. This viewer is also launched by double clicking a converted GPB file within Windows Explorer. See *GPB Viewer Overview* on page 120 for more information.

2.4.8 Current CFG File

This option opens a Waypoint configuration file (.cfg) within Waypoint's ASCII viewer. The CFG file contains all of the installation and processing settings in a project.

2.5 Process Menu

2.5.1 Process GNSS

The Process GNSS dialog is intended to provide a one page startup where the processing method, processing direction, processing options and processing datum can all be conveniently accessed.

2.5.1.1 Processing Method

Differential GNSS

Differential processing can be selected if base station (s) have been added to the project. This method of processing provides access to ARTK, where carrier phase ambiguities may be fixed for high accuracy applications.

Precise Point Positioning (PPP)

PPP is an autonomous positioning method where data from only the remote receiver is used. If base station data has been added to the project, it will not be used when processing PPP. By design, both differential and PPP trajectories can be processed within the same project without over-writing each other.

GrafNav's PPP processor requires dual frequency data, single frequency PPP is not supported.

Upon selecting *Process*, GrafNav's pre-processing checks test whether precise ephemeris and clock data have been added to the project, which are required to remove metre-level error sources. If the project contains only broadcast orbit and clock corrections from the combined ephemeris data (.EPP files), GrafNav's pre-processing checks will warn of this through the *No Precise Files* pre-processing warning.

If it is your intention to process a PPP trajectory without applying any precise corrections, you can do so by deselecting the *Try to fix* option at the bottom of the PPP Pre-processing dialog and then select *Continue*. Users may wish to do this as a quick check on the quantity and quality of collected data, prior to precise ephemeris files or base station data becoming available.

If the *Try to fix* option is selected when you select *Continue*, GrafNav will call the Download Service Utility to automatically download the best available source of precise and ephemeris data given the detected constellations in the remote data file.

2.5.1.2 Processing Direction

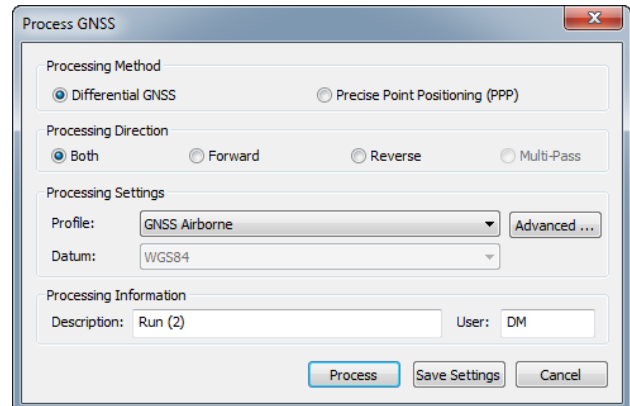
Both

When processing *Both* directions, independent forward and reverse solutions are processed and automatically combined. This method of processing is the default for differential processing.

Combining forward and reverse solutions maximizes solution accuracy and assists in quality control. Depending in part on baseline length, satellite geometry and number of satellites available, forward and reverse solutions may achieve different solution types (fixed/float) for different parts of the survey.

When both directions are combined automatically after processing, GrafNav applies inverse variance weighting to ensure the direction with the lower estimated errors receives the most weight in the combined trajectory.

Position differences between forward and reverse directions can be accessed from the *Combined Separation* and *Combined Separation (fixed)* plots after processing. The latter plot shows the differences in positions only where both have fixed integer solutions. This plot will help detect incorrectly fixed ambiguities.



Forward and Reverse

Changing the processing direction to *Forward* or *Reverse* is normally done only if a problem is detected after processing *Both* directions. The *Advanced* dialog can be accessed to customize processing options prior to reprocessing.

Multi-Pass

This method of processing is available only for PPP. This is because it is a method of processing designed to maximize float solution convergence. This is not normally a consideration in differential processing due to ARTK, where carrier phase ambiguities are fixed.

When choosing multi-pass processing, forward and reverse solutions are not independent. Rather, the data is processed three times sequentially (forward, reverse and forward again). After each direction finishes processing, the converged Kalman filter error states are applied to the next processing direction. The benefit of this method of processing is that float ambiguity convergence is maximized, producing in some cases near fixed integer solution quality.

2.5.1.3 Processing Settings

Profile

Processing profiles are available for aerial, ground vehicle, marine, pedestrian and UAV applications. The processing profile which matches the detected processing environment during decoding of the raw measurement data to GPB is automatically loaded the first time you access the Process GNSS dialog. Users can change their default processing profile, which turns off the auto-detection of the processing profile, within the *Solution* tab of *Settings | Preferences*. Users may wish to change their default profile if a custom profile has been developed or edits have been made to the manufacturer profiles. These profiles load processing settings that have been empirically developed to work well for each application, including changes to the default elevation mask, ARTK options, measurement weighting and more.

Processing profiles are particularly helpful for new users, as adjusting individual processing settings from the *Advanced* options are often unnecessary in order generate a high quality result. For advanced user's, processing settings can be created or customized.

Advanced...

Depending on the processing method selected (differential or PPP), selecting *Advanced* provides access to all available processing settings.

Datum

The processing datum is directly accessible from the *Process GNSS* dialog for both differential and PPP processing. If any base station coordinates have been entered in a different datum than the processing datum, they will be automatically converted prior to processing.

2.5.1.4 Processing Information

Description

The processing description automatically appears as *Run (1)* for the first differential processing run or *PPP (1)* for the first PPP processing run. The counter within the parentheses automatically increases each time a processing run is performed. The description of the processing runs can be edited (optional).

User

You can enter your name or initials here. This can be helpful if multiple users will be processing the same data on the same computer.

2.5.1.5 General (Differential Settings)

Process Data Type

Defines the type of data used for processing.

Automatic

Chooses between dual frequency, single frequency and C/A only depending on what measurements are in common between the base and remote.

C/A code only

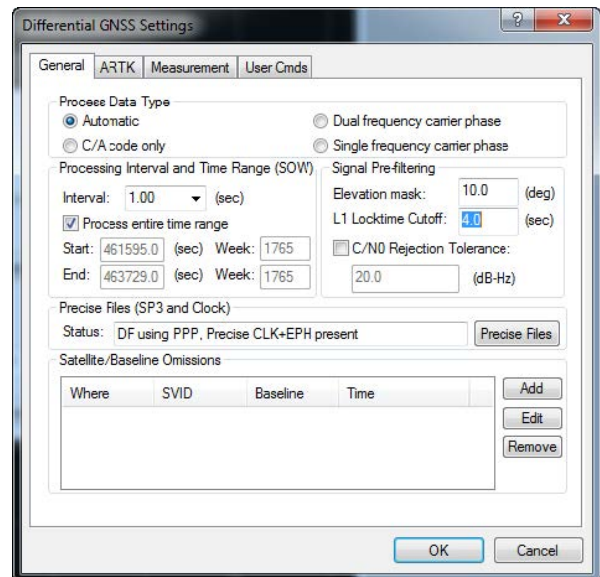
Only C/A code measurements are applied in this method of processing which is limited to metre-level accuracy.

Dual frequency carrier phase

Dual frequency processing should always be used for best results if both base and remote provide dual frequency data. Ambiguity resolution is faster, more reliable and possible at longer baseline lengths than single frequency processing. For long baselines (>7 km by default), ionospheric processing is automatically engaged, helping to preserve post-processed accuracy with increasing baseline length.

Single frequency carrier phase (Differential GNSS processing only)

Single frequency processing uses L1/B1/E1/L1CA measurement only from GPS and GLONASS, BeiDou, Galileo and QZSS if available. While ambiguity resolution can still be successful on short baseline lengths, this method of processing is generally associated with decimetre level applications. As the ionospheric error cannot be directly measured and removed, as in dual frequency processing, post-processed accuracy quickly degrades with increasing baseline length.



Processing Interval and Time Range (SOW)

The data rate of the remote GPB file is used as the default processing interval. However as only common data between the base station and remote can be processed, you will need to ensure the base station(s) were also logged or resampled to the same interval in order to output a trajectory at this interval. GrafNav's pre-processing checks will output a warning if the master data rate is detected to be less than the remote and will automatically resample the base station data to the remote interval to correct the issue should you select *Continue* with the *Try to fix* option engaged on the pre-processing dialog.

By default, all common data between master and remote is processed but a specific time range in GPS seconds of the week can be entered here. The start and end processing times can also be set by right clicking on GrafNav Q/C plots.

Signal Pre-filtering

Elevation Mask

Satellites below this elevation (relative to the horizon) are ignored. Common elevation masks for differential kinematic processing are 10-12 degrees. Static processing generally benefits from a higher elevation mask (15 degrees).

Low elevation signals are more affected by multipath and tropospheric error, and are more likely to be affected by cycle slips due to signal blockages and/or signal attenuation by the antenna. Thus, pre-filtering low elevation signals is generally beneficial to post-processed accuracy. Increasing this value too high may cause satellite geometry to become poor which can affect the performance of integer carrier phase determination.

L1 Locktime Cutoff:

This is the number of seconds that continuous carrier phase tracking is required before measurements will be used. Lowering this value will help to maximize GNSS position availability following a total loss of carrier phase lock. However, using low values increases the likelihood of an incorrect ambiguity fix. This is because the quality of carrier phase measurements may be suspect within the first few seconds the receiver achieves carrier phase lock.

C/N0 Rejection Tolerance

Most often, pre-filtering GNSS signals by elevation mask and L1 locktime cutoff is effective. For specialized applications, introducing an alternative or additional pre-filtering method based on the signal to noise ratio may also be effective.

This option is not engaged by default as not every receiver provides a C/N0 value, and different receivers may output this value at different stages of signal processing. Care should be used if applying this option.

Precise Files (SP3 and Clock)

Precise clock and orbit files can be downloaded by accessing the *Precise Files* button. Adding a precise ephemeris file will help mitigate residual orbital error on long baselines. Precise clock files are not needed in differential processing as this error cancels completely. However, as both files are required should the advanced tropospheric state be engaged or if a Precise Point Positioning (PPP) solution is later computed, both precise files can be added here.

Satellite/Baseline Omissions

GrafNav's pre-filtering options will often remove noisy or problematic data prior to the processing stage. During processing, GrafNav's automatic outlier detection routines work to automatically fix errors when large measurement residuals are detected. Failing all of this, if a problematic measurement or satellite can be identified, usually from repeated warnings during processing regarding a specific satellite prior to a Kalman filter reset occurring, the *Omit Satellite Info* dialog can be accessed to manually enter satellite omissions.

Satellites to Omit**All Satellites**

Disables all satellites from being used.

Only specified satellite

Disables individual satellites from individual constellations.

Baselines to Omit**Omit satellite for all baselines**

Applies the satellite omission to all baselines in the project.

Only selected baseline

Applies the satellite omission only to the specified baseline (applies to multi-baseline projects only).

Time Period**Omit for entire data set**

Applies the omission to the entire processing time range.

Use specified time range

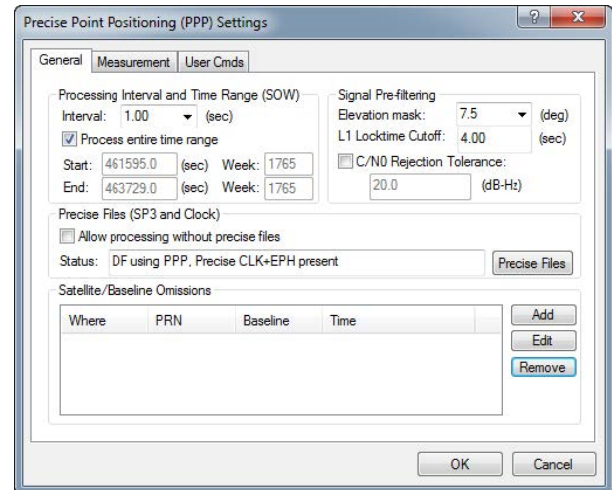
Applies the omission to a specific time period, entered in GPS seconds of the week.

2.5.1.6 General (PPP Settings)

The options found in the General tab of the PPP processing settings are explained in the Differential General tab. See *General (Differential Settings)* on page 42. The one exception is *Allow processing without precise files*.

Allow processing without precise files

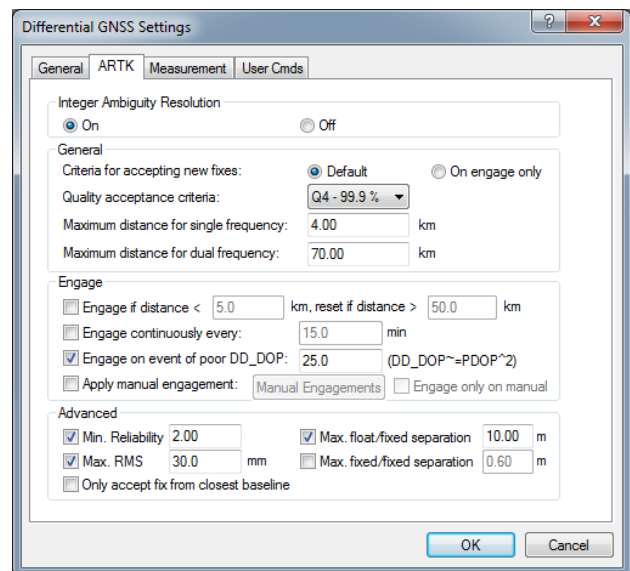
This option removes the restriction where measurements will not be used if precise clock and ephemeris data is unavailable. This enables a user to process PPP using only broadcast ephemeris data for the purposes of a quick check on the quality and quantity of data processed prior to precise products or base station data becoming available.



2.5.1.7 ARTK Options (Differential GNSS processing only)

ARTK (AdVance RTK) is NovAtel's method of resolving integer carrier phase ambiguities. ARTK is engaged by default and should be attempted in high accuracy applications, whenever cm level results are required.

Dual frequency ARTK provides fast, reliable and robust performance. However, in high multipath environments or where the satellite geometry is marginal, the possibility of an incorrect ambiguity fix exists. This is why it is important to access GrafNav's quality control plots which will help detect errors.



Both single and dual frequency ARTK require at least 5 satellites, but 7 or more are preferable.

Integer Ambiguity Resolution processing option settings

On

Engages ARTK for both single and dual frequency data processing.

Off

Disables ARTK. This will produce a float solution.

General

Criteria for accepting new fixes

ARTK can be used in *Default* or *On engage only* modes. These modes are described below.

Default

When ARTK is used in default mode, it is constantly re-checking its solved ambiguities when the satellite geometry changes (i.e. when new satellites come into the solution or when individual satellites are lost). Thus it is possible, even under open sky conditions where no loss of lock occurs, that ARTK will accept a new set of integer ambiguities when there is a change in satellite geometry. This may result in a position jump where the new ambiguities are accepted.

Using ARTK in default mode is thus mostly preferred for ground vehicle applications, as this method provides a high level of solution accuracy over the entire length of a trajectory.

On engage only

This method ensures ARTK engages only at startup, when a complete loss of lock occurs, or after a period of poor satellite geometry. This method is generally preferred for aerial applications as it ensures that new ambiguity fixes are not accepted in the middle of a flight line, where position jumps may be problematic.

Quality acceptance criteria

This is the confidence level required in residual testing for an ARTK fix to be accepted. Using lower quality acceptance criteria increases both the likelihood of achieving a fix and the possibility the fix may be incorrect. Conversely, increasing the quality acceptance criteria helps reduce the likelihood of incorrect ambiguity fixes, but also the chance that no fix is achieved when conditions are marginal for ambiguity determination.

The default criteria applied in all manufacturer processing profiles is the highest possible setting, Q4 (99.9%). This is set purposefully conservative to help guard against the worst-case scenario of an incorrect set of ambiguities being accepted. In this case, the standard deviation of the solution will be cm-level however there may be metre-level error in the solution. It is important to view the *Combined Separation with Fixed Ambiguity* plot to help identify any incorrectly fixed solutions.

The quality acceptance criteria provides a level of control over ARTK performance, however advanced settings can also be applied, including the minimum reliability, maximum RMS, maximum float/fixed separation and maximum fixed/fixed separation.

Maximum Distance

The distance tolerance for engaging ARTK for both single and dual frequency can be defined here. The default values applied are high, and therefore are more often lowered than increased.

If your project involves a long flight to or from the project area, and your base station is operating in the project area, it is generally beneficial to lower the distance threshold to 30 km or less. This will prevent ARTK from engaging itself unnecessarily far from your project area, which increases the likelihood of an incorrect ambiguity fix.

Engage Options

These options control when ARTK is engaged.

Engage if distance < tolerance1, reset if distance > tolerance2:

The first tolerance is used to automatically re-engage ARTK on approach to any new base station. The remote must exceed the second tolerance for ARTK to re-engage when re-approaching the same base station. This option, specifically the first tolerance, is useful in multi-base, corridor-type projects.

Engage continuously every:

Engages ARTK at regular intervals. This option does not check other criteria, such as baseline length or data quality. Thus, it should only be used in slow moving or monitoring applications.

Engage on event of poor DD_DOP:

It is possible to maintain a fixed integer solution through an event which causes poor satellite geometry, provided carrier phase lock is maintained on four or more satellites. When satellites are re-acquired, their

carrier phase ambiguities are not automatically re-established as fixed integer solutions. Thus, it is possible that following a period of poor geometry, more satellites in the solution have float ambiguities than fixed. This will not necessarily result in degraded accuracy, but re-establishing all satellites with fixed ambiguities is generally beneficial to maintaining high accuracies.

Apply Manual Engagement

A manual ARTK engagement forces GrafNav to re-establish carrier phase ambiguities. Introducing a manual engagement is one technique to recover from an incorrect or drifting ambiguity fix. These instances (incorrect or drifting ambiguity fixes) can be identified from the forward/reverse separation plots. If the *Engage only on manual* setting has not been enabled, GrafNav will compute a float solution only until a manual ARTK engage time is reached, at which point GrafNav will attempt to resolve integer carrier phase ambiguities.

Advanced

These options provide advanced users more control over ARTK performance and more tools when reprocessing problematic surveys. By default, conservative values are applied in all manufacture processing profiles only to provide sanity checks on the values returned by ARTK.

Min. Reliability:

The reliability of an ARTK fix is the ratio of the second best RMS and the best RMS. It indicates how much better, statistically, the best solution is from the second best solution. High reliability values indicate the best RMS is significantly better (lower) than the second best RMS, and thus a high degree of confidence can be placed in the solution. This option provides direct control over the minimum reliability ARTK will accept as a pass.

Max. RMS:

An RMS is computed for every possible ARTK fix within a given search area. This RMS, output by GrafNav in units of mm, represents the mathematical fit of the solution or how well the carrier phase measurements in the solution agree with each other. Low values (mm level or sub-mm) represent well fitting solutions, or measurements that agree very closely. Large values (cm level) indicate poorer fitting solutions that are more suspect. This option provides direct user control over the maximum allowable RMS for an ARTK fix to be considered a pass.

Max. float/fixed separation:

Using this option forces the float solution to converge within a specified distance prior to a fix being accepted. This value is usually dependent on the time used by ARTK to fix. If only seconds of data are used, the float solution is likely to be metres away from the fixed. This would be normal and not indicative of a problem. If several minutes of data are used prior to fixing, the float solution may have converged to within a decimetre-level value. Nonetheless, fixed ambiguities with excessively large float/fixed separate values are suspect and large values may indicate heavy multipath conditions.

Max fixed/fixed separation:

This option is of significance when ARTK is used in *Default* mode. In this mode, ARTK is constantly re-checking its carrier phase ambiguities as the satellite geometry changes. When a new fixed integer solution is obtained, the position computed with the new set of fixed ambiguities is compared to the position computed from the previous set of fixed ambiguities and the difference is reported as the *fixed/fixed separation*. Fixed solutions with large fixed/fixed differences may be suspect, and users can directly control how different a new set of fixed integer ambiguities can be from the current. It is recommended not to set this value too low, as it may prevent GrafNav from fixing.

Only accept fix from closest baseline:

In multi-base processing, ARTK uses data from all base stations within the distance tolerance under the *General* ARTK options and chooses the best fix (statistically). As such, the closest base station will not necessarily be the one which has fixed ambiguities. This option is available should users desire or require

to only accept fixed integer solutions from the nearest baseline. This option is not engaged by default as in general it does not produce best results.

2.5.1.8 Measurement

Measurement Standard Deviations

Sets the measurement standard deviations applied to code, carrier and Doppler measurements.

Code

Controls the measurement weighting applied to the double differenced C/A measurements. Regardless of what value is entered here, if ARTK is used to fix integer carrier phase ambiguities, the C/A measurement standard deviation will not significantly impact results. This is because when ambiguities are fixed, the strength of the solution comes from the carrier phase. The C/A measurement weighting can affect float solution convergence and is one of the most effective setting available for optimizing float trajectories.

Carrier phase

Controls the measurement weighting applied to the double differenced carrier phase measurements. This value is automatically increased if ionospheric processing is engaged. Also, an additive PPM value is applied to account for increased noise as the baseline distance increases.

Doppler

Doppler is the instantaneous rate of change of the carrier phase signal as measured in the receiver. Doppler is used to calculate instantaneous velocity. GrafNav assigns a relatively conservative measurement weighting of either 1.0 m or 0.25 m depending on the receiver manufacturer. GrafNav uses a conservative weighting as the quality of Doppler measurements vary significantly from one receiver manufacturer to another. Nonetheless, if a large number of Doppler errors are reported to the processing dialogs and message log files, consider increasing the weighting after viewing the *RMS - Doppler* plot or disengage the option to *Use Doppler for velocity determination* within the *Measurement Usage* settings.

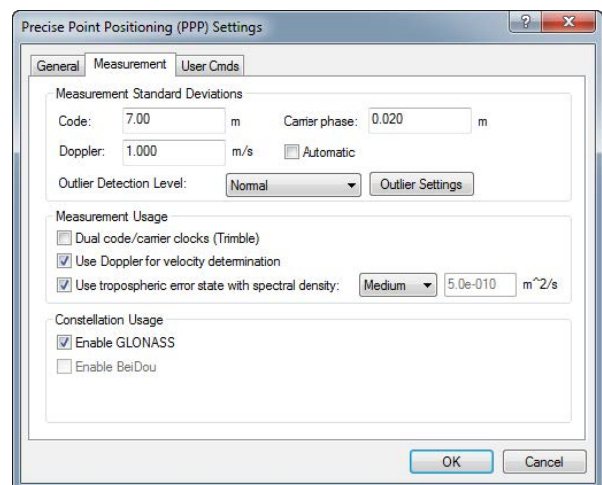
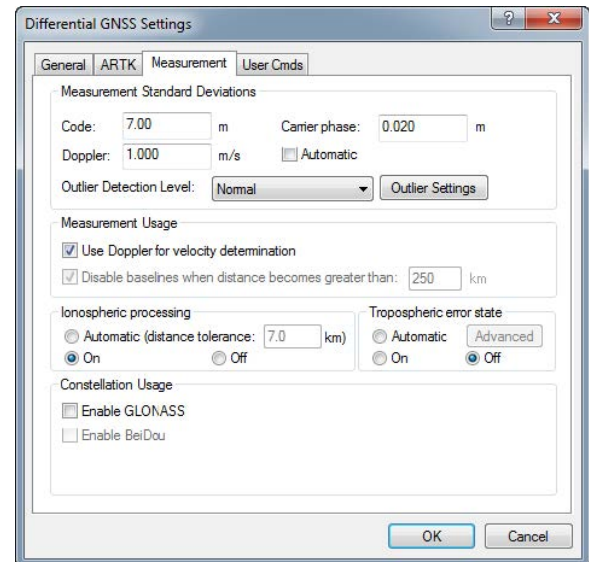
Outlier Detection/Rejection

GrafNav attempts to automatically reject satellites or measurements when large measurement residuals are detected. If a large residual is detected, GrafNav systematically rejects each satellite individually and recalculates the position and residual. If the new residual is significantly lower than the original residual, the satellite is automatically removed from the solution at that epoch. GrafNav's sensitivity to high measurement residuals is controlled through this setting.

Measurement Usage

Dual code/carrier clocks (PPP only)

This option engages the use of separate clock states for the code and carrier measurements. Whether this option should be engaged is completely dependent on receiver design. It is most often needed for Trimble



receivers, so this option is automatically engaged if the remote receiver is detected to be Trimble. If this option is not used when needed, typically, results are obviously degraded.

Use Doppler for velocity determination

If engaged, Doppler is used to derive instantaneous velocity. If many Doppler measurement errors are output to the GrafNav processing dialog, it may indicate the Doppler measurement quality of your receiver is very poor. In this case, it is recommended you disable this option or increase the measurement SD upwards.

Disable baselines when distance becomes greater than (Differential processing only)

This option is used to automatically disable base stations according to baseline length. This is an effective means of managing base station data use in large project areas.

Use tropospheric error state (PPP processing only)

As no base station data is used to reduce correlated errors, such as tropospheric delay, this must be solved as an additional state within the PPP filter. The tropospheric spectral density controls how fast GrafNav allows the tropospheric state to change. *Medium* is suitable for most projects, but *High* may work better if very fast and frequent changes in elevation are expected in your survey. *High* allows the tropospheric conditions to change more rapidly within the filter.

Ionospheric Processing (Differential processing only)

Ionospheric processing requires dual frequency data. It helps maintain GNSS positioning accuracy with increasing baseline length. The ionosphere can be a significant error source for L1 only processing as it is highly variable and can change rapidly.

Ionospheric processing essentially removes the ionospheric delay as an error source, however does so at the cost of higher measurement noise. Thus, best results are achieved on short baseline lengths when ionospheric processing is disabled. However when the baseline distance becomes large, the benefits of correcting for the ionosphere out-weigh the increased noise and best results are achieved when enabling this option.

In order to handle both scenarios, GrafNav has an *Automatic* setting that will turn on or off ionospheric processing depending on the length of the baseline detected in the project. Prior to processing, the unprocessed positions in the remote GPB file are compared with the base station position. If more than 10% of the trajectory exceeds the distance tolerance, ionospheric processing is engaged.

In addition to *Automatic*, ionospheric processing can also be explicitly turned on or off.

Tropospheric Error State (Differential processing only)

Unlike ionospheric error, tropospheric error cannot be directly observed and removed using dual frequency measurements. This is because the troposphere is nondispersive at GNSS frequencies and affects L1 and L2 equally. GrafNav uses a Saastamoinen model to estimate the tropospheric delay at the base and remote. However regardless of what model is applied, tropospheric error is largely removed in differential processing as it is a correlated error on short baseline lengths.

As the baseline length increases (to ~150 km or more) and/or where there is a significant height difference between the base and remote (~10,000 ft), residual tropospheric error can become the largest error source; reaching magnitudes as much as 30 cm in some cases.

In order to reduce the tropospheric error under these conditions, GrafNav leverages the ability of the Precise Point Positioning engine to observe the actual tropospheric delay at the base station. In PPP, tropospheric error is observed as an additional Kalman filter state. Hence, GrafNav first solves the actual tropospheric delay at the base station and then, as a second step, applies this information in differential processing.

The advanced tropospheric state can reduce residual tropospheric error significantly, further preserving GNSS postprocessing accuracy as baseline length increases.

The *Automatic* setting will automatically engage this option if 10% or more of the unprocessed positions are over 150 km from each base station OR if 10% of the survey is detected as being flown in excess of 3000 metres, or 10,000 feet above the base stations. In both cases, a minimum of two hours of data is required for this option to automatically engage, as it can perform poorly on short data sets where there is insufficient data to provide a well converged solution.

In addition to *Automatic*, the tropospheric error state can be explicitly turned on or off.

Constellation Usage

GrafNav supports GPS, GLONASS, BeiDou, Galileo and QZSS within the differential processor. The PPP processor currently supports only GPS, GLONASS and BeiDou.

GPS, by default, is always engaged in PPP and differential processing and does not appear in the list of constellations you can enable/disable. If data from other constellations are detected within the project, they will appear here and may be omitted from the project by deselecting the check box.

2.5.1.9 User Cmds

User commands only need to be added if it enables special functionality for something that is not directly available through the GUI. Any user command entered which is also available as a GUI option will override the GUI setting.

When opening an older project in a new version, any unrecognized commands will appear within the GNSS user commands. They can be deleted but otherwise will not cause an error or a change in results.

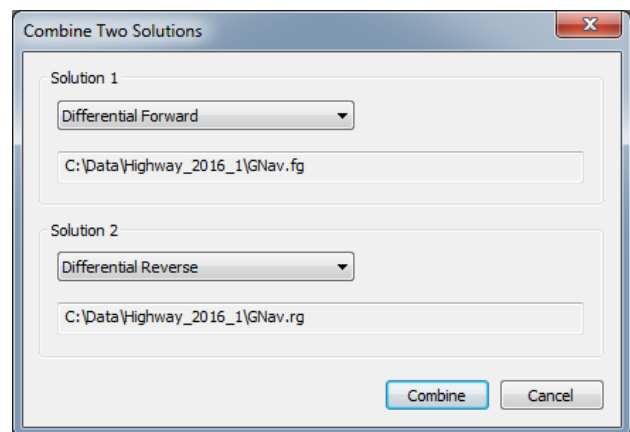
User commands can be used to change commands that are set by the other option tabs, or set commands that are not handled by the other option tabs.

2.5.2 Combine Solutions

The *Combine Two Solution* dialog does not typically need to be accessed within a project as forward and reverse solutions are automatically combined when processing in both directions (or when using multi-pass PPP processing). If however a user has reprocessed one direction only and then they wish to re-combine forward and reverse directions, or if a user wishes to plot the difference between two processed trajectories (i.e. PPP vs Differential), this can be done through the Combine dialog and does not require knowledge of GrafNav's file extensions.

In order to plot the difference between two processed solutions within the project, first choose the two solutions from the *Solution 1* and *Solution 2* pull-down lists and then *Combine*. Only a list of available solutions is accessible within the pull-down lists. As an example, if a user wanted to compare the combined PPP solution to the combined differential solution, choose *PPP Combined* as *Solution 1* and *Differential Combined* as *Solution 2* (or vice versa) and then select *Combine*. After combining the two trajectories of interest, plot the combined separation to view the difference in north, east and height as a function of time.

However, before exporting ensure that either the differential (.cg) or the PPP (.cp) solution is loaded, as the Export Wizard accesses whichever solution is presently loaded. One way of re-loading combined results is to choose the *Differential/PPP forward* and *Differential/PPP reverse* solutions from this dialog and clicking the *Combine* button.



2.6 Settings Menu

2.6.1 Coordinate/Antenna

2.6.1.1 Master Station Settings

This option allows modification of the master station coordinates, station name and antenna information. Individual base stations can also be disabled from this dialog.

Coordinates

The coordinates that appear in this dialog when loading a base station may come from different sources. If loading a base station that has been converted from RINEX (this includes any data retrieved by the Download Service Utility), the coordinates loaded are scanned from the RINEX header. These are by definition labeled *Approximate coordinates* and should be verified by the user. The RINEX header does not define the datum of the coordinates, and as such the user needs to make this selection for each base station loaded.

If loading your own base station data which was converted from a non-RINEX source, the coordinates displayed will be an averaged value computed from the positions extracted from the GPB file. The accuracy of this coordinate will vary and care should be made to ensure precise coordinates are entered. The datum must be selected by the user and optionally the epoch of the coordinates can also be entered.

Datum

GrafNav distinguishes between individual base station coordinate datums and the project processing datum. Each base station may have a different coordinate datum and if so, the coordinates will be automatically converted to the processing datum prior to processing. This facilitates working directly with published coordinates in one datum, yet producing processed output in another datum as required. The processing datum cannot be changed from this dialog but rather from the *Process GNSS* dialog. A user can also select a default processing datum through the *Solution* tab of *Settings | Preferences*.

Epoch

This is an optional field which is used only for reporting/tracking purposes. Coordinates change over time due to plate tectonic motion, and velocities can be several cm per year for datums that are not fixed to a specific tectonic plate. As such, the coordinates produced for any precise application should have a known datum and epoch.

If entering an epoch for one base station, it is required to enter all coordinates relative to the same epoch for all other base stations in the project, even if they are in a different processing datum.

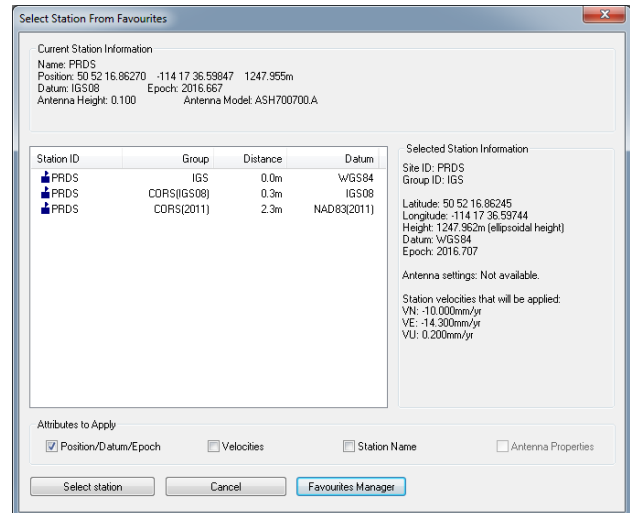
2.6.1.2 Coord. Options

The following options are available from the *Coord. options* pull-down menu.

Select From Favorites

Precise coordinates for CORS, IGN and IGS stations are regularly maintained within GrafNav's manufacturer files. If downloading base station data from one of these networks, you can load the published coordinates using the *Select From Favorites* button in the master coordinate dialog. This returns a list of the closest stations to the coordinates loaded.

When selecting a station from favorites, be sure to note the available *Attributes to Apply* at the bottom of this dialog. This provides the ability to copy not only the position and datum information from the favorites, but also the station name, antenna properties (if available) and station velocities. If velocities are selected, the published velocities are applied to the published coordinates and reference epoch to update them to the epoch of data collection.



Compute from PPP

This feature can be used to compute or check base station coordinates. If used, this feature will check for the presence of precise clock and orbit files required for PPP to deliver accurate results. If no files are present, GPS-only precise products will be downloaded before processing. The *Computing Coordinates Using PPP* dialog will then report the processed position at the epoch of the data collected, within the base station coordinate datum chosen. The horizontal and vertical difference between the computed coordinate and the coordinate currently loaded on the master dialog will be reported. A user can then decide to accept the computed coordinates or to select *Cancel*, if this was only being used as a check.

Use average position

This will load the average position from the GPB file. This position is often only accurate to several metres and is not of sufficient accuracy for the majority of applications.

Enter grid values

This feature launches the *Enter grid coordinates* dialog, which allows a user to directly enter published grid coordinates, such as UTM and State Plane values. ECEF coordinates can also be entered using this feature.

Enter MSL height

This feature launches the *Enter Orthometric (Mean Sea Level) Height* dialog. It allows a user to directly enter a published MSL height for a base station. When doing so, GrafNav still requires that an ellipsoidal height be computed from the MSL height, as all position computations within GrafNav are done relative to the ellipsoid. As such, it is required to point to a geoid in WPG format and the ellipsoidal height will be calculated using the interpolated geoid undulation and the entered MSL height. Please see <http://www.novatel.com/support/waypoint-support/waypoint-geoids/> to access all of Waypoint's geoids in WPG format.

2.6.1.3 Save to Favorites

This option launches the *Add to Favourites* dialog, which allows a user to save master station coordinates, datum, epoch, and antenna information in order to easily apply that information in future projects that use the same base station.

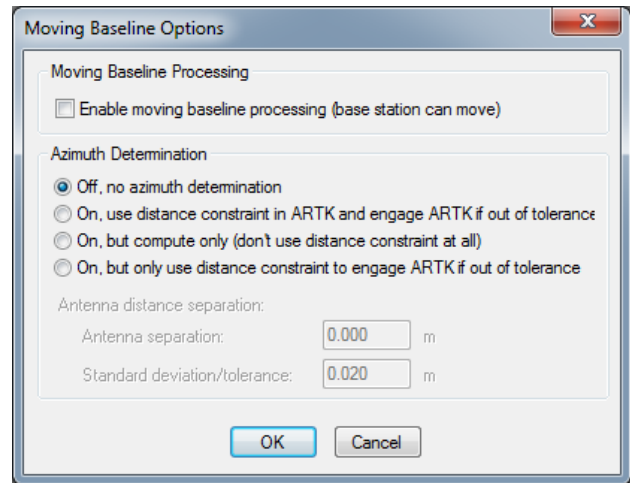
2.6.1.4 Remote Settings

This option lets you customize the remote's antenna information. See *Add Remote File* on page 29 for additional information.

2.6.2 Moving Base Options

Enable moving baseline processing if your application involves azimuth determination between two antenna on the same vehicle or relative vector determination between two moving antenna on separate moving platforms.

When moving baseline processing is enabled, GrafNav cannot fix the base station position. Every processing epoch uses a different base station position, which is read from the GPB file. The absolute positioning accuracy of each instantaneous base station position is thus limited to the autonomous positioning accuracy of the receiver used. This is generally no better than 2 m horizontal and 5 m vertical.



Although the absolute positioning accuracy in moving base mode is approximate, this is not of interest to most moving base applications. Only the relative position difference and/or azimuth between the antennas is typically required. When ARTK resolves carrier phase ambiguities in moving base mode, the relative positioning accuracy between base and remote is the same as in stationary base mode.

If moving base is enabled, choose from one of the four Azimuth determination options explained below.

2.6.2.1 Azimuth Determination Options

Off, no azimuth determination

Use this option if both antennas are on separate moving platforms and the azimuth between the antennas is not of interest (i.e. only the relative position and/or velocity).

On, use distance constraint in ARTK and engage ARTK if out of tolerance

Use this option if both antennas are fixed to the same moving platform and a post-processed azimuth is required. This option requires that you input the surveyed distance between GNSS antennas as it is used as a distance constraint in ARTK.

On, but compute only (don't use distance constraint at all)

Use this option if the surveyed distance between the antennas is not known, or is known to change significantly during the survey.

On, but only use distance constraint to engage ARTK if out of tolerance.

When this option is used, the distance constraint is not applied when resolving carrier phase ambiguities. Rather, it is used only to re-engage when the computed distance disagrees with the surveyed distance significantly (based on the standard deviation applied to the distance constraint).

2.6.3 Grid

GrafNav supports several international and regional grids, such as UTM, US State Plane, British Grid, Irish Grid etc. Custom grids can also be defined by selecting *Define Grids* within the *Grid Settings for Coordinate Input* dialog.

Defining a grid allows the grid to be accessed by the Export Wizard. Base station coordinates can also be added directly in grid format as well.

GrafNav projects store grid information. Set up a grid for the following reasons:

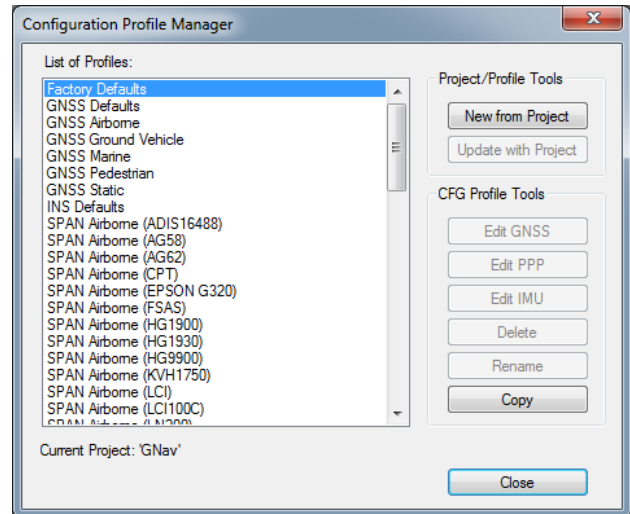
- Master coordinates can be entered directly in a supported grid.
- The *Map Window* can plot in grid coordinates. See *Show Map Window* on page 70 for more details.
- *Export Wizard* can use a defined grid for coordinate output. See *Export Wizard* on page 65 for details.

New grid definitions can be added by clicking *Define Grid* or via *Tools | Grid/Map Projections | Define*. See *Grid/Map Projection* on page 76 for more information.

2.6.4 Manage Profiles

The profile manager allows new profiles to be created or existing profiles to be edited. The profile manager can also be used to edit the GrafNav default settings or restore the factory default settings.

If creating a custom processing GNSS processing profile, *GNSS* must be in the name as we use this keyword to ensure only GNSS processing profiles are accessible under the GNSS processing dialog. Similarly, any Inertial Explorer customers who create custom processing profiles need to use either the keywords *INS* or *SPAN* in order to ensure they are accessible from the INS processing dialogs.



2.6.4.1 Project/Profile Tools

New from Project

Creates a new profile using the current project's settings.

Update with Project

Updates the processing profile with the current project settings. This option is not available for *Factory Defaults* as they cannot be altered.

2.6.4.2 CFG Profile Tools

Edit GNSS/PPP/IMU

Brings up the processing settings menu to allow the selected profile to be modified.

Rename

Allows the profile to be renamed.

Delete

Deletes the selected profile.

Copy

Creates a copy of the currently selected profile.

2.6.5 Compare Configuration Files

This feature allows you to compare the settings applied in two different configuration files. This utility scans both CFG files and creates a report of the differences. This report is displayed in GrafNav's ASCII viewer.

2.6.6 Preferences

The *Preferences* dialog has several tabs. The following sections provide information about the features available in the Settings menu.

2.6.6.1 Display

This tab allows you to edit what is displayed on the *Map Window*. Disabling features or base stations from here will only prevent them from being displayed to the map window and will not remove them from the project.

General

The following settings are available:

Show feature marks

This option controls whether time-stamped events, such as camera marks, features or stations appear on the map window. Users may wish to disable the display of feature marks if they are continually collected throughout the survey, resulting in hundreds or thousands being decoded. If this is the case, the feature marks will make it difficult to see the processed quality numbers on the map window which can be useful in QC.

Draw White background instead of black

Changes the background color of the Map Window from black to white. This may be preferred when printing generated HTML reports.

Show ARTK marks

ARTK marks indicate where fixed integers have been resolved. Users may or may not want to include these in the map window display if printing generated HTML reports.

Show base stations

When disabling the display of base stations, the Map Window automatically zooms to the extents of the project area covered by the remote GNSS antenna. This can be useful for the QC of multi-base or large scale projects.

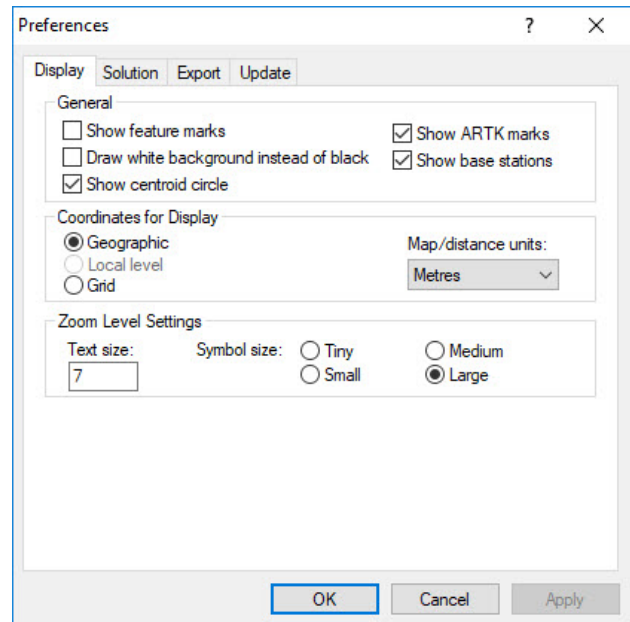
Coordinates for Display

The following settings are available:

Geographic

Displays the latitude and longitude on the screen. The orientation is such that the positive y-axis is true north.

Local level (only available if moving baseline processing has been enabled)



This option can only be enabled when using GrafNav.

Plots the local level vector if moving baseline processing has been performed. Moving baseline processing should only be engaged if both base and rover are kinematic and the relative vector between them is of interest. Moving baseline processing does not produce accurate absolute positioning results, only accurate relative positioning results.

Grid

Displays the coordinates in the grid selected under *Settings | Grid*. By default, the grid applied will be the UTM zone which has been auto-detected from the remote GNSS data.

Map/distance units

Changes the units of the values being displayed for local level or grid coordinates in the *Map Window*. Changes the units displayed when using the *Distance & Azimuth* tool as well. See *Distance & Azimuth Tool* on page 74 for information.

Zoom Level Settings

This set of options is based on the *Zoom Level* specified.

Text Size

Controls the font size. The *Show Text* option allows text to be seen on the screen for the display of base station coordinate names, ARTK forward/reverse text and the number displayed for feature marks.

Symbol Size

Controls the display of symbols, including processed epochs, ARTK indicators, feature marks and base stations.

2.6.6.2 Solution

Processing

Default Datum

Allows you to select a default processing datum for all GrafNav projects. This controls the datum of the processed output. Any coordinates which have not been entered in this datum will be automatically converted to the processing datum prior to processing.

Process forward/reverse directions simultaneously

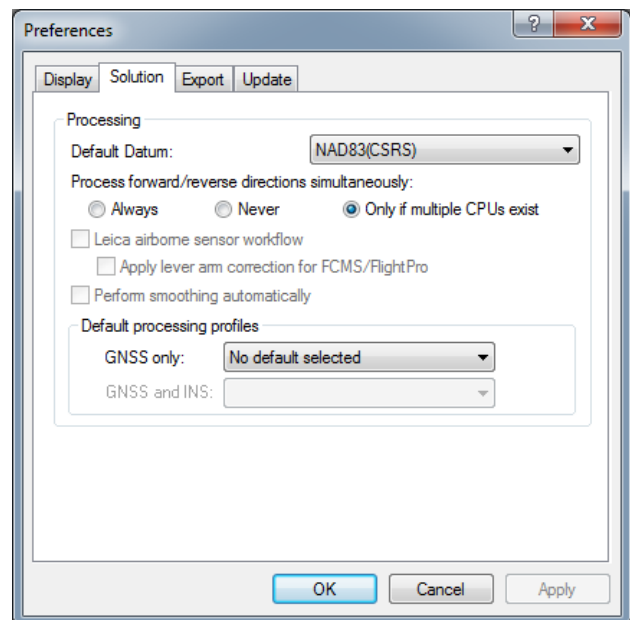
This feature improves processing speed considerably for computers with dual core or Xeon processors.

Leica airborne sensor work flow (Inertial Explorer only)

This option enables the Leica IPAS workflow within Inertial Explorer for FCMS and FlightPro users. Engaging this option affects the folder structure created during decoding and processing and will auto-generate a *.sol file after processing.

Apply lever arm correction for FCMS/FlightPro

When using Leica airborne sensor workflow, a lever arm correction is required with certain FCMS/FlightPro versions. When the *Leica airborne sensor work flow* check box is selected, Inertial Explorer detects the need for the correction based on the data from the flight and corrects the lever arm auto-



matically, showing the corrected settings in the user interface. It is recommended to leave this check box selected.

Perform smoothing automatically (Inertial Explorer only)

With this setting enabled, Inertial Explorer's backsmoother is automatically called following processing. This is recommended for best position, velocity and attitude results.

Default processing profiles

During conversion, the detected processing environment is written to the header of the decoded GPB file from analysis of the unprocessed position records. This allows GrafNav to automatically load manufacturer processing settings for the detected processing environment when the process GNSS dialog is first accessed within a project.

GNSS-only and *GNSS+INS* default processing profiles can be specified here. This will disable GrafNav's auto-detection of the processing profile from the detected processing environment and load a specific profile each time (whether it is a customer created profile or default manufacturer profile).

2.6.6.3 Export

Google Earth

Hold epochs and events to ground

This option plots the trajectory on the ground in Google Earth. This option is recommended when exporting ground vehicle surveys to Google Earth.

Limit epoch output to interval

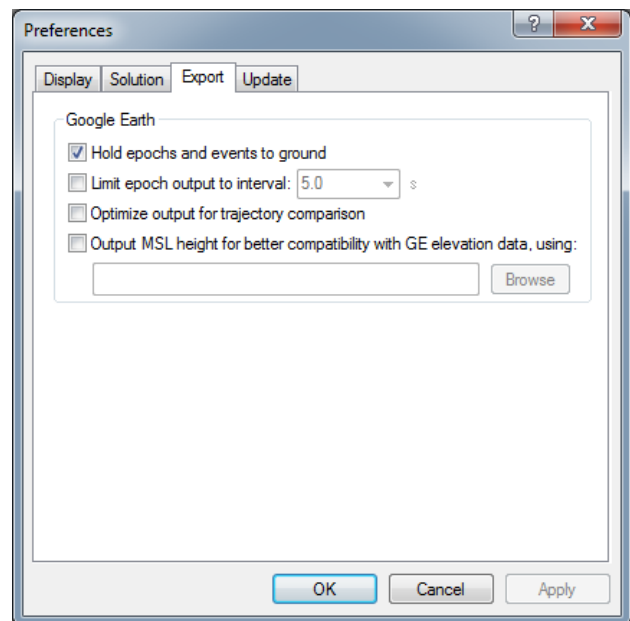
You can reduce the density of the output trajectory by specifying an interval here. This helps reduce file size and loading times in Google Earth.

Optimize output for trajectory comparison

When exporting to Google Earth, the computed quality numbers as displayed to the map window will also be displayed in Google Earth. When engaging this feature, that behavior is overridden and the color of all processed points will be the same color. This allows easy comparison of trajectories when loading from different projects.

Output MSL height for better compatibility with GE elevation data, using

Google Earth expects orthometric (mean-sea-level, MSL) height values. As such, if *Hold epochs and events to ground* is disabled, the plotted height may be below ground. To mitigate this effect, use the *Browse* button to locate an appropriate Waypoint Geoid (WPG) file for your processing datum. Waypoint geoid files are provided here: www.novatel.com/support/waypoint-support/waypoint-geoids/.



2.6.6.4 Update

Auto-Update

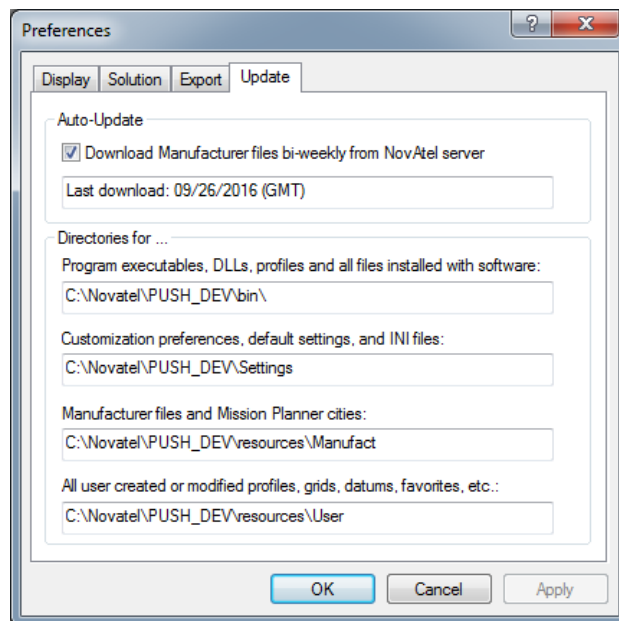
After installation, users are prompted to enable a setting which downloads manufacturer files from the NovAtel server on a bi-weekly basis.

Manufacturer files contain the latest antenna profiles from the National Geodetic Survey, updates to services and stations of permanently operating base station networks (accessed through the Download Service Utility), updated published coordinates for CORS, IGS and IGN base station networks, the latest GPS P1-C/A DCB clock biases (which affects PPP convergence), and any new manufacturer grid or datum conversions. It is recommended to keep these files up to date to ensure the most up to date information available.

Directories for ...

This section shows where various content is located.

The directory that contains *All user created or modified profiles, grids, datums, favorites, etc.* is of particular interest as if users wish to copy any user created content from a previous version to 8.70, this is the directory where any/all user created files from previous versions should be copied to. See *Copy User Files* on page 22 for more information.



2.7 Output Menu

2.7.1 Plot Results

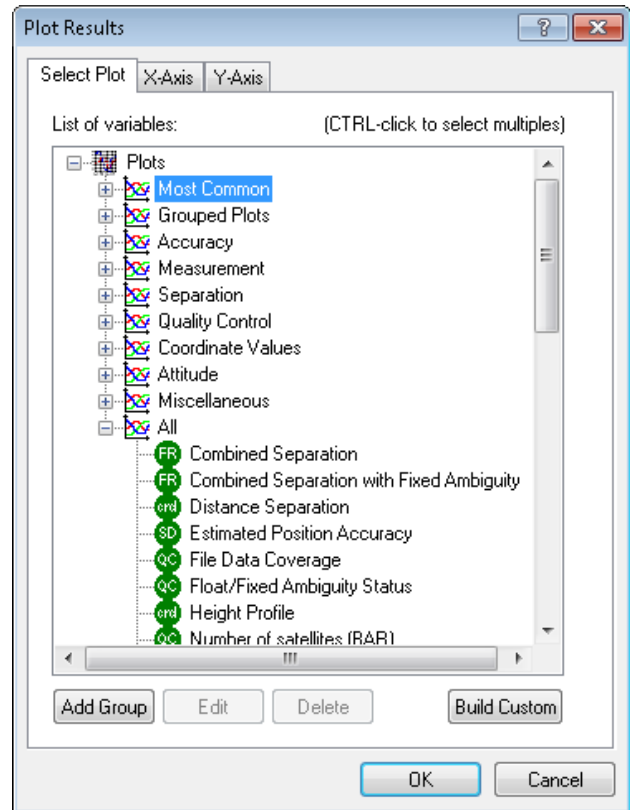
GrafNav's quality control plots are organized within sub-groups, such as *Accuracy*, *Measurement*, *Coordinate Values* and others. The *Most Common* group will appear empty immediately after you install the program for the first time, but over time will be populated with up to 10 of your most commonly accessed plots. To see all of GrafNav's plots, expand the *All* group.

Within each group, plots appear organized alphabetically within three colors: green, blue and black. The green plots are in general the most commonly accessed plots, the blue plots in general less so, and the black plots are in general seldom accessed except by advanced users.

Many plots support different units. For example, you can plot the *Combined Separation*, which shows the difference between forward and reverse solutions in metres or feet. The *Distance Separation*, or baseline distance, can be plotted in units of kilometres, miles or metres. In order to change units on a plot, first select the plot from the list and then access the Y axis tab. This tab has a *units* pull down list which shows supported units for the selected plot. After changing units, your preference is remembered for all projects.

Individual plots can be viewed by double clicking a plot in the list, or by selecting the *OK* button after selecting a plot. Up to two plots can be selected simultaneously by using the Ctrl key in combination with a left mouse click prior to selecting the *OK* button. Further, if a group of plots has been created using the *Add Group* button, all plots within the group are plotted simultaneously.

GrafNav contains a default manufacturer plot group for GNSS QC named *Waypoint GNSS QC*. When accessing a plot group, all plots are generated within the group and an HTML report is automatically generated.



2.7.1.1 Add Group

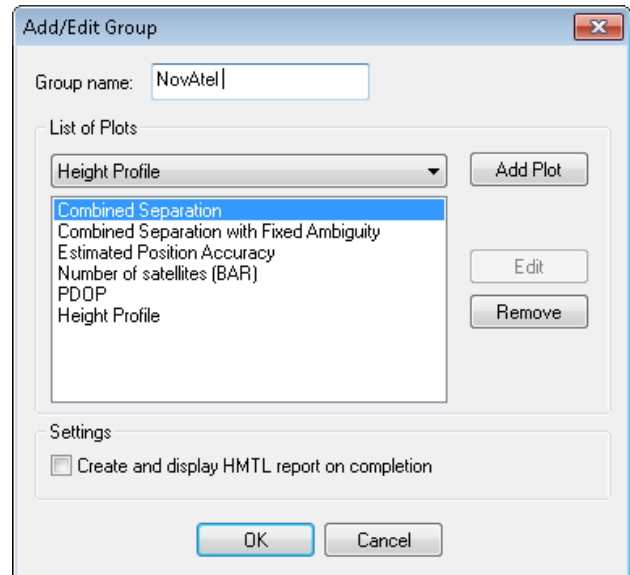
You may wish to create a group of plots for the purpose of plotting the entire group simultaneously. For example, if after processing you always want to see the *Combined Separation*, *Number of Satellites (BAR)*, *PDOP* and *Estimated Position Accuracy*, these four plots can be added to a custom group.

When you click the *Add Group* button, a second dialog appears that allows you to provide the group a name and add plots to your group. There is also an option for launching an HTML report that includes the grouped plots and the Map Window.

2.7.1.2 Build Custom

This option allows plots to be added to the *Custom* group. Adding the plots you most commonly access here makes them more accessible than choosing them out of other groups, or from the *All* list. Note that the plots you access most commonly will already appear under the *Most Common* group.

The difference between creating a *Grouped plot* and adding plots to the *Custom* group is that grouped plots will all be plotted simultaneously, whereas plots to the *Custom* list can still be accessed individually.



2.7.1.3 Plot Options

When you right click on a plot, a menu of options appears.

Properties

Allows access to the X and Y axis properties, X and Y axis labels, plot title and the plot settings.

Copy

Copies the plot to the clipboard as a bitmap (BMP), allowing you to paste the image into another application such as Microsoft Word or PowerPoint.

Save to HTML

Copies a BMP version of the plot into an HTML file, which opens upon completion. The HTML and BMP files are saved to the project folder under a directory called *HTML*.

Refresh

Reloads the selected plot.

X-Axis (Time)...

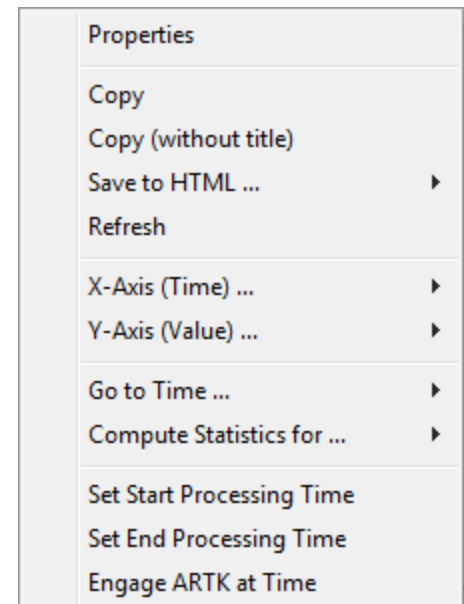
The X-Axis options are described below.

Auto-scale

Shows the entire time range of the data.

Set Minimum

Makes the current time the X-axis minimum.



Set Maximum

Makes the current time the X-axis maximum.

Select X-Range

Previously used settings of the X-axis are stored here.

Apply to All

Scales the X-axis of the other opened plots to facilitate analysis.

Y-Axis (Value)...

The Y-Axis options are described below.

Auto-scale

Shows the entire value range of the data.

Set Minimum

Makes the current value the Y-axis minimum.

Set Maximum

Makes the current value the Y-axis maximum.

Select Y-Range

Previously used settings of the Y-axis are stored here.

Apply to All

Scales the Y-axis of the other opened plots to facilitate analysis.



In order to apply the Y-axis to all plots, the maximum and minimum values must be manually specified, that is, not auto-scaled.

Go to Time...

Gives you the option of finding the nearest available time in the forward or reverse message logs, or finding the nearest epoch on the *Map Window*.

Compute Statistics for...

Calculates useful statistics for either the entire valid processed time range, or, if it has been adjusted, only the time range being plotted. Statistics include RMS, standard deviation, average, maximum and minimum. Note that this feature is only available for plots where meaningful statistics can be computed.

Set Start Processing Time

Makes the selected time the start time for GNSS data processing.

Set End Processing Time

Makes the selected time the end time for GNSS data processing.

Engage ARTK at Time

Engages ARTK at the selected time.

2.7.1.4 Common Plots

Table 3: Common Plots

Plot	Description
Accuracy	
Estimated Position Accuracy	<p>Plots the standard deviation of the east, north and up directions as well as a 3D (labeled <i>trace</i>) value.</p> <p>This plot is a good summary of other factors in your survey, including the float/fixed ambiguity status and satellite geometry. This is because SD values of fixed solutions are generally much lower than float solutions, and spikes in DOP caused by loss of satellite signals are typically correlated with spikes in estimated position accuracy. Please note that the estimated error plot contains no knowledge of any systematic error (such as biased base station coordinates or incorrectly fixed integer ambiguities), and as such the values reported are only (by definition) estimates.</p>
Measurement	
RMS – C/A Code	<p>Plots the RMS of the double differenced C/A residuals for all satellites used in the solution. High C/A residuals often indicate high multipath.</p> <p>Also plotted is the standard deviation applied to the C/A measurements within the Kalman Filter. This value comes in part by the a-priori value set in the <i>Measurement</i> tab. In dual frequency carrier phase processing, where ARTK is used to resolve integer carrier phase ambiguities, the C/A code does not heavily influence solution accuracy. Thus the standard deviation assigned to the measurements is not important, provided it is not overly optimistic.</p> <p>Adjusting the C/A measurement standard to a value more representative of the size of the actual residuals (while still being conservative) will benefit float solution convergence.</p>
RMS – Carrier Phase	<p>Plots the RMS of the double differenced carrier phase residuals for all satellites used in the solution.</p> <p>Carrier phase noise increases as the baseline length grows due to factors such as residual ionospheric and tropospheric error. Further, if ionospheric processing is used, the carrier phase noise will increase noticeably (although it should still be cm level). Thus, while values at or below 1 cm may be typical for short baselines (1-2 km), values of 2-4 cm are typical for longer baselines (10-40+ km).</p> <p>If large differences are found in the <i>Combined Separation (fixed)</i> plot, the RMS of the carrier phase can be a very helpful plot in determining which direction (forward or reverse) resolved the carrier phase integers incorrectly. When doing this, ensure to load each solution (forward and reverse) separately prior to plotting the carrier phase RMS, in order to ensure you are viewing the carrier phase residuals for each direction separately. Large ramping trends are strong indications of incorrect ambiguities.</p>

Plot	Description
RMS-L1 Doppler	<p>Plots the RMS of the double differenced Doppler residuals for all satellites in the solution. GrafNav uses Doppler to compute instantaneous velocity.</p> <p>Also plotted is the measurement weighting applied to the Doppler measurements within the GrafNav Kalman filter. As the quality of the Doppler measurements varies very significantly between receiver manufacturers, GrafNav applies a somewhat conservative default measurement weight. Therefore it is common to see that the actual Doppler residuals are much lower (better) than the weight applied in our filter, although the opposite is also sometimes true depending on receiver type. A discrepancy between the actual magnitude of the Doppler residuals and the a-priori measurement weighting will lead to an inappropriately high (or low) estimation of GNSS velocity.</p> <p>Some receivers output such noisy Doppler values (on the order of 5 m/s) that it will actually cause Kalman Filter resets, significantly degrading positioning accuracy. Thus if you see very large residuals in this plot, we recommend disabling Doppler from the <i>Measurement</i> tab of the GNSS processing options.</p>
Satellite Lock – Cycle Slips	<p>This plot launches a dialog that provides access to cycle slip plots for all GPB files within the project, or a user defined GPB file.</p> <p>Each satellite in the GPB file is plotted as a function of time and is color coded by elevation. See the bottom of the plot for a legend. Cycle slips for individual satellites are represented as a vertical red tick mark on the plot.</p> <p>It is normal for cycle slips to occur on low elevation satellites (< 10 degrees) due to signal blockages or due to attenuation by the GNSS antenna.</p> <p>Cycle slips on high elevation satellites may be expected if surveying in a challenging GNSS signal environment and are thus not necessarily an indication of a problem. However, if the plot shows many cycle slips on L1 or L2 in aerial survey applications where good signal tracking is expected, it can help diagnose receiver or antenna problems that can significantly limit post-processing performance.</p> <p>If you are getting poorer than expected post-processing performance, checking the quality of L1 and L2 signal tracking at the remote and base stations is a good first step in determining the cause.</p>
Individual Satellite Statistics	Provides access to satellite code residuals, phase residuals, elevation angles and C/NO values for individual PRNs.
Separation	

Plot	Description
Combined Separation	<p>Plots the north, east and height position difference between any two solutions loaded into the project. This is most often the forward and reverse processing results, unless other solutions have been loaded from the <i>Combine Two Solutions</i> dialog.</p> <p>Plotting the difference between forward and reverse solutions can be an effective QC tool. When processing both directions, no information is shared between forward and reverse processing. Thus both directions are processed independently.</p> <p>When forward and reverse solutions agree closely, it helps provide confidence in the solution. To a lesser extent, this plot can also help gauge solution accuracy. However, if there is a common bias in both forward and reverse solutions (for example, due to inaccurate base station coordinates or due to a large residual tropospheric error), it will never be seen in the combined separation plot.</p> <p>Large differences in the combined separation plot may be a result of different solution types (fixed/float) or different levels of float solution convergence between the processing directions and thus not a direct indication of a problem. It is important to also consider solution status (fixed/float) when evaluating forward/reverse differences. This is why the <i>Combined Separation with Fixed Ambiguity</i> plot can sometimes be more helpful.</p>
Combined Separation with Fixed Ambiguity	<p>Similar to the <i>Combined Separation</i> plot, however only the position differences between forward and reverse processing are plotted where both solutions have fixed integer ambiguities.</p> <p>Fixed integer solutions are associated with high accuracies (cm, or cm-level accuracies depending on other factors). Knowing this, there is an expectation of cm level differences between forward and reverse fixed integer solutions. If large differences (decimetre or metre level) are obtained, an incorrect ambiguity was very likely obtained in one or both directions.</p> <p>In this event, loading each solution into the project individually and plotting the <i>RMS - Carrier Phase</i> can be useful in determining which processing direction the problem occurred. See the description for the <i>RMS - Carrier Phase</i> plot for more information.</p>
Quality Control	
PDOP	<p>PDOP is a unitless number which indicates how favorable the satellite geometry is to 3D positioning accuracy. A strong satellite geometry, where the PDOP is low, occurs when satellites are well distributed in each direction (north, south, east and west) as well as directly overhead.</p> <p>Values in the range of 1-2 indicate very good satellite geometry, 2-3 are adequate in the sense that they do not generally, by themselves, limit positioning accuracy. Values between 3-4 are considered marginal and values approaching or exceeding 5 are considered poor.</p> <p>If PDOP is poor in your survey, try reprocessing with a lower elevation mask (however care should be taken when lowering this value below 10 degrees).</p>
Float/Fixed Ambiguity Status	<p>This plot indicates where the processed solution is fixed (in one or both directions) or float. If both forward and reverse solutions achieved a fix, the plot shows a value of 2 and is plotted in bright green. If either the forward or reverse achieved a fix, but not both, a value of 1 is plotted. The value will be plotted cyan if the fixed direction is forward and blue if the fixed direction is reverse. If neither direction achieved a fix, a value of 0 is plotted which appears red on the plot.</p> <p>This plot can be helpful to view in conjunction with the <i>Combined Separation</i> plot, as it will help determine if large values in the forward/ reverse separation are expected or not, depending on solution status in each direction. That said, the <i>Combined Separation with Fixed Ambiguity</i> plot is recommended to quickly check for the presence of incorrect ambiguity fixes.</p>

Plot	Description
Number of Satellites (BAR)	Plots the number of satellites used in the solution as a function of time. The bar plot displays the total number of satellites (GPS, GLONASS, BeiDou, Galileo and QZSS). It does not distinguish between how many satellites are tracked from each constellation.
Number of Satellites (LINE)	Plots the number of satellites used in the solution as a function of time. The number of GPS satellites, GLONASS satellites, BeiDou satellites, Galileo satellites, QZSS satellites and the total number of satellites are distinguished with separate lines.
File Data Coverage	Plots the coverage of each GPB file in the project, or a user specified GPB file, as a function of time. This plot indicates whether the data has been converted as static or kinematic (by different color codes) and shows the presence of any detected complete losses of carrier phase lock by vertical bars. This plot is useful in determining whether any base station data does not overlap with the time range collected by the remote receiver.
Coordinate Values	
Distance Separation	This plot shows the distance between the master and remote. For multi-base distance separation, see <i>Plot Multi-Base</i> below.
Height Profile	Plots the ellipsoidal height of the remote as a function of time.
Velocity Profile	Plots the north, east and up velocity. Also plots the horizontal speed.

2.7.2 Plot Multi-Base

Multi-base plots are available if more than one base station has been added to your GrafNav project. In this case, the multi-base plots are often more helpful than the main plots, as they distinguish results from each baseline.

The multi-base plots contain many of the same plots as the main plotting options and therefore only the plots unique to multi-base are described in the following table.

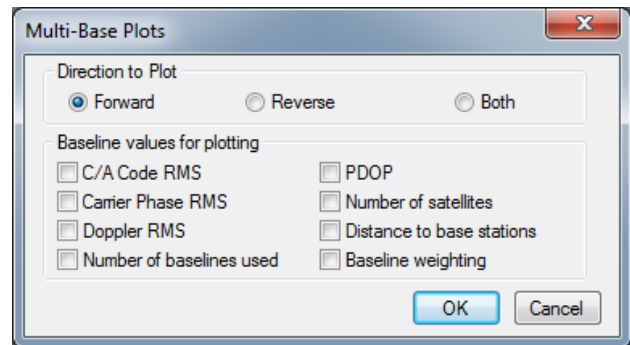


Table 4: Common Multi-base Plots

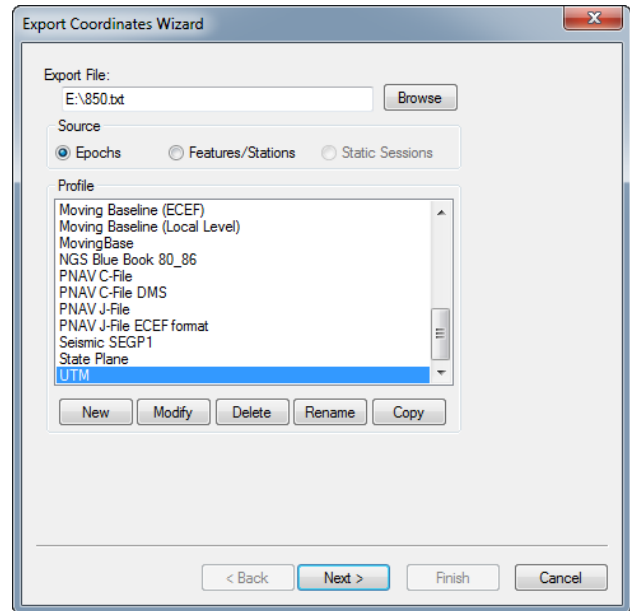
Plot	Description
Baseline Weighting	Plots the relative weighting applied to each baseline. This is largely dependent on the distance to each base station.
Number of baselines used	Shows the number of base stations used as a function of time.

2.7.3 Export Wizard

GrafNav's Export Wizard facilitates customized ASCII exporting of processed results. Manufacturer profiles are included with the installation, however they can be edited and new profiles can be created.

When creating or editing an export profile, you can choose from over 150 source variables. Units, precision, column width, field separators, and header/footer information can all be customized.

You can choose to export all processed epochs, interpolated results for features/stations (such as camera marks) or static sessions. GrafNav will try to auto-detect which *Source* to use given the data in your project. For example, if more than 80% of the remote file is static, the *Source* will default to *Static Sessions*. If more than a handful of features are loaded into the project, the *Source* will default to *Features/Stations* as this is presumably the data of interest.



2.7.3.1 How to create a new Export Wizard profile

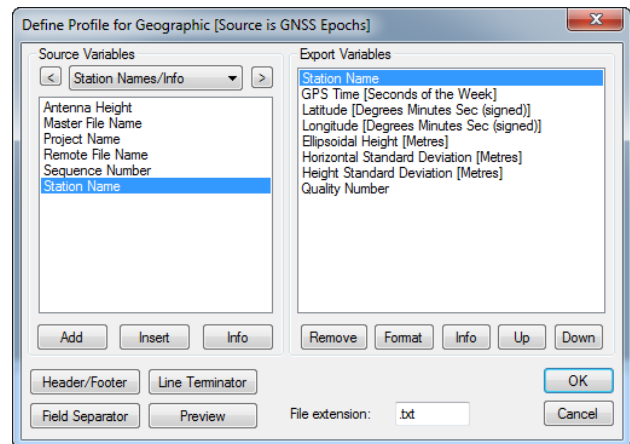
1. Click the *New* button and type a unique name for the profile.

Alternatively, it may be quicker to modify a copy of an existing profile that contains most of the variables required.

2. In the *Define Profile* window, add the desired variables from the *Source Variables* list. All source variables are organized under various headings from a pull down list.

After selecting a variable, click *Add* to add the variable to the bottom of the list or *Insert* to add the variable above the highlighted variable in the list. See the table in *Output Variables* on page A for a list of variables available for output.

3. After you are finished adding all the necessary components of the profile, click the *OK* button to save the profile.



Tips for creating an export profile

- To create a profile that does not have spaces between variable entries and the record is based on column width, follow these steps:
 1. Go to the *Define Profile* window.
 2. Click the *Field Separator* button.
 3. Select *None* under *Separation Character* to remove any field separators in the file.



The same procedure can be used to have the output be space or comma delimited.

- To change the file by adding a header/footer of a specific format, the *Header/Footer* button in the *Define Profile* window allows you to add headers/footers from a predefined text file. If specific characters are needed to designate the start and end of a text file, strings of characters can also be added to the beginning and end of the file.
- For formats that require no decimal points to be shown in the file, like SEGP1 and Blue Book, the decimal points can be removed by going into the chosen variable, clicking the *Format* button in the *Define Profile* window, and enabling the *Do not print decimal point* option.
- If you need a text string label to designate the type of record being printed/read, for example, \$--GLL, *81*, open up the *Miscellaneous* variable category and add the *User Text String* variable. Change the format of the string by entering the text needed for the label and select the *Fixed Width* option if the format is dependent on column width.
- Review the *Header/Footer* button. You can put in your own header file and display datum/projections information, column descriptions and titles. A special character can also be inserted at the start of each header line making it easier for other software to skip past the header. At the bottom of the file, you can add errors/warnings of any problems that were encountered and processing summary information.



The table in *Output Variables* on page A describes the many variables that you can include your output profiles. Not all variables are available for use with each source.

2.7.3.2 How to use the Export Wizard

1. By default, the export file name is the same name and directory as the project file (.cfg), except with a .txt extension. The file name and directory of the export file can be changed using the *Browse* button.
2. Ensure the *Source* has been set correctly according to what you would like to export.
 Choosing *Epochs* produces an output record for each common measurement epoch for the entire trajectory. Choosing *Features/Sessions* exports results, linearly interpolated between the nearest two epochs, for any camera marks, features or stations loaded.
 Static Sessions is accessible provided static sessions have been collected. Choosing this option exports the final post-processed (best converged) solution for each static Session.
3. Choose an export profile and select *Next* to start the Wizard. Depending on the variables in the profile, the Wizard will prompt you for any needed information. For example, if the chosen export wizard profile contains orthometric heights, you will be prompted to locate a Waypoint geoid file (.wpg).
4. Click *Finish* on the last page of the Wizard. If *View ASCII output file on completion* was selected on the last page of the Wizard, the text file will open within GrafNav's internal ASCII viewer.

2.7.3.3 Creating an Output File

The following is an example of the Export Wizard dialogs that appear when exporting *Epochs* using the *Geographic* profile.

Note that when exporting *Features* or *Static Sessions*, or when choosing a different export profile, you may see different dialogs. This is because the Wizard only prompts you for the required information according to your selections.

Select Output Coordinate Datum

The first page of the Wizard provides an opportunity to apply a datum transformation during export. This is required if the datum you wish to export to is not the same as the processing datum.

Select Output Coordinate Datum

Select Datum

☒ Use processing datum
Datum: ITRF05

☐ Convert to another datum
WGS84

Conversion from processing datum to other datum:

☒ Automatic (use default)
ITRF05 to WGS84 (IGN)

☐ Do not convert elevation (leave in processing datum)

☐ Use input datum (convert back to input coordinate system)
Datum: ITRF05

< Back Next > Finish Cancel

Filter Output/Estimated Accuracy Scaling

Results can be filtered using either GrafNav's quality numbers or combined (3D) standard deviation. An example of when it is useful to filter by quality number is when only fixed integer solutions are to be exported. In that case, apply a value of 1 for the quality number filter.

This dialog also provides an opportunity to scale the standard deviations output by GrafNav to a higher confidence interval. By default GrafNav outputs 1-sigma values. However due to the conservative measurement weighting applied in GrafNav to code, carrier, and Doppler measurements, they are not by nature overly optimistic.

Filter Output / Estimated Accuracy Scaling

Filter Output Data

☒ By Quality Number 6 1 6

☐ By Standard Deviation 20.000 (m)

Scale Standard Deviation Values (applied after filtering)

Scale Factor (unitless)

Position: 1.0000

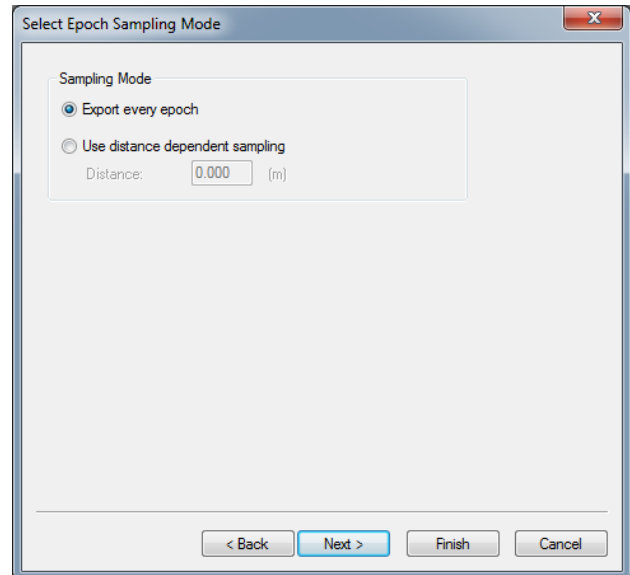
Velocity: 1.0000

< Back Next > Finish Cancel

Select Epoch Sampling Mode (GNSS+INS only)

When exporting epochs, you can choose to export all processed epochs or apply distance dependent sampling.

Note: This option is only available to Inertial Explorer users who are exporting a GNSS+INS trajectory. The *Select Epoch Sampling Mode* page is not applicable to GNSS-only trajectories.



Export Definition Complete

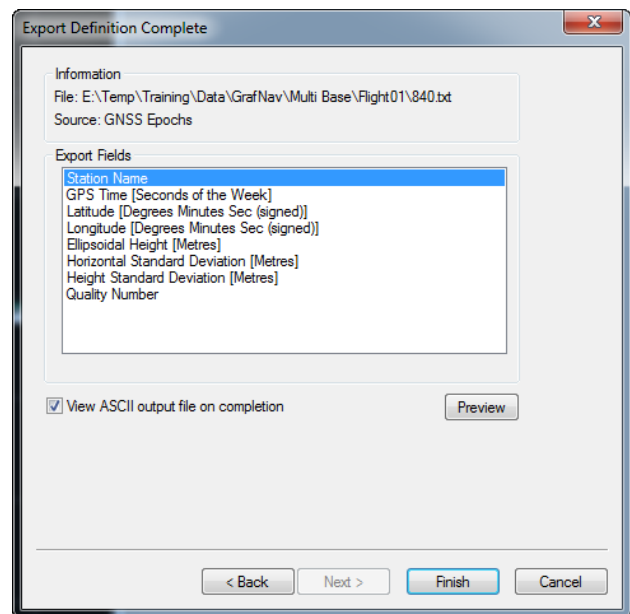
The last page of the Wizard provides a summary of the file name and path where the file will be written and the *Source* to be exported. The export variables within the profile are also summarized. Optionally, the output file can be viewed after export by selecting *View ASCII output file on completion*.

2.7.4 View Coordinates

This opens the last file generated by the Export Wizard in GrafNav's internal ASCII viewer.

2.7.5 Build HTML Report

Creates an HTML file containing a bitmap version of any plot that is currently open, including the Map Window. These HTML and BMP files are saved to the *HTML* folder contained within the project folder. The HTML file also contains information regarding the processing run(s) used to generate the plots.



2.7.6 Export to Google Earth

2.7.6.1 Export and View

Writes a compressed Google Earth (KMZ) file to the HTML sub-directory and automatically opens it in Google Earth.

2.7.6.2 Export Only

Writes a compressed Google Earth (KMZ) file to disk, but does not launch Google Earth.

2.7.7 Export to Waypoint Legacy Format

GrafNav 8.70 generates a new binary trajectory format and no longer supports writing of the former ASCII trajectory files. Third party software packages may accept the former GrafNav CMB file as input however, and as such this utility can be used to export the old trajectory file.

The utility will convert an ASCII trajectory according to which solution is loaded in the project. For example, if a combined forward/reverse solution is loaded, the utility will produce a *.cmb file. If only the forward direction has been processed or loaded, the utility will produce a *.fwd file.

2.7.8 Export to DXF

DXF is a file format read by various CAD packages. This utility outputs the contents of the map window to DXF format.

2.7.8.1 Output File Name

Specify the name and path of the DXF to be created.

2.7.8.2 Output Components and Options

The following options are available:

Stations/Features

Outputs any stations or features loaded.

Baselines/Static Sessions

Outputs baselines between all the static sessions. The color of the baselines will be the same as it appears in GrafNav and is determined by the quality factor.

Epochs

Outputs the trajectory and is only useful for kinematic data. Color is determined by the quality factor.

Join Epochs

Joins a line between epochs.

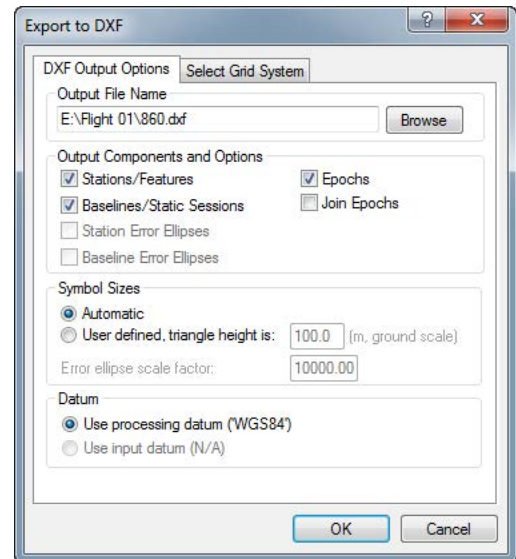
2.7.8.3 Symbol Sizes

These settings govern the size of the features and stations in the DXF file. *Automatic* is suggested for a trial.

2.7.8.4 Datum

Allows you to choose between the processing datum or the input datum.

The grid options are available under the *Select Grid System* tab. For UTM, State Plane or any other zone-dependent grid, check that the zone number is correct because the default is likely wrong.

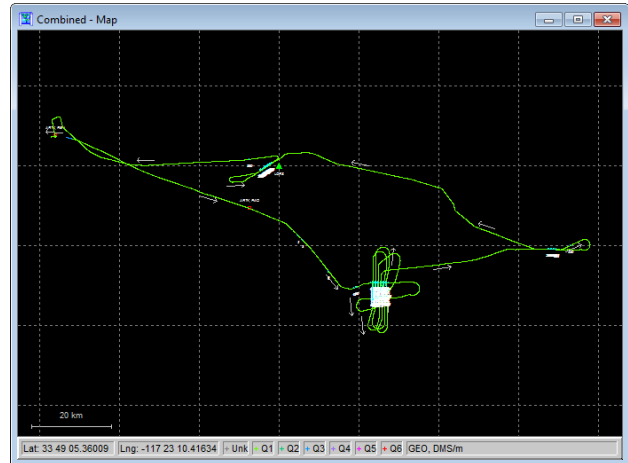


2.7.9 Show Map Window

Prior to processing, the map window displays the unprocessed positions within the remote GPB file. These positions usually reflect the real time position as logged by the remote receiver.

After processing, the map window displays the processed results, color coded by quality number. Quality numbers, which range from 1-6, are meant to convey a general indication of solution quality. A description and the approximate accuracies associated with each quality number is provided in the table below. GrafNav's Q/C plots should be accessed for a more detailed analysis of solution quality. See *Common Plots* on page 61 for descriptions of commonly accessed plots.

The information displayed to the map window is fully customizable from the *Display* tab within *Settings | Preferences*. Users can choose whether or not to display feature marks, ARTK marks and base stations.



The accuracies given are only guidelines. Quality numbers are meant only to provide a high level indication of solution quality. We highly recommend accessing GrafNav's quality control plots for a more in-depth analysis.

Table 5: Quality Number Description

Quality	Color	Description	3D Accuracy (m)
1	Green	Fixed integer	0.00 – 0.15
2	Cyan	Converged float or noisy fixed integer	0.05 – 0.40
3	Blue	Converging float	0.20 – 1.00
4	Purple	Converging float	0.50 – 2.00
5	Magenta	DGPS	1.00 – 5.00
6	Red	DGPS	2.00 – 10.00
Unprocessed	Grey	Has not been processed	N/A

2.7.9.1 Mouse Usage in Map Window

Positioning the cursor on a processed epoch and clicking with the left mouse button accesses a summary of the processing results for that epoch. The time, quality number, number of satellites, standard deviation, forward/reverse separation and other statistics are displayed.

If you have a scroll-wheel on your mouse, you can use it to zoom in and out by scrolling forwards and backwards over the area of interest.

The *Save to HTML* option generates an HTML file containing a bitmap version of the Map window. These HTML and BMP files are saved to the *HTML* folder contained within the project folder.

See *Tools Menu* on page 74 for additional interactive mapping tools.

2.7.10 Processing Window

This window appears during processing and shows position, status, progress and any high priority messages output by the processing engine.

Click the **View** button to customize the fields displayed during processing. See *Output Variables* on page A for descriptions of variables which can be monitored during data processing.

The Processing window is updated twice a second.

2.7.10.1 Status

The Status section of the processing window reports the instantaneous quality number. Quality numbers are meant to provide a high level indication of solution quality and are further described in *Table 5: Quality Number Description* on the previous page.

If integer carrier phase ambiguities have been fixed, a green circle with the word *Fixed* will be shown immediately to the right of the quality number. The ARTK statistics of the fix will be shown in the *Notifications* window below. If integer ambiguities have not been fixed, a blue circle with the word *KAR* (Kinematic Ambiguity Resolution) will be shown instead.

The instantaneous estimated position error will be shown on a meter immediately to the right of the fixed/float ambiguity status.

Immediately to the right of the estimated position error is the static/kinematic processing mode. If the data is processed in kinematic mode, a green *K* will be shown, otherwise if the data is processed in static mode a red *S* will be shown.

2.7.10.2 Progress

The Progress box graphically displays how much of the data has been processed and how much remains.

2.7.10.3 View

In the left-hand window, various parameters are available for display via the *View* button. The list of available parameters is given in *Table 8: Processing Window Parameters* on page 73.

2.7.10.4 Notifications

The *Notifications* window displays all information pertaining to the last ARTK fix. Descriptions of these messages are found in *Notifications Windows Messages* below.

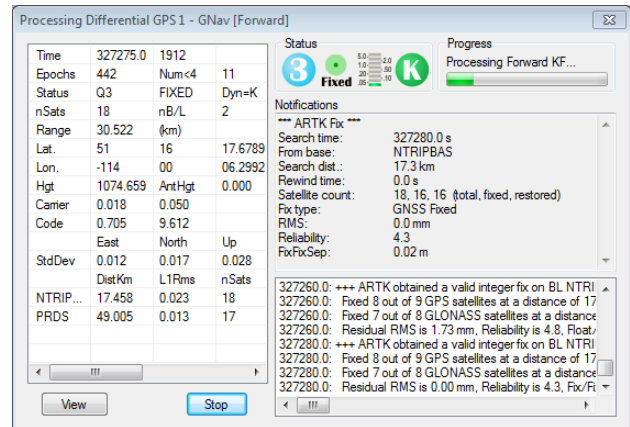


Table 6: Notifications Windows Messages

Message	Description
Search time	Time at which ARTK engaged.
From base	Specifies which base station ARTK used to fix ambiguities. This will often be the closest base station in multi-base projects.
Search distance	This is the baseline distance when ARTK was first engaged.
Rewind time	When ARTK achieves a fix, GrafNav can (data quality permitting) apply the integer carrier phase ambiguities backwards in time to the moment ARTK was engaged. The rewind time reports the number of seconds ARTK was able to restore integer ambiguities backwards from the engage time.

Message	Description
Satellite Count	The number of satellites used by ARTK. The <i>total</i> , <i>fixed</i> and <i>restored</i> numbers are reported. <i>Total</i> represents the number used in the float solution. <i>Fixed</i> indicates the number which achieved fixed integers at the restore time. <i>Restored</i> indicates the number of satellites where GrafNav was able to restore backwards in time (see <i>Rewind time</i>)
Fix Type	Will either be reported as GNSS Fixed or GNSS Fixed/Verified.
RMS	The RMS of an ARTK fix represents the mathematical fit of the carrier phase measurements. Low RMS values (3 mm or less) represent very good fitting solutions. While this does not guarantee a correct solution, it is a good indication. High RMS values (above 20 mm) may still be correct but the chances of an incorrect fix are higher. Regardless, the <i>Combined Separation with Fixed Ambiguity</i> plot can be accessed to help identify incorrect ambiguity fixes.
Reliability	Reliability is a unitless value that indicates how much better the best ARTK fix is from the second best. This is determined by dividing the RMS of the second best fix by the RMS of the best fix. High reliability values (above 3) indicate a high probability the fix is correct as the best ARTK fix appears much stronger than the second best.
FloatFixSep	This is the distance between the fixed integer solution and the last float solution prior to achieving a fix. Large values (metre level) can be expected where ARTK uses only several seconds of data, as the float solution will not be well converged. Unusually high float/fixed separation values of 5 m or more may be suspect.
FixFixSep	This is the distance between the position computed with a previous set of ambiguities and the position computed with newly accepted fixed ambiguities.

Table 7: Notifications for Static Processing

Message	Information
RMS	Similar to the RMS computed for an ARTK fix, the RMS of a fixed static solution represents the fit of the carrier phase measurements.
Reliability	See <i>Reliability</i> for ARTK fixes in <i>Table 6: Notifications Windows Messages</i> on the previous page for a definition. The reliability for long fixed static solutions may be reported as <i>N/A</i> , which indicates that only one fix was within the search area. Thus, there was no second best RMS in order to use in computing reliability.
Frequency	Reported as <i>single</i> or <i>dual</i> to indicate whether an L1 only or L1/L2 solution was computed.
Time	The length of time used by the fixed integer solution in hh:mm:ss format.
Type	Fixed static solution type used. <i>Continuous</i> looks for the best continuous block of cycle slip free data to use within the fixed integer solution. <i>NewFixed</i> (multi-sat) uses all of the data, although it may reject some sections of data for individual satellites.

Table 8: Processing Window Parameters

Parameter	Description
Acceleration Vector	Displays the east, north and height acceleration components in Local Level frame.
Baseline Data (MB)	Displays the distance, carrier phase RMS and number of satellites for each baseline.
Baseline Distance	Distance separation for projects containing only one base station.
Channel (Ambiguity)	Displays the ambiguities, as well as their standard deviation, for each satellite being tracked.
Channel (Az/Elev)	Displays elevation and azimuth for each satellite being tracked, in degrees.
Channel (Flag/Locktime)	Displays the status flag and locktime count for each satellite being tracked.
DOPs	Displays DD_DOP, PDOP, HDOP and VDOP.
Estimated Accuracy	The instantaneous north, east and height standard deviation of the remote position.
Geographic Position	Displays the instantaneous position and antenna height of the remote.
Local Level Vector	Local Level vector in metres.
Measurement RMS	The RMS of the code and phase measurements are displayed, together with their standard deviation (measurement weight) in the Kalman filter.
Speed/COG	Speed of the vehicle is displayed with the Course-Over-Ground (COG), computed between consecutive measurement epochs.
Status Flags	Solution quality information such as number of satellites, quality factor and ambiguity status.
Time/Epochs	Displays time in seconds of the week, as well as a continuous count of epochs processed. The GPS week number is also shown.
Velocity Vector	Components of velocity in the Local Level frame.
Channel Data B/L	Allows for selection of baseline for which to display channel information.

2.8 Tools Menu

2.8.1 Zoom In, Zoom Out & Zoom Reset

The *Zoom In* and *Zoom Out* tools adjust the viewing scope of the map, while the *Zoom Reset* brings the map back into the default view.

If you have a scroll-wheel on your mouse, you can use it to zoom in and out by scrolling forwards and backwards over the area of interest.

2.8.2 Distance & Azimuth Tool

The *Distance & Azimuth* tool can be used between epochs, base stations and feature/station marks that are displayed on the Map window. Left click on the feature or epoch that you wish to measure *from* and then right-click on the feature or epoch that you want to measure *to*. The *Distance and Azimuth* window reports the horizontal, surface, grid and spatial distances between the selected points within the project grid (*Settings | Grid*). The default grid is a UTM zone automatically computed from the rover trajectory. The azimuth and scale factor information are also displayed.

2.8.3 Move Pane

This tool is only accessible provided you have used the *Zoom In* tool to view a smaller portion of the Map window at greater magnification. This tool allows you to access different areas of the Map window without changing the zoom level.

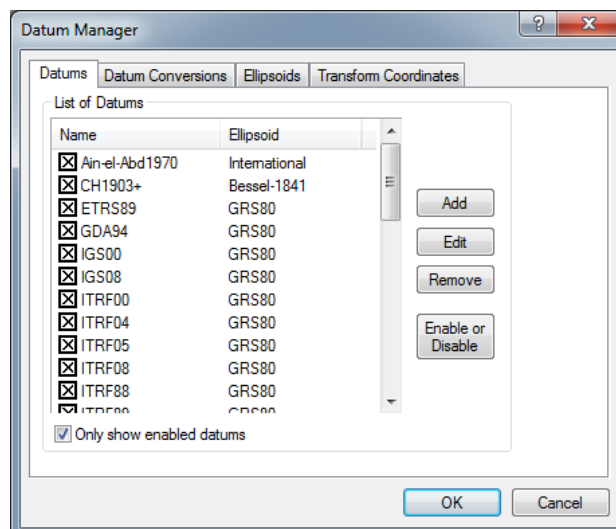
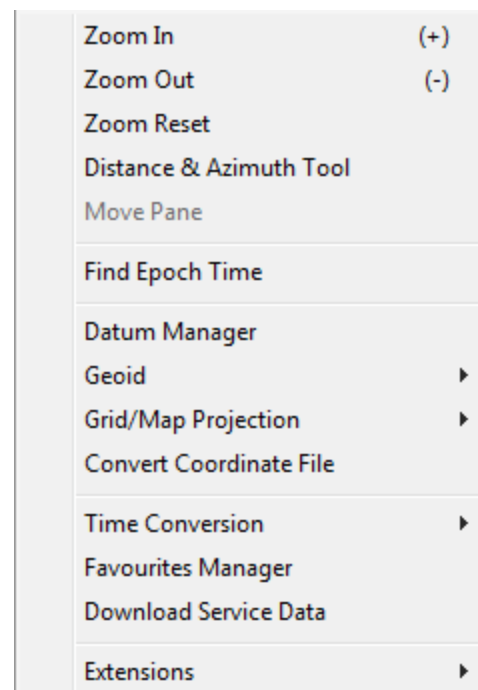
2.8.4 Find Epoch Time

This feature makes it easy to find an epoch on the Map window provided the GPS time in seconds of the week. When used, it circles the epoch in red and if necessary changes the zoom level so that it is in the middle of the Map window.

2.8.5 Datum Manager

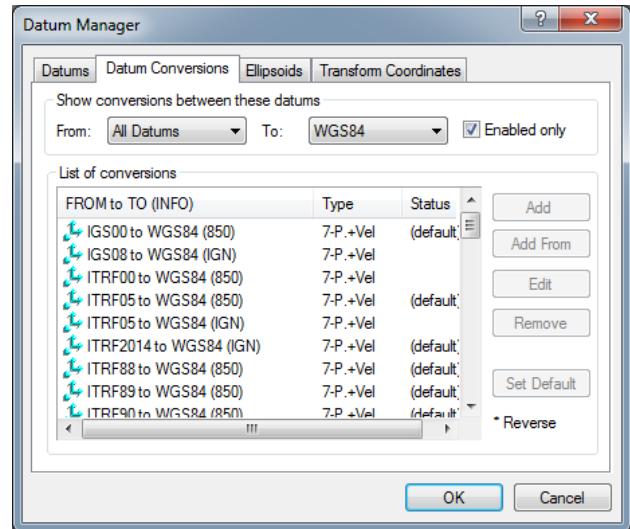
2.8.5.1 Datums

This feature allows custom datums to be added, or existing datums to be enabled or disabled.



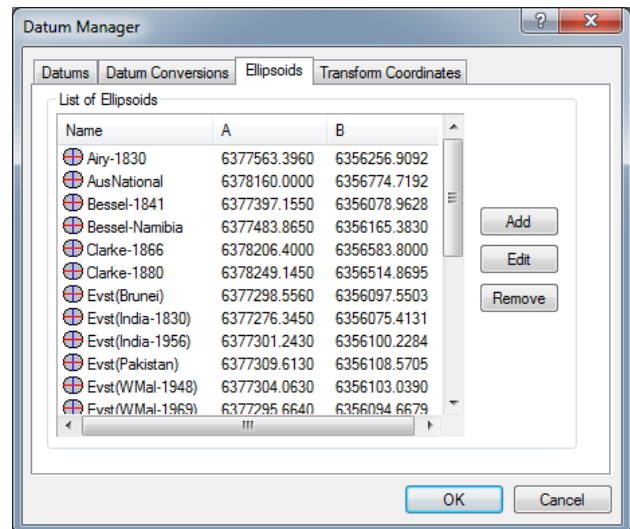
2.8.5.2 Datum Conversions

This tab allows you to view, edit or add conversions between datums.



2.8.5.3 Ellipsoids

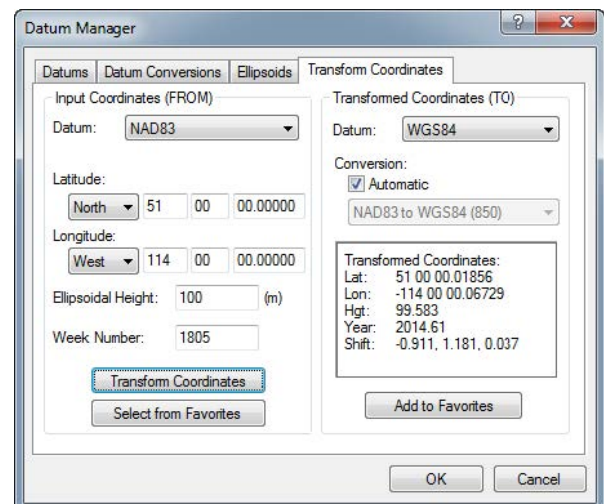
This tab allows you to view the a , b or $1/f$ values for a particular ellipsoid. You can also add new ellipsoids.



2.8.5.4 Transform Coordinates

Use this tab to transform individual points from one datum to another. If you have a list of points to convert, use the *Convert Coordinate File* utility under the *Tools* menu. Points can also be loaded from favorites and after conversion saved back to favorites.

It is generally not necessary to convert base station coordinates to a common datum prior to processing, as this is done automatically for any base stations that have their coordinates entered in a different datum than the project datum.





Specifying the week number of the coordinate effects the final result if using a 14-parameter conversion.

2.8.6 Geoid

Geoid files are required when exporting Mean Sea Level (MSL) heights. Geoid files contain a grid of undulation values that represent the difference between ellipsoidal and MSL height. To calculate MSL height from ellipsoidal height at any geographic position, GrafNav subtracts an interpolated geoid height (undulation value) from the ellipsoidal height. A Lagrange interpolation method is used.

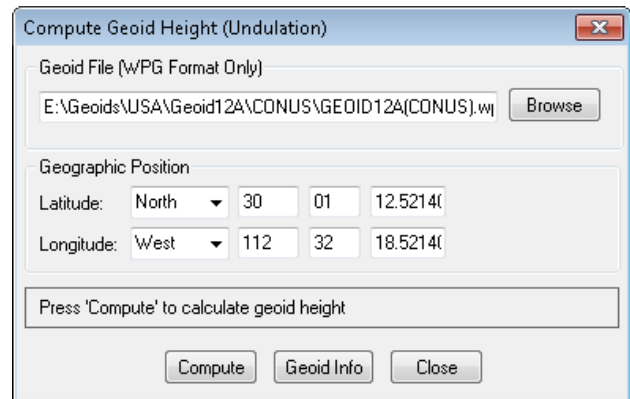
Waypoint software supports a proprietary WPG geoid format. All publicly available WPG files can be found here: www.novatel.com/support/waypoint-support/waypoint-geoids/. Waypoint software also

provides utilities to create WPG files from ASCII files and other known formats in order to create custom or local geoids.

Every GrafNav project requires ellipsoidal base station heights. This is because the geoid is a complicated mathematical surface and all data processing needs to be performed relative to the ellipsoid. However, the *Enter MSL Height* feature on the *Master Coordinate* dialog permits you to work directly with published MSL heights. This works by back-calculating an ellipsoidal height provided an MSL height and a geoid file.

Regardless of how you have entered your base station coordinates (i.e. if you have directly entered an ellipsoidal height or if you have used the *Enter MSL height* feature), the Export Wizard will prompt you for a geoid if your export profile contains MSL heights.

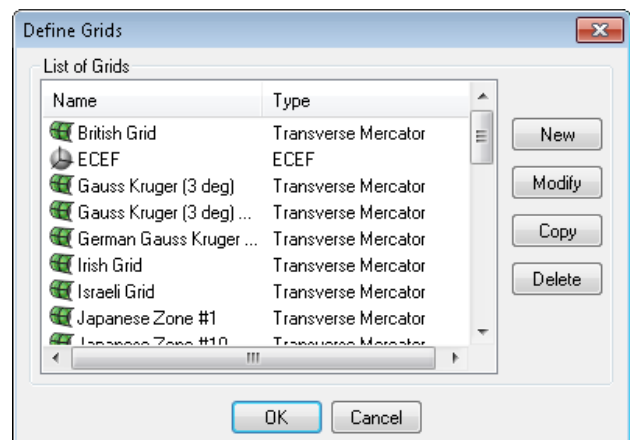
The *Compute Geoid Height* dialog allows you to calculate geoid height for individual coordinates. If you have a list of coordinates to convert from ellipsoidal to MSL (or vice versa), use the *Convert Coordinate File* on the next page feature. The *Geoid Info* button will access basic properties of the WPG file, including the datum, vertical datums and geographic boundaries.



2.8.7 Grid/Map Projection

GrafNav supports grid/map projections in several ways including the following:

- The *Enter Grid Values* feature within the *Coord. Options* pull-down list on the Master Coordinate dialog allows you to enter base station coordinates in any defined grid, including ECEF.
- You can output final coordinates in a map projection of your choice. See *Preferences* on page 54 and *Show Map Window* on page 70 for additional information.
- Several grids, like UTM, TM, and US State Plane, have been pre-defined in the software. However, you can also add your own by selecting *New* within the *Define Grids* dialog as shown on the right.



- Use the *Transform Coordinates* tool under *Tools | Grid/Map Projection* to convert between geographic coordinates and grid coordinates.

2.8.7.1 Transform Coordinates

This tool transforms coordinates for a single point from geographic to grid, or vice versa.



Use the *Add to Favorites* button to save a converted coordinate for easy retrieval in future projects.

2.8.8 Convert Coordinate File

This tool takes an ASCII file containing a list of coordinates as an input and outputs an ASCII file to a different datum or format. You can use this utility not only to convert between datums, but also to change the format of a file. For example, you can convert an input list of coordinates from geographic to ECEF, or a list of coordinates with ellipsoidal heights or MSL.

The *Use first continuous word* option is the default. If the station names contain spaces, select *Use first 'n' characters*. The sign conventions used for geographic coordinates is positive for the northern and eastern hemispheres and negative for the southern and western hemispheres.

Additional options seen on the screen just before generating the output file include the following:

Include column header

Conserves the header information from the input file.

View output files after conversion

Automatically opens the output file after clicking *Finish*.

Input grid coordinates in southern hemisphere

Only necessary if the input data has grid coordinates from a project area that is in the southern hemisphere.

Do not apply datum transformation to height

This option is useful for outputting orthometric heights because no datum transformation are applied in this case.

2.8.9 Time Conversion

This tool converts GPS seconds of the week to hh:mm:ss format (GMT), provided a GPS week number. Alternatively, hh:mm:ss (GMT) can be converted to GPS seconds of the week, provided a month, day and year has been specified.

2.8.10 Favourites Manager

GrafNav's Favourites Manager is used to store known coordinates for GNSS reference stations. This permits easy retrieval without the risk of data entry errors through the *Select From Favourites* feature of the master coordinate dialog, which is accessible under the *Coord. Options* pull-down.

GrafNav's Favourites Manager comes pre-loaded with coordinates for the CORS, IGS and IGN permanently operating reference networks. The CORS(2011) and the CORS(IGS08) groups contain published coordinates for the CORS (Continually Operating Reference Station) network from the National Geodetic Survey. This is a large network of stations, most of which are found in the United States.

The CORS(2011) group provides access to published NAD83(2011) coordinates at epoch 2010 as well as station velocities. The CORS(IGS08) group provides access to published IGS08 coordinates at epoch 2005.0 as well as station velocities.

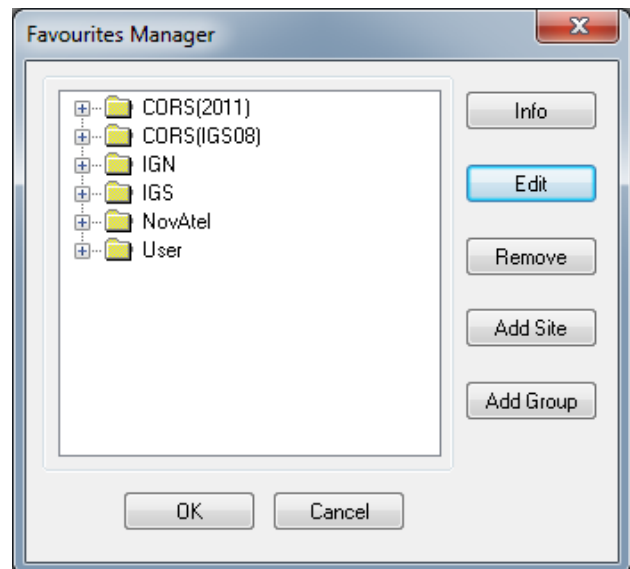
The IGN group provides published RGF93 coordinates from a reference epoch equal to the last time they were updated within the Waypoint manufacturer files, which should be within a month of the present date provided you have current manufacturer files. This service provides good coverage within France and the Island of Corsica.

The Favourites Manager and the Download Utility are complimentary in the sense that the latter provides access to base station data through anonymous FTP and the former ensures precise coordinate and datum information is loaded into your GrafNav project.

Both utilities (the Favourites Manager and the Download Utility) are updated on a monthly basis by Waypoint support staff in order to ensure the list of stations and coordinates are kept current. GrafNav will attempt to automatically download the latest manufacturer files on a bi-weekly basis to ensure they are up to date.

In addition to pre-loaded favourites for specific networks, users can create their own favourite groups in order to store their own surveyed base station locations.

The following options are available in the *Favourites Manager* via the buttons on the right-hand side:



Info

If clicked while a group is highlighted, this returns the total number of sites contained within the group.

If clicked while an individual site is highlighted, the position, velocity and datum are displayed.

Edit

Use this option to modify the information related to a station, including coordinates, antenna information and station velocities.

Remove

Use this option to remove an individual site or an entire group.

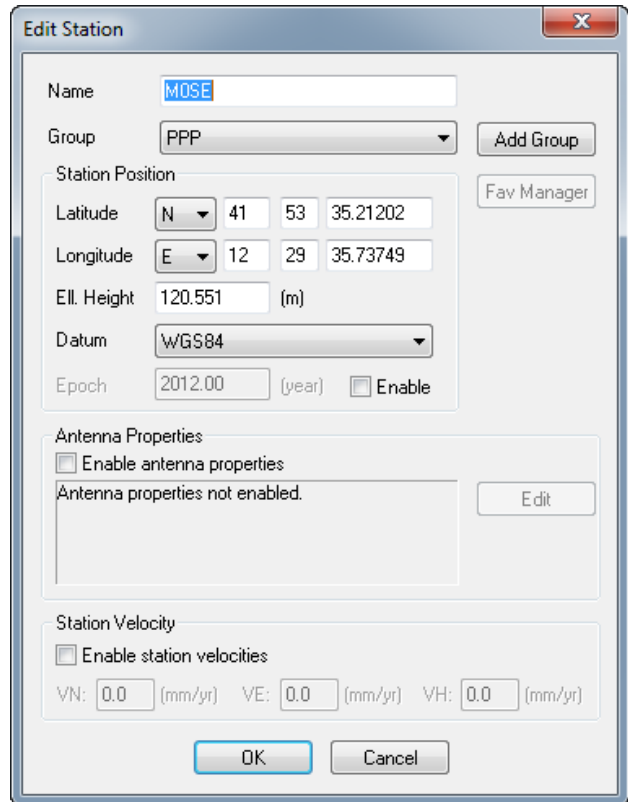
Add Site

Use this option to add a new site into any group.

We recommend creating a custom group prior to adding your own sites.

Add Group

Use this option to add a new group.



The **Edit Station** dialog box contains the following fields and controls:

- Name:** Text field with "MOSE" entered.
- Group:** Dropdown menu showing "PPP". Buttons: "Add Group", "Fav Manager".
- Station Position:**
 - Latitude:** N 41 53 35.21202
 - Longitude:** E 12 29 35.73749
 - Ell. Height:** 120.551 (m)
 - Datum:** WGS84
 - Epoch:** 2012.00 [year] ☐ Enable
- Antenna Properties:**
 - ☐ Enable antenna properties
 - Antenna properties not enabled. Edit
- Station Velocity:**
 - ☐ Enable station velocities
 - VN: 0.0 (mm/yr) VE: 0.0 (mm/yr) VH: 0.0 (mm/yr)
- Buttons:** OK, Cancel

2.8.11 Download Service Data

The Download Service Utility facilitates downloading, converting, and if needed concatenating and resampling of GNSS base station data.

There are currently 18 supported networks, providing access to thousands of publicly available base stations worldwide. Waypoint provides a KML file for all supported networks within the *Waypoint Downloads* section of the NovAtel website.

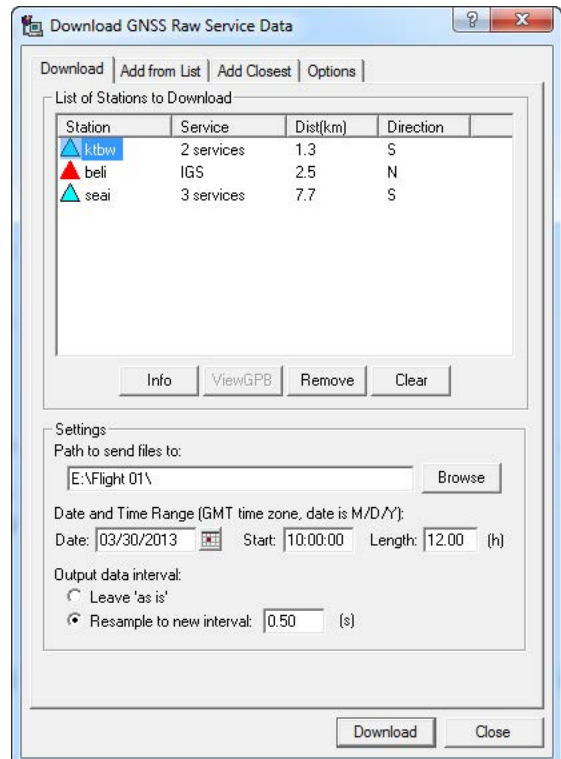
The *Add Closest* tab can be used to search for base station data provided a converted GPB file that you wish to process. This function not only reports a list of the nearest stations, but also automatically scans the date, start/end times, path to download the files to and sampling rate of the GPB file.

The download utility can be used not only to quickly retrieve GNSS base station data, but also to download precise ephemeris and clock files, additional GNSS broadcast ephemeris data and IONEX files (map of the TEQC - only useful for single frequency long distance processing).

2.8.11.1 Download

List of Stations to Download

This displays a list of the stations that have been selected for download. The list is empty until you add to it using the *Add from List* or *Add Closest* tabs.



The **Download GNSS Raw Service Data** dialog box contains the following sections:

- Download | Add from List | Add Closest | Options** (tabs)
- List of Stations to Download:**

Station	Service	Dist(km)	Direction
ktbw	2 services	1.3	S
bell	IGS	2.5	N
seai	3 services	7.7	S
- Buttons:** Info, ViewGPB, Remove, Clear
- Settings:**
 - Path to send files to:** E:\Flight 01\ Browse
 - Date and Time Range (GMT time zone, date is M/D/Y):**
 - Date:** 03/30/2013 Calendar icon
 - Start:** 10:00:00 **Length:** 12.00 (h)
 - Output data interval:**
 - ☐ Leave 'as is'
 - ☒ Resample to new interval: 0.50 (s)
- Buttons:** Download, Close

Settings

The *Path to send files to* field specifies where to save the downloaded files. The *Date and Time Range* parameters indicate the date and time range (GMT) of the data to be downloaded. If using the *GPB search mode* option on the *Add Closest* tab, all of the parameters under *Settings* are scanned automatically.

Selecting *Leave 'as is'* will preserve the original sampling data rate of the downloaded data. Common sampling rates provided by GNSS networks are 1, 5, 10, 15 and 30 seconds. Some networks, such as CORS, only make high rate available for a limited period of time (such as 30 days) prior to archiving the data at a 30 second sampling rate. Therefore it is good practice to retrieve base station data within days of your survey when possible.

In differential processing, only common epochs can be processed between master and remote. Thus, if you require processed output at the same logging interval as the remote, base station data needs to be re-sampled to the same interval should it be collected at a lower rate.

Resampling measurements introduces noise, and the magnitude of the added noise is dependent on the original sampling rate of the data. Waypoint has found that the amount of noise introduced when resampling from an original rate of 5 seconds is negligible. When resampling from 30 seconds however, 1-2 cm of noise (RMS) can be introduced, although that is typically within the noise of a kinematic survey.

2.8.11.2 Add From List

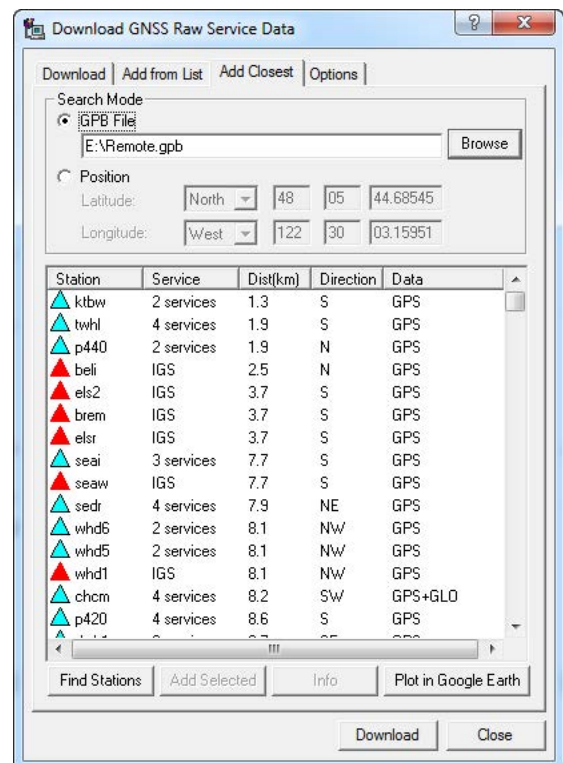
List of Stations

This window provides an alphabetical listing of all services. Expand the list to show the individual stations within each service. The *Info* button provides an approximate coordinate, which is used when searching for base station data using the *Add Closest* tab. The *Add* button places the station on the *List of Stations to Download* under the *Download* tab.

2.8.11.3 Add Closest

This tab supports two search modes: using a GPB file as input or a user defined position.

If inputting a GPB file, the download utility searches your file at regular intervals and will report the minimum distance to each base station at any point in the trajectory.



2.8.11.4 Options

Precise Files

Precise ephemeris and clock data can be downloaded here for GPS, GLONASS and BeiDou. Sources that provide GLONASS and BeiDou corrections also provide GPS corrections, although quality will vary from source to source.

Precise ephemeris and clock data are required for PPP processing in order to correct for metre level errors. Precise ephemeris data is optional in differential projects as much of the orbital error is cancelled, as the line of sight component of satellite orbital error is correlated with baseline length. Differential projects involving baseline lengths in excess of 150+ km may benefit from the inclusion of precise ephemerides.

Other Files to Download

Any files selected here are downloaded for the day(s) specified on the *Download* tab. You can specify any of the correction files listed below for download.

GNSS Broadcast Ephemeris

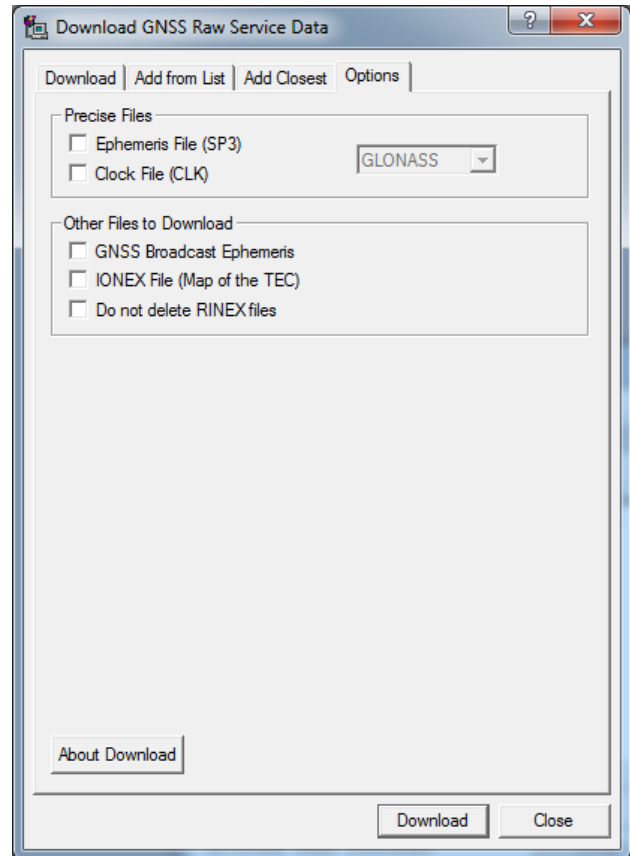
Downloads a GPS and GLONASS global RINEX navigation file for the date specified in the Download tab and converts to Waypoint's EPP file format. Can be used to supplement missing ephemeris data in a project.

IONEX File

Contains information regarding the total electron count (TEC) of the ionosphere. This is useful in single frequency processing to help reduce ionospheric error. IONEX data is not helpful to, and thus not applied, if dual frequency processing is used.

Do not delete RINEX files

The Download Utility will automatically delete downloaded RINEX files after conversion to GPB. If you wish to keep the original RINEX data, select this option.



2.8.11.5 Add Stations and Services

The services currently found within the download utility are supported because they provide public access to data and they are known to us.

If you know of another service which provides public FTP access to GNSS reference data, contact Waypoint support (support@novatel.com) as it may be possible to add the service to the software. This has the added benefit of making the service available to all other GrafNav users as well.

If you prefer to add your own custom service, create a *user.xml* file within your User directory (C:\NovAtel\WayptGPS870\Resources\User). The first line of the *user.xml* file must contain <DN1> and the last line must be </DN1>.

Service and station records must conform to the format described below.



You might find it easier to copy a service and station record from the *manufact.xml* file and paste it into *user.xml* file for modifying.

Adding a service requires knowledge of the FTP address at which the data is stored. The directory structure and file type must be known.

Service records must conform to the format described below. Refer to the *manufact.xml* file for examples of service and station records.

Station record format

```
<station>
  <name></name>          Four-character station name as saved on FTP server. See Note 1.
  <download>
    <appxlat></appxlat>  Latitude in decimal degrees (signed).
    <appxlon></appxlon> Longitude in decimal degrees (signed).
    <appxht></appxht>    Ellipsoidal height, in metres.
    <serv>
      <name></name>      Name of service to which the station belongs. See Note 1 and Note 3.
    </serv>
  </download>
</station>
```

Service record format

```
<service>
  <name></name>          Name of service, up to a maximum of 8 characters. See Note 1.
  <data></data>
  <protocol></protocol>  Type of file transfer protocol used by the service (FTP or HTTP).
  <address></address>    Address of the FTP server.
  <username></username>  Required to log into nonpublic sites. See Note 1 and Note 4.
  <password></password> Required to log into nonpublic sites. See Note 1 and Note 4.
  <ofile></ofile>        Generic path to the observation file. See Note 6.
  <dfile></dfile>         Generic path to the compressed observation file. See Note 4 and Note 6.
  <nfile></nfile>         Generic path to the GPS navigation file. See Note 6.
  <gfile></gfile>         Generic path to the GLONASS navigation file.
  <hofile></hofile>       Generic path to the hourly observation files. See Note 4 and Note 6.
  <hdfile></hdfile>      Generic path to the compressed hourly observation files. See Note 4 and
  Note 6.
  <hnfile></hnfile>       Generic path to the hourly GPS navigation file. See Note 6.
  <hgfile></hgfile>       Generic path to the hourly GLONASS navigation file.
  <color></color>         Color to use for symbols in utility's interface. See Note 4 and Note 5.
</service>
```

Station and Service record notes

1. This field is case-sensitive.
2. Only the Z, GZ, and ZIP formats of compression are supported.

3. The service name must match the *ServID* field of a service record, as defined in the *manufact.xml* file or, if the service is user-created, in your *user.xml* file. If the station is found on more than one service, enter a separate <name> entry for each service.
4. This field is optional and, thus, does not need to be present.
5. The color defined here is used in the interface to identify the stations belonging to this service. The following colors are available: red, green, blue, magenta, cyan, gray, wine, black, gold, darkgray, darkgreen, darkblue, lightcyan, and darkmagenta.
6. This field identifies the format of the directory structure used on the FTP site to organize the data. Any folders in the structure that are common to all data must be hard-coded into this field. The rest, however, must be defined using the following case-sensitive strings:

[JJJ]	<i>Julian Day</i>
[YYYY]	<i>Year</i>
[XXXX]	<i>Station ID</i>
[week]	<i>GPS week</i>
[wkrl]	<i>GPS week - 1024 - padded with leading zeroes</i>
[wkm]	<i>GPS week -1024 - without padding</i>
[yy]	<i>Last two digits of the year</i>
[d]	<i>Day of the week (0 – 6)</i>
[MN]	<i>Month number</i>
[DM]	<i>Day of the month</i>
[H]	<i>Hour of the day, in upper case (A-X)</i>
[II]	<i>Hour of the day, numeric (00-23)</i>
[mmm]	<i>first three letters of month (Jan-Dec)</i>
[CITY]	<i>any custom string (such as the name of a city or region) contained within an FTP sites folder structure that varies for individual stations</i>

2.9 Window Menu

This menu option displays the GrafNav windows in different ways.

2.9.1 Close Window

Closes the currently selected window or plot.

2.9.2 Close All Windows

Closes all windows except the Map window.

2.10 Help Menu

2.10.1 Help Topics

Opens an HTML version of this manual. This feature can be very useful as a quick and easily accessible reference.

2.10.2 Check for update...

Provided an internet connection, this feature checks the Waypoint server to see if any GrafNav updates are available. If so, they can be directly downloaded and installed.

2.10.3 Download manufacturer files

Provided an internet connection, use this option to download the latest manufacturer files from Waypoint's FTP site. The files downloaded are listed below.

2.10.3.1 List of files downloaded when manufacturer files are updated

manufact.dcb

List of the differential code biases, in nanoseconds, between the P1 and C/A code for each satellite. Used by PPP and applied to any receivers that track the C/A code on L1 (as opposed to P1). If this file is out of date it may limit PPP solution convergence.

manufact.xml

List of base stations available for the *Download* utility. This is usually updated monthly.

manufact.dtm

List of datums, ellipsoids and transformations between datums.

manufact.fvt

List of *Favourites* and the groups they are contained in.

manufact.grd

List of manufacturer defined grids.

manufact.utc

List of UTC leap seconds and dates they were or will be introduced.

manufact.atx

Composite absolute antenna calibrations in ANTEX (new IGS) format.

2.10.4 NovAtel Waypoint Products

This option opens the Waypoint Software page in your default web browser. From here, more information on Waypoint Products can be found, including information regarding the latest version, notices of training seminars, links to FAQ/training materials and technical reports.

2.10.5 About GrafNav

This window displays information about the software version, build dates and copyright information.

Chapter 3 GrafNet

3.1 GrafNet Overview

GrafNet is a batch static baseline processor and network adjustment package. It is used to establish or check base station coordinates for later use within GrafNav, or survey entire static networks. GrafNet accepts GNSS data only, no terrestrial observations can be imported.

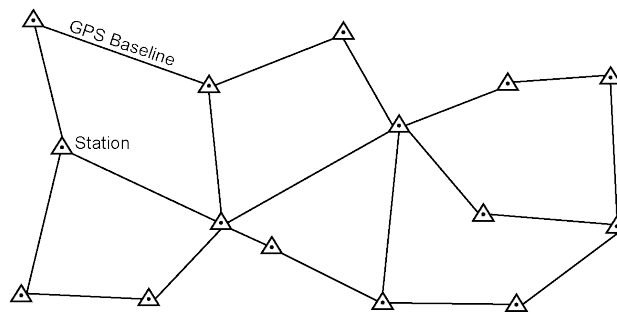
GrafNet is included with both GrafNav and Inertial Explorer, however can also be purchased separately as *GrafNav Static*. This section includes examples of networks that are commonly processed in GrafNet, as well as step-by-step instructions for first time users.

3.1.1 Types of Networks

3.1.1.1 Closed Loop Network

Surveyors often use this style of network because of increased reliability. Due to the closing of the loops, any baseline determination errors will show up as tie point errors. Such closure values can be seen via *Process | View Traverse Solution*. If just two GNSS receivers are employed, then a method called “leap-frogging” can be used to collect the data. In this procedure, starting from a known point, the lead receiver is placed on the first point to be surveyed. After the first session is complete, the trailing receiver is moved ahead of the lead receiver so that it now becomes the lead. The next baseline is observed and this procedure is repeated until small (4-6) loops are closed.

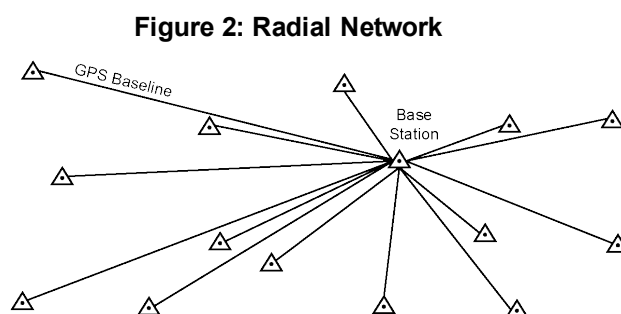
Figure 1: Closed Loop Network



Antenna height measurement errors will often cancel with this method and should therefore be double-checked. Methods involving more than two receivers become quite complex, and are past the scope of this section.

3.1.1.2 Radial Network

Also referred to as *Single Base Station*. Applications where productivity is more important, like GIS, do not need the same degree of reliability as the closed loop network. For these situations, use open loop networks. An example of this a network is shown below. For this method, one receiver is left stationary over a reference or control point. One or more remote GPS receivers are moved from point to point being surveyed.



3.1.2 Static Solution Types

GrafNet automatically forms sessions between any GPB files that have a minimum amount of overlapping data. The default value is 180 seconds, but this can be edited from the *Import Options* button when adding observations to a project. There are three modes of static processing, including:

3.1.2.1 Fixed Solution (ARTK)

In this mode of processing, integer ambiguity resolution is attempted using ARTK.

When choosing this mode, GrafNet will attempt to fix integer ambiguities regardless of the baseline distance separation. This will overwrite the *Automatic* setting, which chooses between fixed and float solution using the baseline distance and the tolerances set within the *ARTK* tab.

The settings within the *Advanced* tab control whether ionospheric processing is engaged when attempting a fixed integer solution and whether the tropospheric error state is engaged.

GrafNet attempts to fix new ambiguities whenever there is a change in satellite geometry, i.e. when a new satellite rises or a satellite drops below the elevation mask. A history of fixes are saved throughout the session and the final result is by default the averaged value.

3.1.2.2 Float Solution

This method does not attempt to resolve integer ambiguities. Float solution accuracy is largely dependent on the length of the occupation, as float ambiguities improve with time as they converge towards integer values.

Using this setting will process a float solution for the baseline(s) and override the *Automatic* mode which chooses between fixed and float modes using the baseline distance and tolerances set within the *ARTK* tab.

The settings within the *Advanced* tab control whether ionospheric processing and the tropospheric error state are engaged when processing a float solution.

3.1.2.3 Automatic

Automatic mode chooses between fixed and float modes using the baseline distance and the tolerances set within the *ARTK* tab as criteria.

The following table contains a list of common solution types in GrafNet.

Table 9: Common Solution Types

Solution Type	Fixed Integer	Ionospheric Correction	Tropospheric Error State	Description
L1-Float	N	N	N	Single frequency float solution without ionospheric correction or tropospheric error state
L1-ARTK	Y	N	N	Single frequency fixed solution without ionospheric correction or tropospheric error state

Solution Type	Fixed Integer	Ionospheric Correction	Tropospheric Error State	Description
L1L2-Float	N	N	N	Dual frequency float solution without ionospheric correction or tropospheric error state
L1L2-Float-Iono	N	Y	N	Dual frequency float solution with ionospheric correction and without tropospheric error state
L1L2 Float-Iono-Tropo	N	Y	Y	Dual frequency float solution with ionospheric correction and tropospheric error state
L1L2-ARTK	Y	N	N	Dual frequency fixed solution without ionospheric correction or tropospheric error state
L1L2-ARTK-Iono	Y	Y	N	Dual frequency fixed solution with ionospheric correction and without tropospheric error state
L1L2-ARTK-Iono-Tropo	Y	Y	Y	Dual frequency fixed solution with ionospheric correction and tropospheric error state

3.1.3 Computing Coordinates

Once the processing is complete, there are two methods to produce coordinates for each station.

3.1.3.1 Traverse Solution

This solution automatically computes during processing. It starts from known stations and transfers positions to neighboring stations one baseline at a time. A tie or closure will be computed where it is possible to derive a station coordinate from two or more directions as indicated by the vector arrows which show the direction of coordinate transfer.

3.1.3.2 Network Adjustment

This method includes all processed vectors and estimated accuracies into a single weighted least-squares adjustment. Errors are distributed using least squares throughout the network to produce more accurate station coordinates than the traverse solution. The network adjustment may flag poor fitting baselines within the *Output Vector Residuals* section of the network report.

3.2 Start a Project with GrafNet

3.2.1 Install Software

GrafNet is automatically installed when installing either GrafNav or Inertial Explorer. If you have not previously installed the software, see *How to install Waypoint software* on page 16 for installation instructions.

3.2.2 Convert Data

GrafNet will only import GPB files. As such, prior to importing data to a GrafNet project the data must first be converted. See *GNSS Data Converter Overview* on page 125 for information about how to convert raw GNSS data to GPB format.

3.2.3 Create a Project

Follow the steps below to create a project.

1. Convert all raw data to Waypoint format prior to creating a GrafNet project. See *GNSS Data Converter Overview* on page 125 for more information.
2. Open *GrafNet* from the *Waypoint GPS* program group in your Start menu.
3. Select *File | New Project*.
4. Browse to where you would like to create the project.
5. Give the project a name and click *Save*.



Entering the name of a project that already exists overwrites the file contents.

3.2.4 Add Observation Files to the Project

Follow the steps below to add observation files.

1. When creating a new project, the *Add Observation* window launches automatically after giving your project a name.
2. Click *Get Folder* and select the directory containing the converted data (GPB files).
3. Select the files that you want added or choose *Select All*. Select *Add* after all of the desired files have been added.
4. Verify the station name, antenna height and antenna model for each station loaded.
5. Click the *OK* button for each station loaded.
6. When finished loading all stations, select *Close* on the *Add Observations* window. Unprocessed vectors will then be displayed to the GrafNet map window.



If data has been collected over the same point more than once, the station ID should be the same for each observation. Otherwise, two separate stations will be formed and solved for.

3.2.5 Add Control and Check Points

A Ground Control Point (GCP) is a base station with known coordinates. GrafNet computes positions of unknown points by transferring positions throughout the network using the processed vectors from control points.

Check points are points with known coordinates, but their positions will not be constrained in the network. Rather, they will be used only to check the difference between the known coordinate and the processed position for that point. Adding a minimal amount of control to your project (one 3D GCP) and then adding all other control points as check points is a good way to check the agreement between control points in your network prior to processing a fully constrained solution.

Follow the steps below to add a ground control point.

1. Select *File | Add / Remove Control Point*.

Alternatively, you can right click on the station you want to add as a GCP and choose *Add as Control Point*. If you use this latter approach, skip directly to step 4.

2. Click the *Add* button.

3. Select the ID corresponding to the control point to be added.

If the GPB file was converted from RINEX and coordinates were scanned from the RINEX header, these will be automatically loaded.

4. Enter or verify the coordinates and datum for that station.
5. Click the OK button.

Repeat similar steps to add check points.

3.2.6 Set the Processing Options

After adding at least one GCP to your project, you will be able to access GrafNet's *Process Session* menu under the *Process* menu.

If you are processing a new project, it is recommended to use the GrafNet default options. GrafNet automatically chooses the type of solution to process based on the type of data available (single or dual frequency) and the baseline length.

If you wish to override any of the default processing settings, you can do so by editing the options available under the *Process Session* dialog prior to processing.

1. Select the desired static processing mode. These modes are described in *Static Solution Types* on page 86.

3.2.7 Process All Sessions

The *Process* tab of the GrafNet processing options controls which baselines will be processed. When first accessing a new project, the default selection should be *All unsuccessful (status less than good)* which will result in all of the baselines in the project being processed.

1. Ensure *All unprocessed (status less than good)* is selected under as the *Sessions to Process* on the *Process* tab.
2. Click the *Process* button.
3. Upon processing, baselines will either be color coded green (good) or red (failed). If baselines appear red, see *Fix Bad Baselines* on the next page.

3.2.8 Verify That All Baselines Have Passed

Passed baselines are plotted in green, failed baselines in red, purple or blue. Duplicate baselines appear yellow.

3.2.9 View Traverse Report

Access the traverse report through *Traverse | View Traverse Solution*. Loop, check and duplicate ties will be reported at the bottom of the report, which is valuable information for QC.

3.2.10 Run Network Adjustment

Follow the steps below to run a network adjustment. After these steps are completed, the *Network Adjustment Results* opens, while error ellipses are plotted for each station on the *Map Window*.

1. Select *Process | Network Adjustment*.
2. Click the *Process* button.

3.2.11 Export Station Coordinates

Follow the steps below to export station coordinates.

1. Select *Output | Export Wizard*.
2. Enter an output file name.
3. Select the source for the coordinates (usually *Network*).
4. Select a profile containing the desired output variables.

3.2.12 Fix Bad Baselines

The following sections contain ideas to try when attempting to fix bad (red) baselines in GrafNet.

3.2.12.1 Fixed Static Solutions

If a fixed integer solution is not achieved, consider lowering the ARTK quality acceptance criteria to its lowest setting (Q0) and reprocessing. When doing so, it is important to check any loop, check and duplicate tie points in the traverse report to ensure the quality of the solution.

If a fixed integer solution is still not achieved, check the baseline distance and plot the number of satellites, DOP and estimated carrier RMS in order to check if conditions are not favorable to integer ambiguity determination.

3.2.12.2 Change the Processing Direction

Switch from Forward to Reverse processing. The reverse solution might pick a different base satellite and have a different solution that passes.

3.2.12.3 Change the Elevation Mask

GrafNet by default uses a 15° elevation mask. This is because tropospheric, ionospheric and multipath errors increase significantly on low elevation satellites. Lowering the mask to 10° allows more satellites into the solution, strengthening the geometry. The improved geometry may more than compensate for increased measurement errors.

3.2.12.4 Change the Processing Time Range

The start / end times can be modified from within the *General* tab. Sometimes a data set will benefit if a problematic section is removed, such as an extended period where very few satellites are available (plot the Number of Satellites to check this).

3.2.12.5 Satellite Omission

A bad satellite has many bad data warnings in the message log file (FML/RML). Omit this satellite with the *Advanced* tab options.

3.3 File Menu

3.3.1 New Project

Use this option to create a new GrafNet project, which carries a GNT extension.

3.3.2 Open Project

To open an existing project, follow the steps below.

1. Select *Open Project* from the *File* menu.
2. Choose the name of the project from the dialog box that appears prompting you to select the name of an existing project (GNT file).
3. Click the *Open* button.

3.3.3 Save Project

This option saves the GrafNet project file (.gnt) to disk, including all observations added to the project.

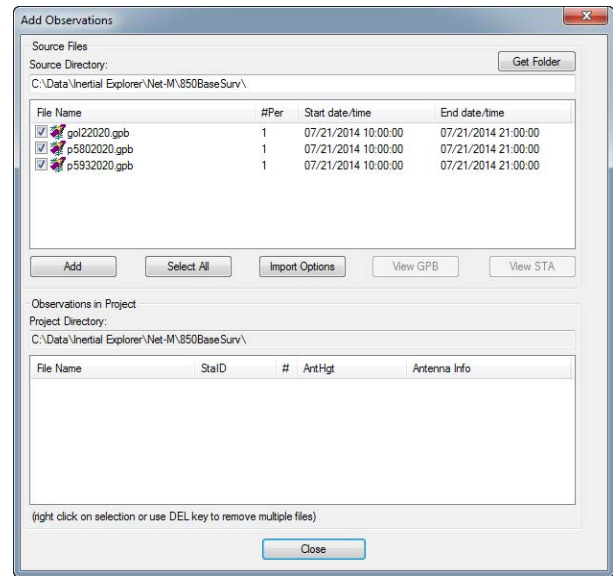
3.3.4 Save As

Use the *Save As* command under the *File* menu to create a new project that has identical processing options as the current project. This allows you to change the options in the new project and process the data without losing the solution computed by the original configuration.

3.3.5 Add / Remove Observations

This feature adds observation files to GrafNet projects. These files must be converted to GPB files using *File | Convert | Raw GNSS to GPB*.

If the GPB file was converted from RINEX, the station name, antenna height and antenna profile may be loaded automatically when adding stations. Verify this information is imported correctly for each loaded station.



3.3.5.1 Import Options

Clicking the *Import Options* button provides access to the following options:

Prompt for station name and antenna height

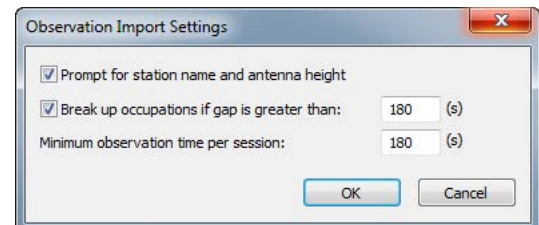
This option is on automatically as it is good practice to ensure the station name, antenna height and antenna model are correctly loaded into the project for each station. If however you are confident the data will be loaded correctly automatically and you are loading a large number of observations, consider disabling this option.

Break up occupations if gap is greater than: 180 (s)

If a GPB file contains a data gap larger than this adjustable threshold, GrafNet will treat the data before and after the gap as separate sessions. The default value is 180 seconds. If more than one session is detected in your data and you are confident the station did not move, deselect this option when importing data.

Minimum observation time per session:

GrafNet will not form sessions between stations that contain less than this adjustable threshold. The default value is 180 seconds. This is a good way of filtering out short and unintentional baselines from being included in your project.



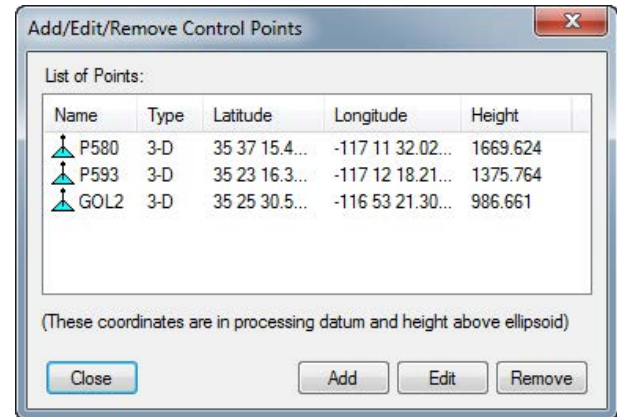
3.3.6 Add / Remove Control Points

Add at least one 3D or horizontal ground control point before processing. Sessions will not be processed unless they are connected to a control point. The three types of control points include the following:

- 3D: constrained horizontally and vertically
- 2D: constrained horizontally
- 1D: constrained vertically

After selecting *Add / Remove Control Points* from the *File* menu, click *Add* to enter a new control point or *Edit* to adjust the station, position or Datum of a control point. Control and check points can also be added by right clicking on the stations in the GrafNet map window. When right clicking on a station, *Add as Check Point* and *Add as Control Point* are available menu items. The station ID should match that of the corresponding station.

Standard deviations can be entered at this stage. The default values are 5 mm for horizontal and 5 mm for vertical. Standard deviations are only taken into account in the network adjustment. They are useful for combining high and low accuracy control points and will control the extent to which the network adjustment adjusts control point positions.

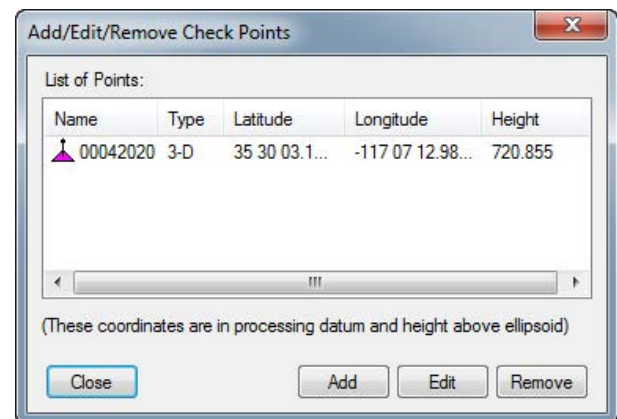


3.3.7 Add / Remove Check Points

Check points are useful for gauging how well the network fits the existing control fabric. They are added in the same manner as control points, except that standard deviations are not applicable.

3.3.8 Add Precise Files

Use this feature to add precise ephemeris and clock files to the project. Precise ephemeris files will reduce residual satellite orbital error on long baselines. See *Add Precise/Alternate Files* on page 30 for more information.



3.3.9 Import Project Files

This feature imports stations and baselines from another GrafNet project into the current project.

3.3.10 View

3.3.10.1 ASCII File

See *ASCII File(s)* on page 39 for information regarding this feature.

3.3.10.2 Raw GNSS Data

See *Raw GNSS Data* on page 39 for information regarding this feature.

3.3.11 Convert

3.3.11.1 Raw GNSS to GPB

Users have to convert their raw data files to GPB format prior to importing into GrafNet. More information on this utility is available in *Convert Raw GNSS data to GPB* on page 125.

3.3.12 GPB Utilities

A number of utilities are available for use with GPB files. See *Utilities* on page 120 for information regarding any of these utilities.

3.3.13 Recent projects

Displays recent projects.

3.3.14 Exit

Exits the program.

3.4 Process Menu

3.4.1 Processing Sessions

This option brings up the *Process Sessions* window, where all processing options are accessed.

3.4.1.1 Process Options

Sessions to Process

Allows you to decide which session to process. The options are listed below.

All unprocessed

Processes all sessions listed as either *Unprocessed* or *Approximate*. These sessions are blue or purple in the *Map Window*.

All unsuccessful

Processes all sessions that do not have a *Good* status. This includes all sessions that are not green in the *Map Window*. Processing will start nearest to the control points and move outward.

Only those sessions shown in Data Manager

Process only the sessions that are presently listed in the *Data Manager* window.

Reprocess entire project

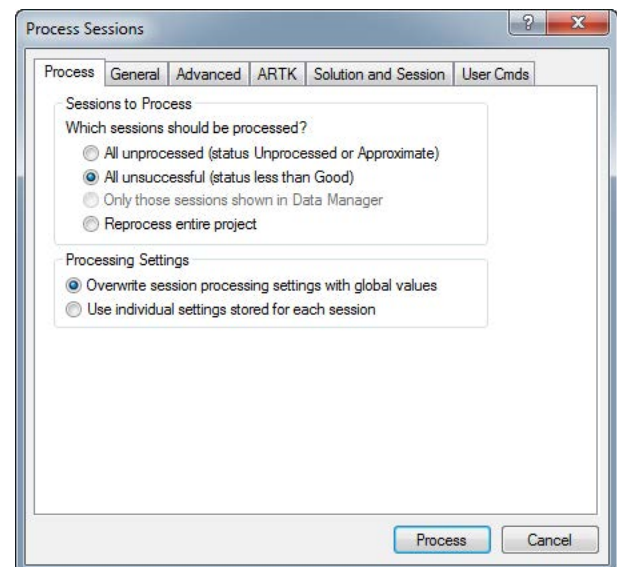
Reprocesses all solutions, regardless of status.

Processing Settings

Determines which processing settings to use for each baseline. The options are listed below.

Overwrite session processing settings with global values

Applies the options set under *Options | Global Settings* to all baselines being processed. Any individual baselines whose settings were changed will have their settings overwritten.



Use individual settings stored for each session

Uses the options as individually set for each baseline for processing.

3.4.1.2 General Options**Process Direction**

The direction can be set to *Forward*, *Reverse* or *Both directions*. The forward and reverse solution should provide similar solutions for a static session but in some circumstances, a reverse solution passes when a forward fails, or solutions may differ because of different base satellite selections.

Static Solution Type

See *Static Solution Types* on page 86 for information.

Frequency

Defines the type of data used for processing. The following settings are available:

Single frequency

Overrides automatic selection and applies single frequency (L1 only) processing.

Dual frequency

Overrides automatic selection and applies dual frequency processing. L1 / L2 data must be present in all observation files.

Automatic

Chooses between single and dual frequency processing depending on the common data available between the base and remote.

Constellation Usage

GrafNet supports GPS, GLONASS, BeiDou, Galileo and QZSS. By default, all common data will be processed, however individual constellations (other than GPS) can be disabled here.

Elevation Mask

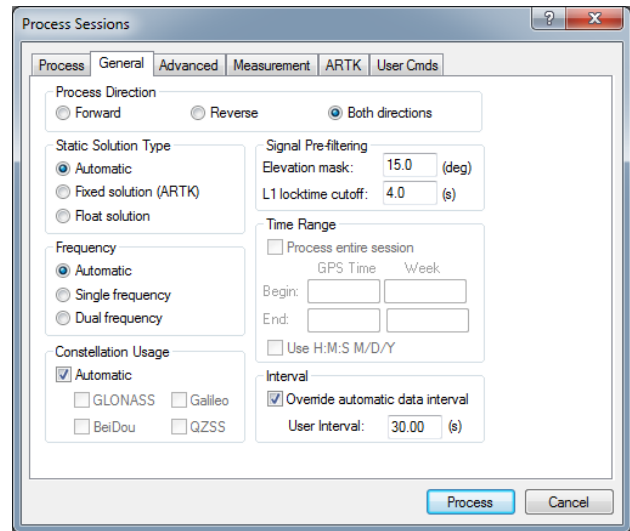
Satellites below this mask angle will be ignored. The default value is 15°. Lowering this value allows more satellites to be used, possibly improving a solution with poor geometry.

Time Range

This option is only available when processing sessions individually.

Interval

Allows you to choose the processing interval. 30 seconds is the default processing interval as processing high rate data does not typically improve static processing results.



3.4.1.3 Advanced Options

Satellite Omissions

See *Satellite / Baseline Omissions* in the *General (Differential Settings)* on page 42 for more information.

Ionospheric Options

See *Ionospheric Processing (Differential processing only)* on page 48 for a description of the Ionospheric options.

Tropospheric Error State

See *Tropospheric Error State (Differential processing only)* on page 48 for a description of the Tropospheric options.

Forward/Reverse Process Direction Handling

Use solution last processed

Does not combine forward and reverse solutions if available, but rather uses the last solution processed in the traverse and network solutions. This setting is useful when reprocessing problematic baselines.

Combine FWD/REV solutions

If both forward and reverse solutions are available they are combined statistically. This is the software default.

GrafNav / GrafNet Interface Settings

If you export baselines to GrafNav for processing, the options below are available to specify how changes made to the processing settings in GrafNav affect those in GrafNet and how the two programs communicate.



If you decide to have the processing settings in GrafNet updated to match those used in GrafNav, they will only be stored for the individual baseline that was exported. The global processing options for the GrafNet project are unaffected.

Always update session settings

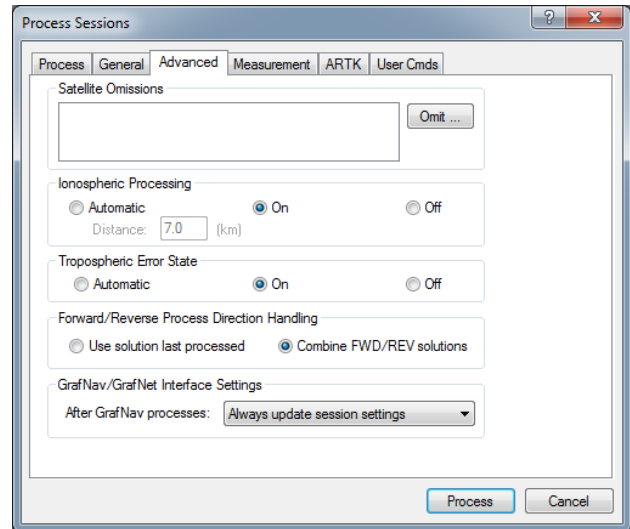
Any changes made to the processing settings in GrafNav will be saved to that baseline's processing settings in GrafNet.

Never update

Any changes made in GrafNav will not be saved in GrafNet. As such, GrafNet will retain the settings that were used at the time of export.

Prompt user before update

You will be prompted after every processing run in GrafNav as to whether or not the processing settings used should be saved to GrafNet.



3.4.1.4 Measurement Options

See *Measurement* on page 47 for information regarding the settings on this tab.

3.4.1.5 ARTK Options

Quality Acceptance Criteria

The criteria used in statistical testing in order to accept or reject an ARTK fix. Consider increasing this value if the solution type of vectors in your network indicate fixed solutions, and high loop, check, or duplicate ties are reported in the traverse report.

The higher this threshold is set, the less likely it is that incorrect integer ambiguities will be accepted. Conversely, the higher this is set, the less likely any fixed integer solution will be achieved.

Maximum Distance for Single Frequency

Controls the maximum distance at which a fixed integer solution will be attempted using ARTK for single frequency data.

Maximum Distance for Dual Frequency

Controls the maximum distance at which a fixed integer solution will be attempted using ARTK for dual frequency data.

Solution Type

Whenever there is a change in satellite geometry (i.e. a new satellite rises or one drops from view), GrafNet attempts to recompute fixed integer ambiguities. A history of fixed integer solutions throughout the session is saved and the solution GrafNet chooses is controlled by this option. The default is to average all available ARTK fixes but choosing the solution with lowest (best) variance, lowest (best) RMS or highest (best) reliability may help when troubleshooting a problematic baseline. In order to evaluate the effectiveness of each option, check the magnitude of the loop and check and duplicate ties in the traverse report.

Minimum Reliability

ARTK will not return a successful solution unless the reliability of the ARTK fix meets this threshold. This option is off by default.

Maximum RMS

ARTK will not return a successful solution unless the RMS of the ARTK fix meets this threshold. This option is off by default.

3.4.1.6 User Cmds

This changes any command that is passed to GrafNet. It can be used to change commands that are set by the other option tabs or set commands that are not handled by the other option tabs.

When a configuration file is loaded, all commands that are not handled by the other option tabs appear here. This includes commands that are not supported in the version of GrafNet being used. These commands can easily be deleted here.

3.4.2 Rescan Solution Files

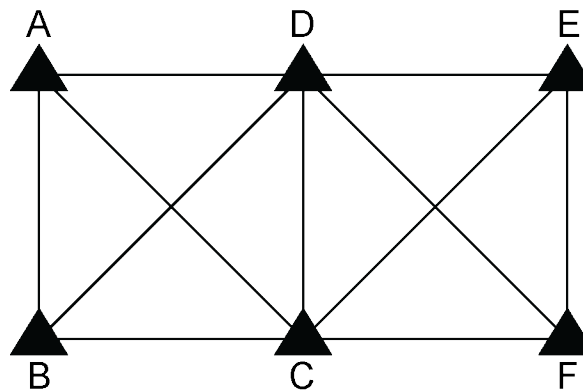
This option rescans the FSS (forward static solution) and RSS (reverse static solution) files. This option will only have an effect if baselines have been processed outside of the GrafNet interface and GrafNet is not recognizing the updated processing results. Normally, this happens automatically but this is controlled through the GrafNav/GrafNet interface settings found in the *Advanced* tab of the GrafNet processing options.

3.4.3 Ignore Trivial Sessions

GrafNet defines trivial baselines as those that are unnecessary as a result of multiple receivers simultaneously running. The problem with this is that the baseline solutions computed by GrafNet are correlated, and so they are dependent. Removing trivial baselines reduces these dependencies, while still maintaining a closed loop. It also creates a network where the standard deviations reflect the actual errors more accurately.

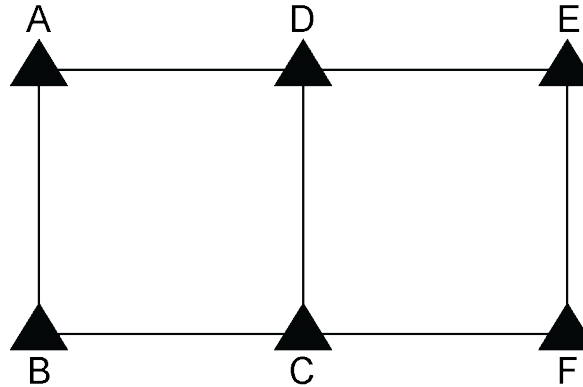
Consider the network in *Figure 3: Trivial Baselines* below. The six stations are surveyed with four receivers during two one-hour sessions. During the first session, stations A, B, C, and D are observed. During the second session, the points C, D, E, and F are observed.

Figure 3: Trivial Baselines

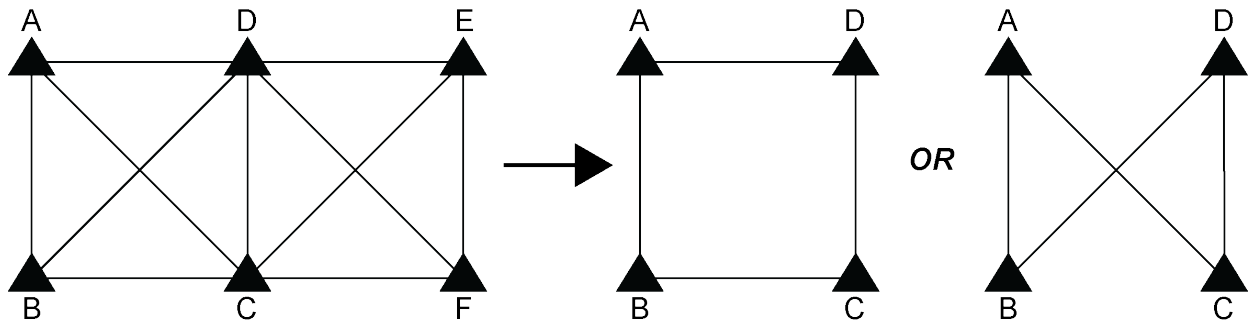


This network can be divided in two sub-networks, formed by the first and second time periods. Before the trivial baseline removal, every baseline in these two sub-networks is dependent on the other baselines. These dependencies cause the loop ties to be low.

With four receivers or more collecting data at the same time, a sub-network is very over-determined. Using three GPS receivers, the network is still over-determined, but all baselines need to be included to form a closed loop. GrafNet removes these dependent or trivial baselines by creating a single loop that connects all of the points in the sub-network. *Figure 4: Network with Trivial Baselines Removed* on the next page illustrates that it is easy to remove these baselines.

Figure 4: Network with Trivial Baselines Removed

With four receivers, there are two dependent baselines in each sub-network. GrafNet removes these trivial baselines for each sub-network. *Figure 5: Removal of Trivial Baselines* below shows two possibilities of what GrafNet might do with the first sub-network.

Figure 5: Removal of Trivial Baselines

GrafNet removes the trivial baseline by setting their session status to *Ignore*. It is possible to un-ignore any session by simply changing its status back to *Unprocessed*. GrafNet tries to keep the sessions that are of best quality. The following criteria is considered:

- The amount of time the baseline was surveyed.
- The frequencies used in the surveying of the session.
- The length of the baseline.
- The number of connecting baselines to the two end-points.

As shown in the figure *Figure 4: Network with Trivial Baselines Removed* above, GrafNet automatically excluded AC, BD, CE, and DF. It then forms a single loop for each of the time periods. DC is a baseline with a duplicate session.

3.4.4 Unignore All Sessions

This feature changes the status of all ignored sessions from *Ignore* to the status they had previously.

3.4.5 Compute Loop Ties

In some cases, the Traverse or Network residuals show a poor fit. The first step is to ensure that the network is minimally constrained, which means that there should only be one 3-D control point, or one horizontal and one vertical control point. Convert any additional control points to check points. See *Add / Remove Check Points* on page 92 or *Show Data Manager* on page 106 for help.

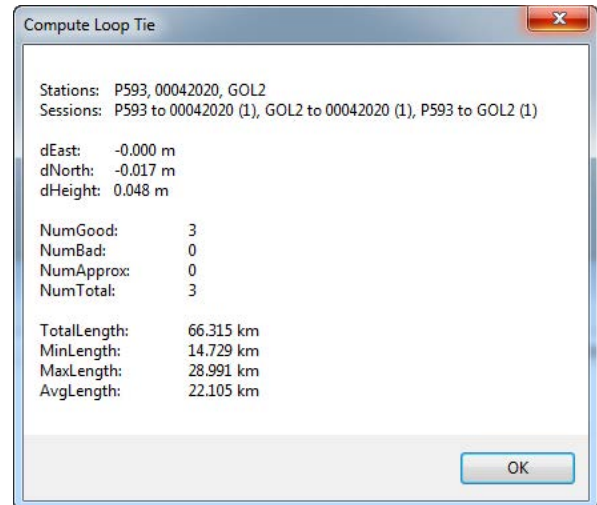
For a constrained network, the poor fit indicated by large residuals can be caused by the following two issues:

- Incorrect antenna heights used for multiple occupations of a point
- Baseline solution is incorrect (by far the most common cause)

In some cases, it is obvious from the traverse output which baseline is the culprit, but often further investigation is required. The *Compute Loop Tie* feature makes such examinations much easier. By adding the vectors of a loop within the network, discrepancy values are formed in the east, north and height directions. For a loop without problems, these values should be near zero. If not, then one of the baselines forming the loop has an error. Loops can be formed in the following two ways:

- Selecting stations
- Selecting baselines forming loops

Make the selections on the map or select the stations or sessions in the *Data Manager* window. After selecting the first station or session, hold down the *Ctrl* key while selecting the remaining ones. Selection must be continuous, but it does not matter if the loop is formed in the clockwise or counter-clockwise direction. Once a complete loop is formed, select *Process | Compute Loop Tie* or right-click on one of the selections in the *Data Manager* window and select *Compute Loop Tie*. A window containing various statistics for the closed loop is displayed.



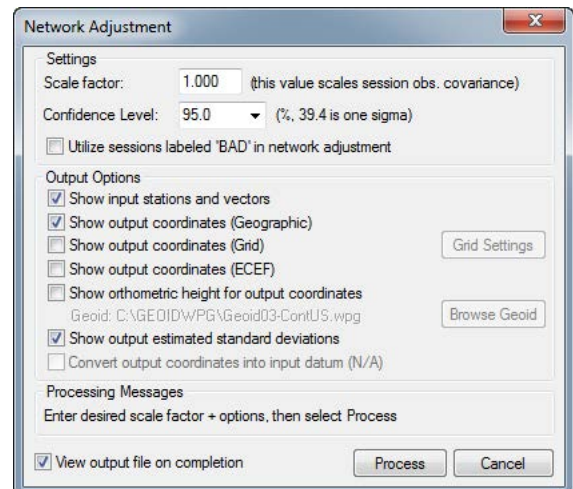
3.4.6 Network Adjustment

GrafNet contains a least-squares network adjustment that can be accessed through *Process | Network Adjustment*. External network adjustment programs, such as StarNet, also support GrafNet's output format.

Network adjustments are a means to more accurately compute each station's coordinates given the solution vectors computed for each session / baseline. Such an adjustment uses the X, Y and Z vector components and also utilizes the 3 x 3 covariance matrix which is the standard deviation values + coordinate-to-coordinate correlation. Using least squares, the errors are distributed based on a session's estimated accuracy. More weight is placed on sessions with lower standard deviations.

3.4.6.1 Advantages

In the traverse solution, each station's coordinates are determined using one session from one previous station. For networks with redundant measurements, which is usually the case, this will lead to sub-optimal determination of a station's coordinates. The network adjustment does a much better job of distributing errors. This



makes it less sensitive to errors as long as a session's estimated accuracy is representative of actual errors. Thus, the network adjustment always produces the best station coordinates.

Another advantage of the network adjustment over the traverse solution is that it computes a standard deviation for each station coordinate, which is not possible in a traverse solution.

Before running the network adjustment, all baselines must have already been processed. Only good (green) baselines will be used, unless otherwise specified with the *Utilize sessions labeled 'BAD' in network adjustment* option.

3.4.6.2 Settings

Scale Factor

Error ellipses should appear on the stations in the *Map Window*. These ellipses are scaled by this option.

Confidence Level

The level of confidence (in percent) of the error ellipse can also be adjusted. This uses a statistical 2-D normal distribution. Changing this value does not alter the final coordinates, but it will scale the final standard deviations and covariance values. For example, 95% results in a standard deviation scale factor of 2.44.

3.4.6.3 Output Options

Controls what is output from the network solution.

Show input stations and vectors

Outputs all the control and check points and their vectors. The coordinates are output in geographic form.

Show orthometric height for output coordinates

Requires that you provide a geoid file, which can be selected with the *Browse Geoid* button.

Other output options include outputting the estimated standard deviations.

To process the network adjustment, click the *Process* button. This step must be performed each time a project is re-loaded.

Show output coordinates

Output coordinates may be shown in *Geographic* (latitude/longitude/ellipsoidal height), *Grid* and/or *ECEF* coordinates.

View output file on completion

Lets you view the ASCII solution file once the adjustment has been made.

3.4.6.4 Using Multiple Control Points

When multiple control points are present, it is suggested to initially use only one. This prevents errors in the existing control from causing otherwise correct session vectors not to fit. Therefore, large tie errors in the traverse solution or large residuals in the network adjustment are attributed to GNSS processing and not poorly fitting base station coordinates.

The variance factor is only truly valid as a scale factor for a minimally constrained adjustment. See *Interpreting the network adjustment report* on the next page for information about interpreting the output. Once satisfied with the quality of the GNSS data and the fit of the session vectors, you can add additional control points with *File | Add / remove Control Points* or by right-clicking on a station in the *Map Window* and selecting *Add as Control Point*.

Since the network adjustment is a least-squares adjustment, it will move control point coordinates to make the network fit better. This is an undesirable effect for many applications. To avoid it, give control points very low standard deviations. The default value is 5 mm, which might have to be lowered if the network fit is poor. Lowering the standard deviation to 0.0001 m forces the control point to "stay put". A standard deviation of zero is not

allowed. Change the standard deviation for control points via *File | Add and Remove Control Points*. Select the desired control point and click *Edit*.

3.4.6.5 How to Process with the Network Adjustment

1. After successfully processing all of the baselines within GrafNet, access the network adjustment via *Process | Network Adjustment*.



The network adjustment only accepts session data flagged as *Good*. Other baselines will be ignored unless otherwise specified with the *Utilize sessions labeled 'BAD' in network adjustment* option.

For the initial run of the network adjustment, the scale factor should be set to 1.0. This will not scale the final standard deviations to match observed session vector residuals. See *Variance Factor and Input Scale Factor* on the next page for more information.

2. Click the *Process* button to compute a network adjustment solution. Any errors encountered are displayed.
3. If there are any “hanging stations”, which are stations that are not attached to the network or are attached by a *Bad* baseline, the adjustment will fail. It is possible to change the status of the baseline to *Good* from the *Sessions* window in *Data Manager*.
4. A .net file is created, which can be viewed via *Process | View Network Adjustment Results*.



The network adjustment must be re-run if you have reprocessed sessions or changed the station configuration.

3.4.6.6 Interpreting the network adjustment report

The network adjustment output is an ASCII file that can be viewed and printed from GrafNet.

Input Stations

This is a list of the control (GCP) and check points in the project. Their associated geographic coordinates and standard deviations are also shown.

Input Vectors

This is the ECEF vector components for each session that has a *Good* status. The lower triangular of the ECEF covariance matrix is shown next to the vector components. The value in brackets is the standard deviation of the ECEF X, Y or Z axis in metres. The covariance values are not scaled by the Scale Factor entered at the start.

Output Vector Residuals

This indicates how well the session vectors fit in the network. The residual values are shown in local level, where RE is the east axis residual, RN is the north axis residual and RH is the Z axis residual. These values are expressed in metres and should ideally be a few centimetres or less. Larger values may be acceptable for larger networks.

In addition to the residual values, a parts-per-million (PPM) value is shown. This indicates the size of the residuals as a function of distance. 1 PPM corresponds to a 1 cm error at a distance of 10 km. The baseline length is also shown in kilometres. Baselines less than 1 km can have large PPM values. This is because other errors such as antenna centering become an influencing issue. This might not indicate an erroneous session solution. The last value is the combined (east, north and up) standard deviation (STD).

Check Point Residuals

If check points have been added, this section shows how well the known coordinates compare to those computed by the network adjustment.

Control Point Residuals

This section shows the adjustment made to control point residuals. When just one control point is used, then the adjustment will always be zero. With two or more points, the adjustment depends on the input control point standard deviation and the session vector standard deviations.

Output Station Coordinates

This shows the computed coordinates for each of the stations both in geographic and ECEF coordinate systems. The output datum is indicated by the *Datum* parameter at the top of this file.

Output Variance / Covariance

This section shows the local level (SE, SN and SZ) standard deviations along with ECEF covariance values. The standard deviation values are scaled by both the input scale factor and the statistical (confidence) scale factor. The covariance values are only scaled by the input scale factor. If error ellipse parameters are desired, then the *Write Coordinates* feature should be used.

Variance factor

See *Variance Factor and Input Scale Factor* below for information.

3.4.6.7 Using Horizontal and Vertical Control Points

GrafNet supports horizontal and vertical control points in addition to full 3-D control. To utilize either option, you must have available 1-10 m accurate coordinates for the unknown axes (that is, Z for horizontal control and latitude and longitude for vertical control). These coordinates can be obtained from the single point solution or from an initial network adjustment run using just one 3-D control point. The latter method is normally used.

3.4.6.8 Variance Factor and Input Scale Factor

The variance factor is at the bottom of the network adjustment report. It is the ratio between the observed residual errors and the estimated session (baseline) accuracies. Ideally, the variance factor should be 1.0. This indicates that the estimated errors correspond well to observed errors. A variance factor less than 1.0 indicates that the estimated errors are larger than the observed errors (that is, session standard deviations are pessimistic). Most often, a value greater than 1.0 denotes that observed errors are larger than estimated accuracies (that is, session standard deviations are optimistic) unless the GPS data is very clean. Thus, low variance factors are normally desired. Very large variance factors of 100+ normally indicate abnormally large session errors (that is, a very poor network fit), and you should try and investigate the source of the problem before using the coordinates produced.

The variance factor can also be used to scale the station standard deviations to more realistic values. The network adjustment is initially run with a unity scale factor. The resulting variance factor can then be inserted in the scale factor field from the first screen. After running the network adjustment with this new scale factor, you will notice larger or smaller standard deviations and that the new variance factor should now be ~1.0. This procedure will only work for a minimally constrained adjustment (that is, one 3-D control point, or one 2-D and one 1-D control point).

3.4.7 View Traverse Solution

GrafNet computes a traverse solution automatically after processing each session. The traverse report is written to a TRV file and opened automatically in GrafNet's internal viewer.

3.4.7.1 Traverse Solution

Prior to generating the network adjustment report, it is recommended that you view the traverse report. The traverse report contains useful information, particularly a report on any loop, check and duplicate ties in the project.

For stations that have more than two baselines connecting, a loop tie is computed. This means that there is more than one possible transfer of coordinates to this point. The first transfer is used for coordinate generation. Subsequent transfers are used to compute loop ties. The loop ties are good for locating erroneous baselines but they are an accumulated error of many baselines to that point. This means that the last baseline in that traverse leg may not be the erroneous one. These ties also give a good indication of the accuracy of the network, but the magnitude of the errors will be larger than the network adjustment residuals. The traverse method accumulates errors (closures) while the network adjustment spreads these errors across the whole network.

Traverse Solution Report:

```

*****
* GrafNet - GRAPHIC GPS NETWORK PROCESSING *
* SOFTWARE PACKAGE *
* TRAVERSE SOLUTION: *
* Copyright Nuvoton Inc. (2014) *
* Version: 8.60.2019 *
* PROJECT: New.gnt *
*****

DATE: 8/19/2014 (n/d/y)
TIME: 13:35:32

DATUM: WGS84
GRID: UTM, Zone 1
UNITS: metres (see Preferences to change)
GEOID: (none)

*****
STATIONS (STATUS):
*****

Station Type HgtStatus Result Coordinates derived from...
00042020 Loop Tie OK Good GDL2
GDL2 Control-3D OK Pub(3D) (-)
P580 Control-3D OK Pub(3D) (-)
P593 Control-3D OK Pub(3D) (-)

*****
STATIONS (COORDINATES):
*****

Station Latitude Longitude Grid-E Grid-N EllHgt OrthHgt
(D H S) (D H S) (m) (m) (m) (m)
00042020 35 30 03.14438 -117 07 12.98802 6185431.795 6182473.802 722.181 (-)
GDL2 35 25 30.56809 -116 59 21.38009 6195445.443 6115651.619 684.461 (-)
P580 35 37 15.40985 -117 11 32.02274 6085198.316 6109026.501 1669.624 (-)
P593 35 23 16.33063 -117 12 18.21870 6110345.973 6082157.891 1375.764 (-)

```

3.4.8 View Processing Report

This option displays the RPT file containing information about the stations, sessions, baselines and observations. It also gives a summary for each session processed.

3.4.9 View All Sessions

This option will display all sessions in the Data Manager.

3.4.10 View All Observations

This option will display all observations in the Data Manager.

3.4.11 View All Stations

This option will display all stations in the Data Manager.

3.5 Options Menu

The following options are available on the *Options* menu.

3.5.1 Global Settings

This feature accesses the global processing options. The options set here are applied to all baselines in the project, overriding any settings that may have been customized for individual baselines. The processing settings for individual sessions can be customized by right-clicking on the session in the *Data Manager* and selecting *Options*.

3.5.2 Sessions Settings (Shown in Data Manager)

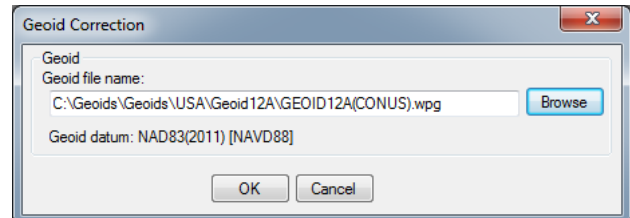
This feature allows you to set the processing options for only the sessions currently appearing in the *Data Manager*. In order to use this feature, the *Sessions* window of the *Data Manager* must be open.

3.5.3 Grid Options

See *Grid/Map Projection* on page 76 for information regarding this feature.

3.5.4 Geoid Options

This feature allows specification of the project geoid. The geoid selected is used as a reference when outputting orthometric heights in the Traverse Solution and network adjustment.



3.5.5 Preferences

3.5.5.1 GrafNet Display

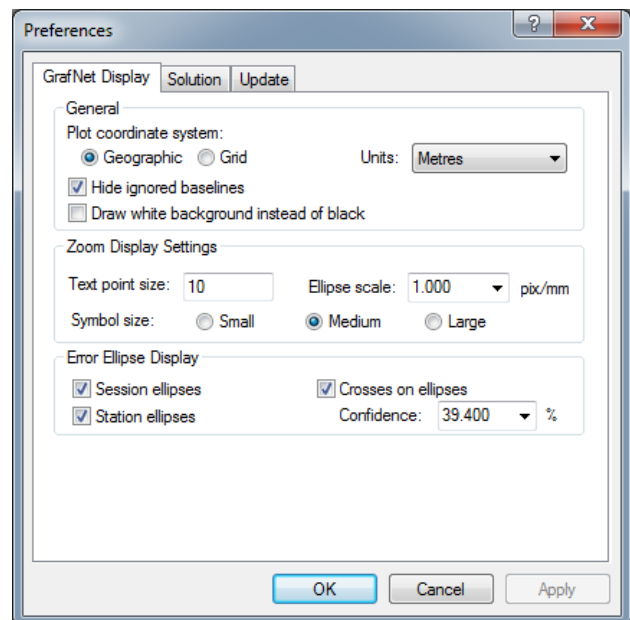
See *Preferences* on page 54 for information regarding any options not described here.

Zoom Display Settings

The *Ellipse scale* field changes the size of the error ellipses. Projects covering large areas might have large ellipses and decreasing the values for all three zoom scales (0, 1, and 2) will make the ellipses smaller.

Error Ellipse Display

Controls whether session and station ellipses are plotted. Station ellipses are only generated after a network adjustment. The crosses on the ellipse option shows the axes of the error ellipses.



3.5.5.2 Solution

Allows the user to choose their default datum and simultaneous forward/reverse processing.

3.6 Output Menu

3.6.1 Export Wizard

See *Export Wizard* on page 65 for information regarding this feature.

3.6.2 Output to Google Earth

See *Export to Google Earth* on page 68 for information regarding this feature.

3.6.3 Export to DXF

Only the options specific to GrafNet are discussed here. For descriptions of the other options, see *Export to DXF* on page 69.

3.6.3.1 Station Error Ellipses

Displays the error ellipses around each station and is only available if a network adjustment has been completed.

3.6.3.2 Baseline Error Ellipses

Only the baselines that were processed.

3.6.3.3 Error ellipse scale factor

The ellipse scale factor scales the ellipses so they will be visible if you do not see them in the DXF file.

3.6.4 Export to STAR*NET

This feature creates an EXP file which is accepted as input to MicroSurvey's STAR*NET network adjustment software.

3.6.5 Build HTML Report

Creates an HTML file containing a bitmap version of any plot that is currently open, including the Map Window. These HTML and BMP files are saved to the HTML folder contained within the project folder. The HTML file also contains information regarding the processing run(s) used to generate the plots.

3.6.6 Show Map Window

3.6.6.1 Map Window

If you have unintentionally closed the GrafNet Map window, it can be re-opened using this option.

3.6.6.2 Mouse Usage in Map Window

Either double-clicking or right-clicking on a station, gives you access to several options, which are described in *Show Data Manager* on the next page.



Clicking on a station displays the station in the Stations window of the Data Manager, while clicking on a baseline will display that baseline and any duplicates in the Sessions window.



3.6.7 Show Data Manager

3.6.7.1 Data Manager

This interactive window allows for easy display and organization of all project data.

3.6.7.2 Observations Window

The *Observations* window displays information regarding all the observation files (GPB) that are included in the project.

Columns in the Observations Window

Name

Name of the station (entered or scanned during data import).

AntHgt

Antenna height for the period at which the observations were made.

AntType

Name of absolute antenna model applied.

File

File, path and name of the GPB observation file.

#

If multiple observation periods are contained within one GPB file, this column indicates which of those observation periods is being referred to. Observation periods are numbered sequentially in the order they appear in the GPB file.

Length

Length of the observation period in HH:MM:SS.

Start Date

Date when the observation period started in MM/DD/YYYY.

Start Time

Time of day at which the observation period started in HH:MM:SS.

Receiver

Name of receiver as decoded to the GPB file.

Freq

Indicates whether data is single or dual frequency.

Int(s)

Interval, in seconds, at which the data was logged.

Right-click Options for Observations in Project Window

The following options are available by right-clicking on an observation:

View

Displays the *Information* window for the observation file.

Edit

Opens the *Add / Edit Observation* window, in which the station name and antenna information can be corrected.

Delete Observation

Removes the observation period from the project.

View GPB File

Opens the observation file in *GPB Viewer*.

View STA File

Opens the station file for the associated GPB file.

View Ephemeris File

Opens the ephemeris file (EPP) for the associated GPB file.

Plot Coverage

Opens the *File Data Coverage* plot for all observations in the project. See *Common Plots* on page 61 for information regarding this plot.

Plot L1 Satellite Lock

Launches the *L1 Satellite Lock / Elevation* plot. See *Common Plots* on page 61.

Plot L2 Satellite Lock

Launches the *L2 Satellite Lock / Elevation* plot. See *Common Plots* on page 61.

Show Sessions using Observation

Displays all sessions involving the observation period in the *Sessions* window.

Expanding the *Observations* branch in the *Data Objects* window on the left-hand side of the *Data Manager* allows the observations to be displayed individually in the *Observations* window. Expanding each observation in the *Data Objects* window displays the station that was observed.

3.6.7.3 Stations Window

The *Stations* window displays information regarding all the points observed in the network.

Columns in the Stations window**Name**

Name of station.

Type

See *Table 10: Station Color Legend* on the next page for information on station types.

Latitude

Latitude of the station.

Longitude

Longitude of the station.

EllHgt

Ellipsoidal height of the station.

Source

Indicates whether the station coordinates are from the traverse solution or the network adjustment.

#Files

Number of observations periods for that station.

TotalLen

Total observation time made at that station.

A(mm)

Semi-major axis of error ellipse at that station, as defined from the network adjustment.

B(mm)

Semi-minor axis of error ellipse at that station, as defined from the network adjustment.

DH(mm)

Estimated height standard deviation.

Right-click Options in the Stations Window

The following options are available by right-clicking on a station:

View Solution

Displays the solution from traverse computation and network adjustment, if valid.

Add as Control Point

Allows you to define the station as a control point.

Add as Check Point

Allows you to define the station as a check point.

Edit Control / Check Point

Allows for editing of the input coordinates of stations already defined as check or control points.

Toggle between Control / Check Point

Switches status between control point and check point.

Add to Favourites

Adds the station to the *Favourites* list, using the computed coordinates.

Remove Processing Files

Removes all observation files logged at that station from the project.

Show Observations

Displays all observation periods for that station in the *Observations* window.

Show Connecting Sessions

Displays all sessions involving that station in the *Sessions* window.

Expanding the *Stations* branch in the *Data Objects* window on the left-hand side of the *Data Manager* allows for the stations to be displayed individually in the *Stations* window. Further expanding each station in the *Data Objects* window displays all observation files in which the station was observed.

Table 10: Station Color Legend

Color	Description
Cyan	Control point – A reference station with known coordinates
Dark Purple	Check point – Station has known coordinates available, but they will only be used as a check. Comparisons are found in the TRV file. The network adjustment output file (NET) also shows check point residuals.
Light Purple	Tie point – Two or more sessions are connected as remotes to this station via the traverse solution. The TRV file will show traverse ties.
Yellow	Traverse point – No tie information can be computed as there is only one avenue for establishing coordinates for this station.

3.6.7.4 Sessions Window

The *Sessions* window displays information regarding all the sessions in the network.

Columns in the Sessions Window

Name

Name of the session, which serves to indicate the direction of coordinate transfer.

SD

Standard deviation, in mm, of the baseline as calculated by the Kalman filter.

Reliability

Reliability of the fixed static solution, if available.

RMS

RMS of the fixed static solution. Applies only to fixed baselines.

SolType

Indicates solution type. See *Static Solution Types* on page 86 for a full description.

Time

Length of session, in *hh:mm* format.

Dist

Baseline distance, in km.

Status

Solution status. See *Static Solution Types* on page 86 for descriptions.

From

Indicates the *FromStation*.

To

Indicates the *ToStation*.

#

If multiple sessions exist for the same baseline, indicates which session is being referred to.

Right-click Options in the Sessions Window

The following options are available by right-clicking on a session:

View Results

Displays the results of forward or reverse processing, or the combined solution.

View Information

Displays the *Information* box for the session.

View File

Opens the message log, static summary, trajectory output or configuration files.

Plot

Launches the plots discussed in *Common Plots* on page 61.

Options

Allows access to the processing settings so that they can be set individually for this session. See *Process Menu* on page 93 for additional information.

Override Status

Manually sets the status of the session. See *Static Solution Types* on page 86 for information. Ignore redundant or troublesome sessions. You can assign a *Good* status to a failed baseline if the solution is, in fact, correct. Only do this on closed loop networks.

Process

Processes the session independently of all others.

GrafNav/IE

Launches the baseline into GrafNav. See *Process Menu* on page 40 for additional information. information.

Delete

Deletes all of the processing files related to that session, or deletes either the forward or reverse solution.

Compute Azimuth / Distance

Displays the *Distance and Azimuth* box for the session. See *Distance & Azimuth Tool* on page 74 for help.

Show To / From Stations

Displays both stations in the *Stations* window. See *Stations Window* on page 107 for information.

Show To / From Observations

Displays both station *Observations* windows. See *Observations Window* on page 106 for information.

Expand the *Sessions* branch in *Data Objects* of the *Data Manager* to display individual sessions in the *Sessions* window.

3.6.7.5 Control / Check Points Window

The *Control / Check Points* window displays information regarding all the stations assigned known coordinates in the network.

Columns in the Control / Check Points Window**Name**

Name of the station.

Type

Type of control or check point, which can be 3D, horizontal or vertical.

Latitude

Known latitude of the station.

Longitude

Known longitude of the station.

EllHgt

Known ellipsoidal height of the station.

HzSD

Standard deviation of the known horizontal coordinates. Applies only to 3D and horizontal control points.

VtSD

Standard deviation of the known vertical coordinate. Applies only to 3D and vertical control points.

dE

Easting residual between input coordinate and traverse solution at check point.

dN

Northing residual between input coordinate and traverse solution at check point

dH

Height residual between input coordinate and traverse solution at check point

Right-click Options in the Control / Check Points Window

The following options are available by right-clicking on a control or check point:

View Info

Displays the *Information* box for the point.

Edit

Allows for editing of known coordinates via the *Add / Edit Control Point* window.

Toggle between Control / Check

Switches status between control point and check point.

Show Station

Displays the station in the *Stations* window. See *Stations Window* on page 107 for information.

Expanding the Control or Check Points branches in the *Data Objects* window on the left-hand side of the *Data Manager* allows for the points to be displayed individually in the *Control / Check Points* window.

3.6.8 Baselines Window

The *Baselines Window* displays information regarding all the sessions in the network. See *Columns in the Sessions Window* on page 109 for a description of the columns displayed and the options available by right-clicking on a session.

Expanding the *Baselines* branch in the *Data Objects* window on the left-hand side of the *Data Manager* allows for the sessions to be displayed individually according to the baseline they are expanded from. Expanding each baseline in the *Data Objects* window allows for the display of any individual session in the *Sessions* window.

Table 11: Baseline Color Legend

Color	Description
Blue	Unprocessed – Normally represents an unprocessed baseline. In some cases when processing quits prematurely, the color may remain blue. The return error message can be viewed by right-clicking the baseline in the <i>Sessions</i> window of the <i>Data Manager</i> and selecting <i>View Information</i> .
Grey	Ignored – Indicates a session that is to be ignored.
Yellow	Duplicate – Indicates a duplicate baseline, meaning that it has more than one session. Such baselines are plotted with two colors, with one being yellow. The second color represents the best solution among all the sessions for the duplicate baseline.
Red	Bad / Failed – Represents a baseline where processing failed one or more tests and is thus deemed to be bad. Right-click the baseline in the <i>Sessions</i> window of the <i>Data Manager</i> and select <i>View Information</i> to determine the problem. If you are confident that the solution is okay, the status can be changed from the <i>Sessions</i> window as well. You can control when float solutions pass via the <i>Solution</i> tab under <i>Options Preferences</i> .
Green	Success – Indicates a session that has passed all tests.

3.7 Tools Menu

See *Tools Menu* on page 74 for information regarding the features available through this menu.

3.8 Help Menu

See *Help Menu* on page 83 for information about these features.

Chapter 4 File Formats

This chapter describes the format of the files used by GrafNav and GrafNet.

4.1 CFG File

A CFG file is a GrafNav project file. This file is written by GrafNav when creating a new project and contains all processing options used in the project. The name of the CFG file defines the name of all ASCII and binary files written by GrafNav when processing.

4.2 GNSS Data Files

The following files are produced by GrafNav's raw GNSS data conversion utility.

4.2.1 GPB File

Raw code, carrier and Doppler measurements are converted to a GPB file. These are the raw measurements required for post-processing. Also written to the GPB file is a position for each measurement epoch, date and time information and other information.

GPB files can be opened within GrafNav's *GPB Viewer*, which allows you to view the raw measurements collected and perform basic editing functions if needed. Requests for the GPB file format should be made to support@novatel.com.

4.2.2 STA File

A station file contains any decoded camera marks, antenna heights and station names. It is read automatically by GrafNav when adding a GPB file to a project. The first line of a station file should contain \$STAINFO.

The station file may have a header record. If a *Pos* record is detected, it will be imported automatically when adding the GPB file as a base station to the project. The following is a description of the header format.

Hdr

```
{
  Proj:      "Name of Project"      Field project name
  User:      "User Name"           Name of field operator
  Time:      hh:mm:ss LOCAL/GMT    Start time
  Date:      mm/dd/yyyy            Start date
  RxName:    Receiver              Receiver type
  RxSub:     Model                 Receiver sub type
  Hi:        Hi_m VERT/SLANT        Antenna height, measured vertically or slanted
  Ant:       V_Offset H_Offset "Name" Antenna info (vertical offset to phase center, horizontal distance to measurement mark, antenna model name)
  Pos:       phi lamda ht ELL/ORTHO Computed position of antenna
  Mode:      SP/DGPS/RTFL/RTFX/RTK/FIX Mode of solution (RTFL=float, RTFX=fixed, RTK=float/fixed not known, SP=single point, GPS=DGPS, FIX=known)
}
```

The following is the format for the stationary station marks:

Sta

```

{
  *ID:      "Station ID"
  *GTim:    SecOfWeek [WeekNo]      GPS Time
  UTim:     SecOfWeek [WeekNo]      UTC Time could be used instead of GTim but this is not recommended
                                         and often not supported.

  Pos:      phi lamda ht ELL/ORTHO   Computed position of antenna
  Mode:     SP/DGPS/RTFL/RTFX/RTK/FIX Mode of solution (RTFL=float, RTFX=fixed, RTK=float/fixed not
                                         known, SP=single point, DGPS=DGPS, FIX=known)

  Std:      SdE SdN SdH              Standard deviation, in metres
  Hi:       Hi_m VERT/SLANT           Antenna height, measured vertically or slanted
  Ant:       V_Offset H_Offset "Name" Antenna info (vertical offset to phase center, horizontal distance to
                                         measurement mark, antenna model name)

  OffR:     Range TrueAzimuth DH      Offset to actual point (2D range in metres, azimuth in degrees, height
                                         difference in metres)

  OffL:     DE DN DH                 Offset in local level frame, in metres
  OffB:     DX DY DZ                 Body frame offset, where X-RightWingPos, Y-ForwardPos, Z-UpPos
  Att:      roll pitch heading        Attitude, in degrees
  Desc:     "description"
  Rem:      "remarks"
  Nsv:      NumSats NumGPS
            NumGlonass
  Dop:      PDOP HDOP VDOP
  Rms:      L1Phase CACode
  Age:      Sec                      Age of last correction or RTK receipt
  Enable:   1/0
}

```



* indicates a required field.

The station file format also handles event marks. Saving a project with event marks loaded brings the event marks into the station file. The following is the event mark format.

Mrk

```

{
  *Event:    Number                  Event number or name (no spaces)
  Desc:      "Name"                  Roll name
  *GTim:     SecOfWeek [WeekNo]      GPS Time
  *UTim:     SecOfWeek [WeekNo]      UTC Time could be used instead of GTim but this is not recommended
                                         and often not supported

  Pos:      phi lamda ht ELL/ORTHO   Computed position
  Mode:     SP/DGPS/RTFL/RTFX/RTK/FIX Mode of solution (RTFL=float, RTFX=fixed, RTK=float/fixed not
                                         known, SP=single point, DGPS=DGPS, FIX=known)

  Std:      SdE SdN SdH              Standard deviation, in metres
  Vel:      VE VN VH                 Velocity, in m/s
  Att:      roll pitch heading        Attitude, in degrees
  Rem:      "remarks"
}

```

```

Nsv:   NumSats NumGPS
       NumGlonass
Dop:   PDOP HDOP VDOP
Rms:   L1Phase CACode
Age:   Sec                               Age of last correction or RTK receipt
Enable: 1/0
}

```



* indicates a required field.

4.2.3 EPP File

Waypoint's software uses a custom ASCII file format for the ephemeris records. These records are created by the *Convert Raw GNSS data to GPB* utility. Duplicate records will be automatically ignored by the software. Requests for the EPP file format should be made to support@novatel.com.

4.3 Output Files

This section discusses some of the output files created when processing with Waypoint software.

4.3.1 FML, RML, FSL and RSL Files

The Forward Message Log and Reverse Message Log files (FML and RML) contain all of the messages generated by the differential processing engine. FSL and RSL files contain all of the messages generated by the Precise Point Positioning engine. Some common messages are described here:

Reading ephemeris files...

Processing ephemeris file 'C:\GPSData\rover_.epp'

Detected 40 GpsEph, 0 GlonassEph, 0 Gpslono and 0 GpsAlmanac records

This message is generated just prior to processing. GrafNav combines all ephemeris measurements at the base and rover before processing.

Best base on BL1 is PRN 17 with 4 points and elevation of 62.1 degrees

Second best on BL1 is PRN 16 with 2 points and elevation of 51.7 degrees

This message indicates the base satellite (and its elevation) selected after a base change or at outset. The second best base is also shown. Base satellite selection is based on a point system that includes a number of factors such as elevation above the horizon and whether it is rising or falling.

Detected bad Phase measurement @ 9.1 sigma. Rms is 0.336 m (Worst Prn is 14 on B/L BL1 with residual of 0.465)

This can be caused by undetected cycle slips or noisy measurements due to a challenging GNSS signal environment. GrafNav's outlier detection routines will attempt to fix the problem by rejecting individual measurements and recomputing the residual.

+++ ARTK obtained a valid integer fix on BL BL1

Fixed 8 out of 8 satellites at a distance of 8.3 km

Residual RMS is 2.47 mm, Reliability is 3.8, Float-fix-sep. is 0.243 m

ARTK not engaged--rewind ignored

ARTK success!

Message displayed for a successful ARTK fix

Epoch rejected due to poor satellite geometry--DD_DOP of 918.0 too large

This message warns that an epoch has been rejected because of poor satellite geometry.

Doppler L1 cycle slip on PRN 24 of 1575419.57 cycles on baseline BL1

Indicates that a large change in carrier phase has been detected which is interpolated as a cycle slip.

Locktime cycle slip on PRN 4 of -5.92 cycles on baseline BL1

Cycle slip has been reported by base or remote receiver.

Inserted L1 cycle slip due to locktime reset for PRN 4 on baseline BL1

Receiver cycle slip counter reset at some time in the past but was not caught. Therefore, slip inserted now.

Less than four satellites at startup--Will try next epoch(s)

Software needs at least 4 satellites and good measurement quality at startup.

Warning: Epoch with less than 4 good satellites (Cycle slips)

This message warns about an epoch with less than 4 satellites.

Locktime cycle slip on PRN 26 of -41.31 cycles on baseline BL1**Small L2 cycle slip on PRN 26 of 0.65 cycles on baseline BL1**

Both messages warn of cycle slips on L2. The DPH is an indicator of the size of the cycle slip. It shows the difference in phase. If the data contains many L2 cycle slips, it will make for a bad ionospheric-free solution. If there are many L2 cycle slips, try using the relative ionospheric solution.

Prn 15 is below mask angle of 10.0 degrees

This message indicates that a satellite has gone below the elevation mask.

Satellite 7 is rising or re-appearing

This message is usually caused from a satellite on the horizon.

Prn 27 disappeared for 33.0 seconds on baseline BL1

Indicates that as the satellite dropped out and is reappearing, a new ambiguity will be solved.

Calculating fixed solution**Calculating RMS values**

Continuous fixed solution reliability: 7.43 (PASSED), RMS: 0.0372 m (PASSED), STD: 0.0014 m

Continuous fixed solution position is: 39 01 23.54716, -84 36 21.25817, 259.7909 m

Computing New Fixed solution

This message shows the results from the multi-satellite fixed solution. The reliability is the ratio between the second best RMS and the best RMS. The minimum reliability for a pass is 1.35. The RMS is the RMS fit of the fixed solution. This number is in metres and the maximum value to pass is 0.025 m + 1PPM for dual frequency and 0.015 + 1PPM for single frequency.

Warning: No precise ephemeris available for prn 21

Message warns that a precise ephemeris is missing for a satellite. The user may want to try another SP3 file to better the results.

\$\$\$ GPS data errors detected--will try and reject measurements, baselines or satellites

Error messages starting with \$\$\$ indicate bad carrier or code measurements encountered. The above message should be following another message indicating what residuals are out-of-range and which satellite has the largest value. The indicated satellite may not be the actual problem one because the Kalman filter distributes the errors around. A number of tests will be performed to isolate the problem data and satellite. Therefore, this message is followed by the messages shown below.

On code, worst PRN is 20, RMS is 1.46 m (PASS), reliability is 1.84 (FAIL)

A further test on the combined code-carrier solution to ensure that the code is OK.

On phase, worst PRN is 28, RMS is 0.0949 m (PASS), reliability is 1.19 (FAIL)

This test will generally indicate if a missed cycle slip to other carrier phase problem was fixed by removing a particular satellite. The above message indicates that the problem could not be fixed, and will generally be followed by a filter reset message. See below. The reliability must be greater than 4.0 to be signaled as a pass. The user

should investigate the clock offset information at this epoch via **GPBView** to see if the problematic epoch is due to an incorrectly computed clock shift.

\$\$\$ Engaging filter reset--Accuracy is severely reduced

This is printed when the filter reset is being engaged. It should be preceded by a message indicating why the filter reset was issued. A filter reset is when a cycle slip is issued to all satellites and the position is reset to startup values.

(+) ARTK engaged due to occurrence of filter reset

Following any filter reset, ARTK is re-engaged

Locktime and doppler cycle slip on PRN 30 of -307.64 cycles on baseline BL1

Indicates that a cycle slip has occurred and it has been detected by both the locktime and a large change in the carrier phase.

%%% PRN 18 was omitted for time range 488400.0-488500.0 s on ALL baselines

%%% ALL satellites were omitted for time range 8000.0-8100.0 s on baseline mast

'%%%' followed by a message indicates when and how long a baseline and/or PRN was omitted from processing.

4.3.2 FSS & RSS Files

Reported in the solution summary files is a summary of each ARTK fix and static session.

```
-----
-----
Configuration and processing settings
-----
-----
Project settings:
Master 1          : Name      GRN04-0107a      ENABLED
                  : Antenna   SIMPLE_VERT    0.000 m
                  : File      \\waypoint01\c\GPSData\Manual_
Data\GRN04.gpb    : Position  43 45 49.97515 -87 50 51.75271
198.262
Remote           : Name      Remote          ENABLED
                  : Antenna   SIMPLE_VERT    0.000 m
                  : File      \\waypoint01\c\GPSData\Manual_
Data\air_rover.gpb
                  : 0 static sessions
Direction        : FORWARD
Process Mode     : Dual frequency carrier phase
Static Initial.  : Float
Use AR           : Yes
Use Glonass      : Yes
```

The file may look different depending on whether static or kinematic processing was performed. When static processing, the output includes the final coordinates and various statistics associated with those coordinates. In kinematic processing, the ARTK summary record is the only output if ARTK resolved carrier phase ambiguities.

Following are the final coordinates that are output in a static solution. The difference between the fixed and float output is the fixed will have an RMS and reliability. The RMS represents the fit of the carrier phase measurements in the solution. The reliability is the ratio between the second best RMS and the best RMS.

```

-----
Final FIXED static position for Station STATIC, Base BL1
-----

```

```

-----
Static {
  ToSta:          "STATIC"
  FromSta:        "BL1"
  IsBest:         Yes
  AntHgt:         0.486 m

  StartTime:      6240.00 1318 01:44:00.0 04/10/2005
  EndTime:        6375.00 1318 01:46:15.0 04/10/2005
  TimeLen:        2 minutes, 15 seconds

  Latitude:       -39 00 33.18453
  Longitude:      174 10 46.74393
  EllHeight:      63.8096
  SolType:        L1L2-ARTK
  IsFixed:        Yes
  RMS:            0.0040 PASS ; m
  Reliability:    10.3 PASS ; RMS ratio

  StdDev:         0.0063 0.0068 0.0147 ; m (e,n,h)
  EcefVec:        45.4059 -48.5693 -63.9423 ; m
  EcefCov1:       2.02423923e-004
  EcefCov2:       -5.94309046e-005 4.99990537e-005
  EcefCov3:       6.87795183e-005 -1.87233603e-005 5.03819486e-005
  AvgDDDop:       3.35
  AvgPDop:        2.12
  AvgNumSats:     7.0
  Quality         1

  SlopeDist:      92.246 ; m
  HorizDist:      92.235 ; m
  SurfaceDist:    92.235 ; m
  Azimuth12:      151 42 36.21749
  Azimuth21:      331 42 35.07388
}

```

The only output from kinematic processing is the ARTK summary record as shown below. Note that if kinematic processing is used without ARTK, no output will be shown in the FSS/RSS files.

```

; ----- ARTK Results -----
Kar {
  ARTK: 1
  EngageTime:    130770.00 1802 12:19:30.0 07/21/2014
  RestoreTime:   153780.00 1802 18:43:00.0 07/21/2014
  SearchTime:    153780.00 1802 18:43:00.0 07/21/2014
  TimeSkipped:   23010.0 s
  TimeUsed:      5280.0 s PASS
  RMS:           0.5 mm PASS
  Reliability:   1.9 PASS
  FixFixSep:     0.01 m PASS
  SearchDist:    14.73 km "GPS Fixed"
}

```

```
    AvgDist:      14.73   km
    AvgSats:      9.0
    SearchSats:   10      "G07G07G07 G01 G04 G08 G11 G15 G17 G26 G28
G30"
    RestoreSats:  10      "G07G07G07 G01 G04 G08 G11 G15 G17 G26 G28
G30"
    RestoreDop:   1.5
    RestorePos:   35 30 03.14304 -117 07 12.98110 722.151
}
```

4.3.3 FG, RG, CG, FP, RP and CP files

FG, RG and CG files are created in differential processing whereas FP, RP and CP files are created in PPP. A trajectory record is written for each processed measurement epoch.

A new output binary format has been created for version 8.70 that reduces the number of trajectory files output from Inertial Explorer. For a copy of the binary structure definitions that define these files contact sup-port@novatel.com. The legacy ASCII files can be output using the *Output | Export to Waypoint Legacy Format* option.

4.3.4 FBV & RBV Files

Binary Value files contain individual satellite residuals and multi-base data which is not written to the standard output files. These files contain:

For each baseline:

- i. Code, carrier and Doppler RMS values
- ii. Code, carrier and Doppler SD values
- iii. Code and carrier phase separation values
- iv. DOP values
- v. Ambiguity drift
- vi. Effective weighting

For each satellite:

- i. PRN
- ii. Baseline
- iii. Rejection + base satellite flags
- iv. Code, carrier and Doppler residual values
- v. Code, carrier and Doppler SD values

Chapter 5 Utilities

This chapter describes the following utilities that are included with Waypoint's software:

- GPB Viewer
- Concatenate, Slice and Resample
- GNSS Data Converter

This chapter goes through each menu of their interfaces. Step-by-step instructions for first time users are also included.

5.1 GPB Viewer Overview

GPB files are in a binary format and cannot be viewed with a normal text editor. *GPBViewer* allows you to both view and edit your raw GNSS data.

5.1.1 File Menu

The following options are available on the *File* menu.

5.1.1.1 Open

Any GPB file can be opened with this feature.

5.1.1.2 Close

This feature closes the GPB file without exiting from *GPBViewer*.

5.1.1.3 Save As

If you are making modifications to a GPB file (such as the static/kinematic flag), this feature can be used to create a copy of your file prior to making any changes. An associated ephemeris file (.epf) will automatically be written when using the *Save As* feature.

5.1.1.4 Export to Waypoint Trajectory

This feature saves data from the binary GPB file into a Waypoint trajectory file.

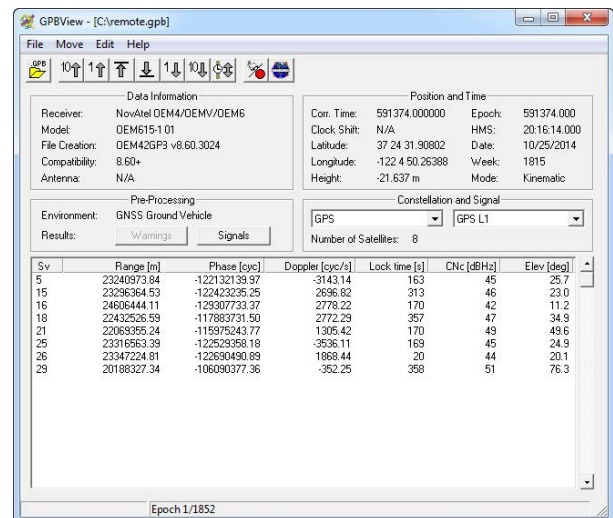
5.1.1.5 Load Alternate Ephemeris File

The GPB viewer uses ephemeris data to calculate and display satellite elevations at each epoch. If no ephemeris data was decoded, an alternate ephemeris file can be loaded here. Ephemeris data is required when performing certain editing functions within the GPB viewer.

GrafNav's *Download Service Data* utility can be used to download and convert GNSS broadcast ephemeris data. See *Download Service Data* on page 79 for more information.

5.1.1.6 Exit

Exits the program.



5.1.2 Move Menu

5.1.2.1 Forward n and Backward n

Scrolls through n epochs in the direction indicated.

5.1.2.2 Start of file and End of file

Moves to the first and last epoch in the file.



It is easier to scroll through the GPB file using the shortcut keys, specified under the *Move* menu beside each option.

5.1.2.3 Search

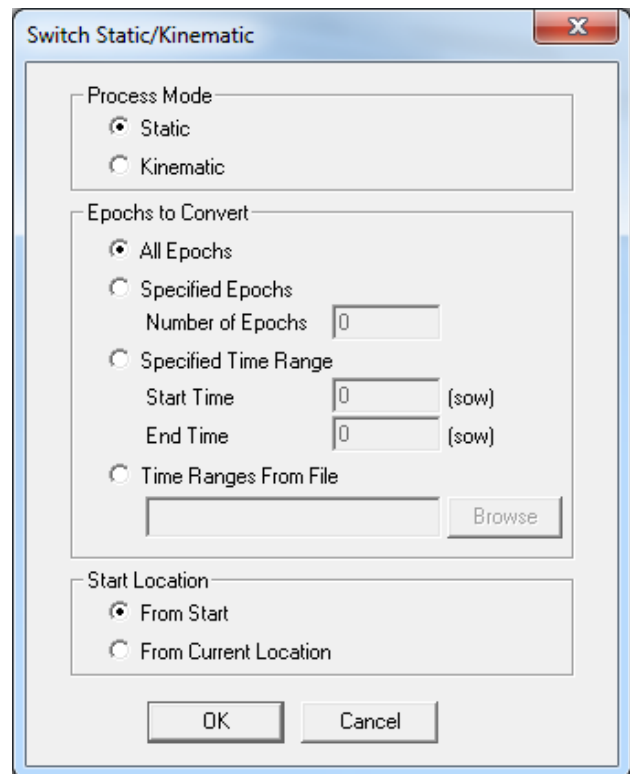
Moves to a specific location in the file. You can specify an epoch number or a time, in either GPS seconds of the week or GMT format.

5.1.3 Edit Menu

Several options under this menu make permanent changes to the GPB file. Prior to doing so, you may wish to create a copy of the original file using the *Save As* option under the *File* menu.

5.1.3.1 Switch Static/Kinematic...

GrafNav's processing mode (static or kinematic) is determined by the static/kinematic flag decoded to the GPB file. This flag is normally set during decoding, however it can be altered after decoding using this option.



The static/kinematic flag is found in the Position Information section of the GPB Viewer.

Process Mode

Specifies whether the mode is to be set to *Static* or *Kinematic*.

Epochs to Convert

Determines which epochs will be switched.

All Epochs

Switches all epochs from the start of the file onwards or from the current location onwards, depending which starting point is specified under *Start Location* options.

Number of Epochs

Converts the specified number of epochs, subject to the chosen starting point. You can also convert a specific time range that is based on GPS seconds of the week.

Specified Time Range

Converts the specified time range based on GPS seconds of the week.

Time Ranges from File

Inputting start and stop times to a text file is an efficient method of converting multiple ranges of epochs.

When converting from static to kinematic, use the following format: Start(SOW) Start(week) End(SOW) End(week).

When converting from kinematic to static, use: ID Start(SOW) Start(week) End(SOW) End (week) Description.

In both cases, do not write a header to the file.

Start Location

Use in conjunction with *All epochs* and *Specified Epochs*, under *Epochs to Convert*. Determines the starting point of the conversion.

5.1.3.2 Week Number

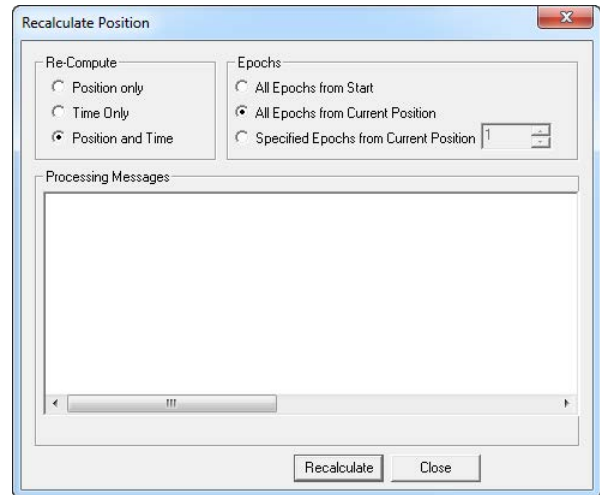
Week numbers are extracted during conversion of raw GNSS data. In the rare event that a receiver does not output a week number or outputs an incorrect week number, GrafNav may not be able to post-process the data. This issue should be addressed with the GNSS receiver manufacturer, but it can also be fixed here.



5.1.3.3 Recalculate Position and Time

If position records are requested when logging data, GrafNav's Raw GNSS Converter writes them to the GPB file. If no position records are logged, GrafNav's pre-processing functions will compute a single point C/A only solution during data conversion. This is done in order to plot the unprocessed trajectory to the Map window and, more importantly, is also used to determine whether ionospheric processing should be engaged as the average baseline distance is checked prior to processing.

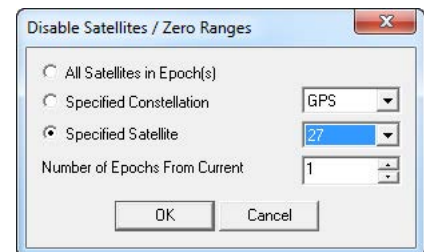
GNSS ephemeris data is required should the pre-processing functions attempt to recalculate missing position records. If neither position records nor ephemeris data were requested when logging data, no position records are written to the GPB file. If this is the case, recalculating position and clock data for a file can be done using this option. You may be required to load alternate ephemeris data (*File | Load Alternate Ephemeris*), should this be the reason no position data is present in your original file. See *File Menu* on page 120 for more information.



5.1.3.4 Disable Satellite(s)

Disabling satellites is normally done within the *Satellite/Baseline Omissions* section of GrafNav's processing options. See *Satellite/Baseline Omissions* on page 43 for more information. This is the recommended method of ignoring satellite data, however in rare cases a bad satellite may be causing other problems in the data such as a grossly erroneously computed clockshift value. In this case, it may be necessary to disable the satellite in the GPBViewer and then recompute the clockshift.

Disabling a satellite through the GPB viewer cannot be undone, unless a copy of the original GPB file was saved using *File | Save As*, or by re-decoding the raw GNSS data.



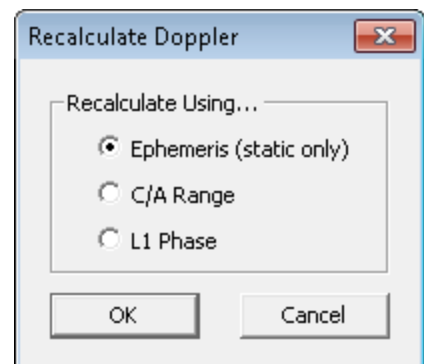
5.1.3.5 Recalculate Doppler

Missing or erroneous Doppler measurements are normally fixed automatically by the converter's pre-processing functions. Therefore recalculating Doppler from the GPB Viewer is not a commonly needed function. Prior to version 8.40, when pre-processing functions were introduced, this feature was more commonly needed.

5.1.3.6 Edit GPS L2C Phase Correction

L2C measurements are affected by an offset relative to L2 P/Y signals. This offset is dependent not only upon the manufacturer of your GNSS receiver, but also the firmware version used. GrafNav's raw GNSS converter applies a default L2C offset for each supported data type, however this may need to be adjusted for your specific receiver.

The correct L2C offset is needed in order to correctly resolve integer carrier phase ambiguities. If the incorrect L2C offset is applied, integer ambiguity resolution will fail even in ideal conditions. That is, even with a short distance between base and remote antenna, low multipath and unobstructed tracking of all available GNSS satellites, correct ambiguity resolution becomes impossible.



GrafNav's RINEX converter applies a default L2C offset of 0 cycles, as it is common for receiver manufacturers to remove the L2C offset during conversion to RINEX. If this is the case, measurements will be decoded as L2C (due to a flag set within the raw GNSS data), however the correction needs to be zeroed as it has already been removed by third party software.

If converting RINEX data that is known to contain a non-zero L2C offset, or any receiver which requires a different L2C offset than is applied by default, the correct value can be entered either during conversion (see the receivers global conversion options) or after conversion using this feature. There are four possible L2C offset values regardless of receiver manufacturer or firmware version: -0.25, 0.25, 0.5 or 0.

5.2 Concatenate, Slice and Resample Files

This utility is available from *File | GPB Utilities*. This utility can be used to:

- Combine multiple GPB files from the same receiver into one. This could be used to combine multiple hourly observations into a larger file prior to processing.
- Resample static data to a higher interval (1 Hz to 10 Hz), or reduce the sampling rate of any file (static or kinematic) to a lower rate (10 Hz to 1 Hz).
- Produce multiple time sliced output files from one larger file (e.g. produce 24 individual hourly files from a single 24 hour file).

5.2.1 Input Files

Use the *Add* button to locate the input GPB file(s). To concatenate several files, add them all at once as they will be automatically sorted chronologically.

5.2.2 Output File(s)

Determines how the creation and naming of new files is handled. For concatenating files, use the *Combine all Input Files into one file* option and provide a name for the output GPB file. For resampling or splicing multiple files, use the *Process Input Files individually* option. The name of the created output files depend on the name of their respective input file and the suffix that is specified. To break up a file into multiple files of n minutes, enable the *Break up input files into time sliced output files* option.

5.2.3 Time Interval Options

Copy each epoch

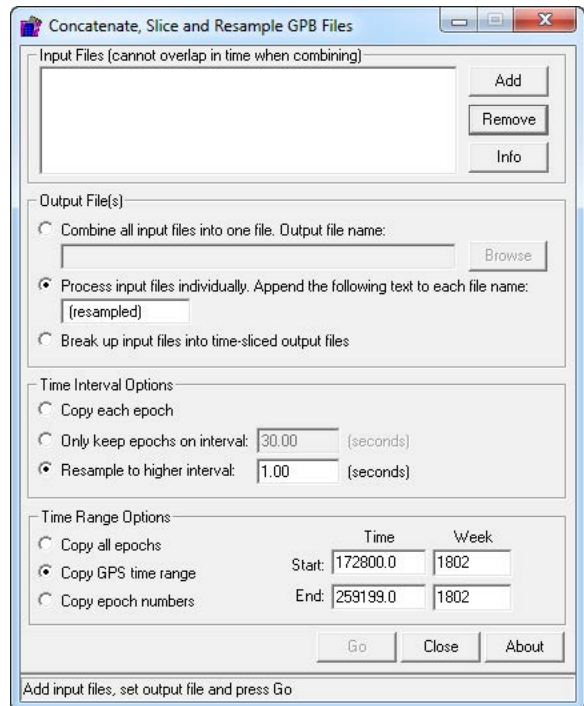
Select this if the data rate of the output file is to match that of the input file.

Only keep epochs on interval

Use this when a file is resampled to a lower data rate. The interval specified determines which epochs are copied into the output file.

Resample to higher interval

Use this when a file is resampled to a higher data rate.





Resampling can only be performed on static data.

5.2.4 Time Range Options

Determines the range of time that is to be used for the creation of the new file. *Copy all epochs* is generally for resampling purposes. Splicing a file requires the selection of either *Copy Time Range* or *Copy Epoch Numbers*.

5.3 GNSS Data Converter Overview

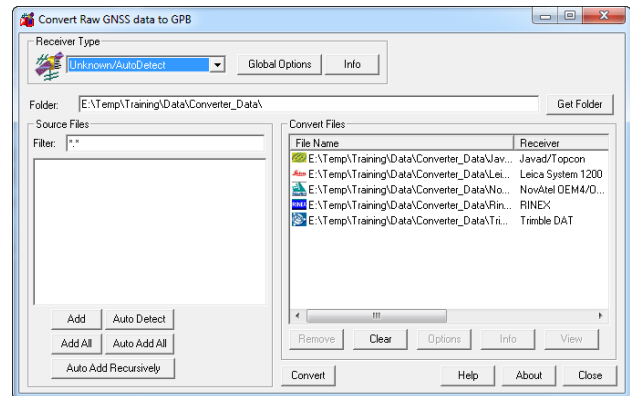
This utility converts raw GNSS data into GPB format. Supported receiver formats are documented in *Supported Data Formats* on page 127.

5.3.1 Convert Raw GNSS data to GPB

5.3.1.1 Receiver Type

Choosing a receiver type prior to conversion applies a file filter commonly associated with the receiver type. This causes only files with these extensions to be listed under *Source Files* within the current folder. You may add or modify the default filter for any receiver type.

After pointing to the folder containing GNSS data to be converted, it is generally recommended to leave the receiver type as *Unknown/AutoDetect* and use either the *Auto Add All* or *Auto Add Recursively* functions.



Global Options

To view decoding options for individual receiver types, choose the receiver type from the pull down menu and then select *Global Options*. Any changes made to the global options are remembered and applied in the future.

You may wish to access the global options of a particular receiver in order to change the static/kinematic decoding preference or the default L2C offset.

Info

Provides information on the version and status of the DLL file used for the conversion.

5.3.1.2 Folder

Use the *Get Folder* button to browse to a folder containing raw GNSS data.

5.3.1.3 Source Files

Lists the files in the folder with extensions matching those specified in the *Filter* field.

Add

When clicking *Add* after selecting an individual file under *Source files*, the converter attempts to auto-detect the receiver type if it has been left as *Unknown/AutoDetect*. If auto-detection succeeds, the file is added under the *Convert Files* section.

Add All

If a receiver type has been chosen from the pull down menu, all files are added for conversion under this receiver type. If *Unknown/AutoDetect* is selected as the receiver type, an auto-detection is performed on

every file in the *Source Files* list.

Auto Detect

Auto-detects the selected file in the *Source Files* window for conversion.

Auto Add All

Auto-detects all the files in the *Source Files* list for conversion.

Auto Add Recursively

Auto-detects all files in the immediate folder and its subfolders. The maximum number of files that can be added is 256.

5.3.1.4 Convert Files

This lists all the files to be converted. The icon displayed to the left of the filename indicates the detected receiver type. Once the files have been converted, the icon changes to either a green check mark if conversion succeeds or a red X if conversion fails. Options available here including the following:

Remove

Removes the selected file from the *Convert Files* window.

Clear

Removes all files from the *Convert Files* window.

Options

Displays the options associated with the receiver type of the selected file. Any changes are only applied to the selected file and will not be retained.

Info

Displays the file path, receiver type and conversion status of the selected file.

View

Opens the converted GPB file within the GPB Viewer.

5.3.2 Pre-processing Checks

After conversion to GPB, pre-processing checks are performed in order to help ensure the file is ready for post-processing. Functions performed by the pre-processing checks include:

- Ensuring positions are present in the GPB file. If no position records have been requested during data logging, pre-processing computes a code only single point solution. This computed position is then written to the GPB file. GrafNav uses this position to display the unprocessed trajectory and determine whether ionospheric processing will be automatically engaged. The latter option depends on the scanned baseline distance prior to processing.
- Ensuring an accurate clock shift has been decoded to the GPB file. This is needed in order for GrafNav to correctly process and export results relative to GPS time. If this value is incorrect by a large amount it can result in gross processing errors.
- Automatic rejection of impossibly large or small pseudorange observations, which can occur due to unusual receiver signal tracking issues. Also automatically rejected are any duplicate PRN numbers (which will cause a processing failure), duplicate epochs and other unusual raw data problems.
- Computing missing Doppler measurements. A common issue with some RINEX data is that Doppler measurements are provided as 0 for the entire file. As GrafNav uses Doppler for cycle slip detection, this would result in large processing errors if it is uncorrected. Pre-processing checks ensure any missing Doppler measurements are recomputed from the C/A code.

- Static/Kinematic detection. The pre-processing checks attempt to set the static/kinematic flag appropriately. For surveys with significant position changes from epoch to epoch (such as would be the case for a kinematic survey) data is converted as *kinematic*. Conversely, if no significant movement is detected from epoch to epoch, portions of the data may be converted as *static*. The ability of the pre-processing check to reliably detect static data largely depends on the noise level of the unprocessed (or computed) position data.
- Processing environment detection. The unprocessed position records are scanned in order to determine if the dynamics are characteristic of aerial, ground vehicle or marine surveys. The detected environment is written to the header of the GPB file, which allows GrafNav to automatically load an appropriate processing profile (*GNSS Airborne*, *GNSS Ground Vehicle*, or *GNSS Marine*) the first time the processing dialog is accessed for a project.

5.3.3 Supported Data Formats

This section discusses the data formats that are currently supported by the *Raw GNSS Data to GPB* converter. This information includes the conversion options and supported records.

5.3.3.1 Javad and Topcon

The following describes the options available for this converter:

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Use locktime records for cycle slip detection

Locktimes from the Javad receiver are used instead of those computed by the decoder. Enable this if Javad locktimes are problematic.

Decode epochs with bad checksums

If disabled, epochs containing records with failed checksums will not be decoded. Otherwise, only the affected data is ignored.

Use SAVE marker to store sites to .sta file

Markers are saved to an STA file.

Verbose messaging mode

Alerts you of warnings and errors that have occurred.

L2C phase correction

If your receiver logs L2C measurements, then the phase offset must be entered. If you are unsure, you can disable its usage.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

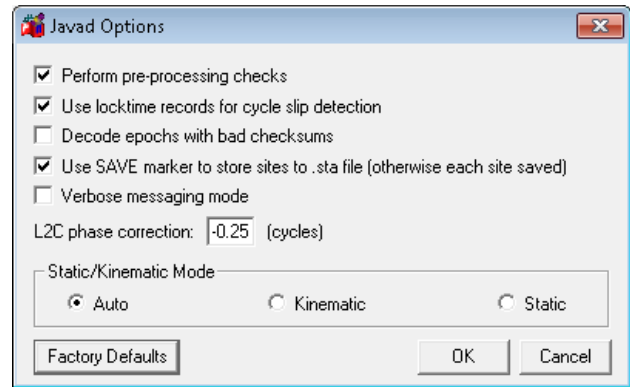


Table 12: Records Supported for Javad and Topcon

Record	Type	Comment
RC, rc	C/A Code Measurement Block	One of these is required, RC suggested.
1R	L1 P-Code Measurement Block	
3R	L2 C/A Code Measurement Block	
R2, r2, 2R, 2r	L2 P-Code Measurement Block	2R suggested.
PC, pc, CP, cp	L1 Phase Measurement Block	CP suggested.
P2, p2, 2P, 2p	L2 Phase Measurement Block	2P suggested.
3P, 3p	L2C Phase Measurement Block	
DC	L1 Doppler Measurements	Recommended.
GE	GPS Ephemeris	Required.
NE	GLONASS Ephemeris	Required for GLONASS users.
TO	Clock Offset	
TC	Locktime	

Record	Type	Comment
PO	Position	Recommended.
SI	PRN List	Required.
RD	Receiver Date	Required.
--	Receiver Time	Required.

5.3.3.2 Leica System 500

This decoder handles data from the System 500 or SR530 receivers.

The following describes the options available for this converter:

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Combine multiple (.o00,.o01...) files into single GPB file

Leica SR530 receivers write all data into separate files from one session with different extensions. Enabling this option will combine files from one session into one GPB file

Verbose message information output

Alerts you of additional warnings and errors that have occurred.

Insert kinematic markers after gaps and stations

Ensures that static sessions are properly created.

Table 13: Records Supported for Leica 500

Record	Type	Comment
19	Measurements (compressed)	One of these records is required; record #20 is needed if Doppler data is of interest.
20	Measurements (expanded)	
15	Ephemeris	Required.
10	Position	Recommended for GrafNet users.
13	Station/Event Mark	Written to STA file.
9	Antenna Height	Written to STA file.
108	Antenna Type	Written to STA file.

5.3.3.3 Leica System 1200

The following describes the options available for this converter:

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Combine multiple observation files

Leica receivers write data into separate files from one session with different extensions. This option combines files from one session into one GPB file

Break multiple observations into separate GPB files (requires 5 minute data gap)

If you have logged data from multiple sessions and/or days, enable this option to create a separate GPB file for each.

Verbose message mode

Alerts you of additional warnings and errors that have occurred.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

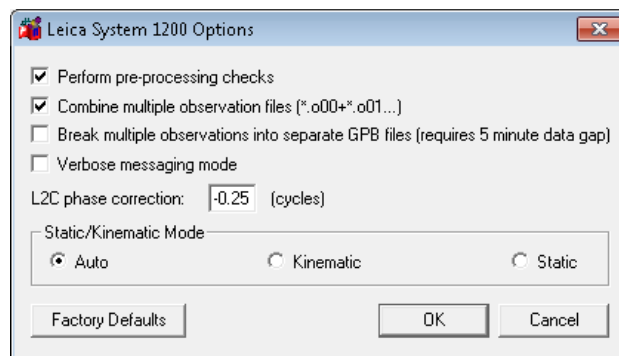


Table 14: Records Supported for Leica 1200

Record	Type	Comment
119	Measurements	One of these records is required, but #120 is recommended
120	Measurements	
115	Ephemeris	Required.
110	Position	Recommended for GrafNet users.
109	Antenna Height	Written to STA file.
113	Event Mark	Written to STA file.

5.3.3.4 NavCom

The following describes the options available for this converter:

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Verbose messaging mode

Allows you to see additional warning messages.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

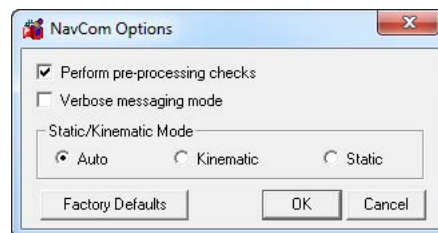


Table 15: Records Supported for NavCom

Record	Type	Comment
0xB0	Measurements	Required.
0x81	Ephemeris	Required.
0xB1	Position	Recommended for GrafNet users.
0xB4	Event Marker	Written to STA file.

5.3.3.5 NavCom Sapphire

The following describes the options available for this converter:

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Verbose messaging

Alerts you of additional warnings and errors that have occurred.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

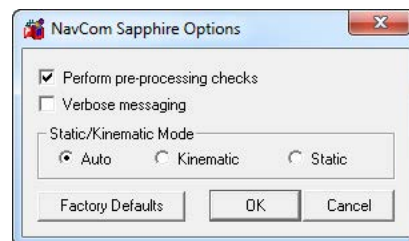


Table 16: Records Supported for NavCom Sapphire

Record	Type	Comment
MEAS1B	Measurements	Required.
EPHEM1B	Ephemeris	Required.
ALM1B	Almanacs	Required for GLONASS users.
PVT1B	Position	Recommended for GrafNet users.

5.3.3.6 BAE Systems / NovAtel CMC

This decoder handles data from the NovAtel CMC AllStar and SuperStar receivers.

The following describes the options available for this converter:

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Verbose messaging mode

Displays additional warning messages.

Reject satellites with low C/N0

Satellites with C/N0 values below the specified threshold will not be decoded.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

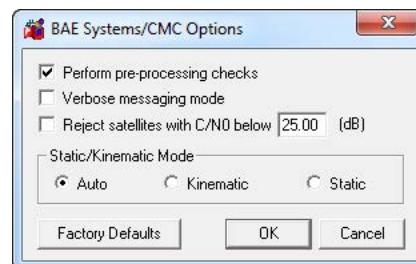


Table 17: Records Supported for BAE Systems / NovAtel CMC

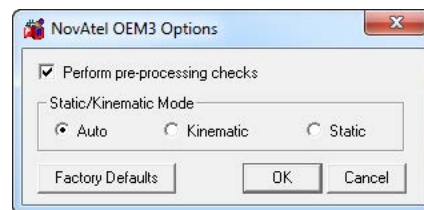
Record	Type	Comment
ID #23	Measurements	One of these records is required, but ID #23 is strongly recommended over the others.
ID #13	Measurements (old style)	
ID #14	Measurements (old style)	
ID #15	Measurements (old style)	
ID #16	Measurements (old style)	
ID #20	Position	Recommended for GrafNet users; should be requested last.
ID #22	Ephemeris	Required.

5.3.3.7 NovAtel OEM3

The following describes the options available for this converter:

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.



Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

Table 18: Records and Files Supported for NovAtel OEM3

Record/File	Type	Comment
RGEB (ID #32)	Measurements (expanded)	One of these records is required, but RGED is recommended.
RGEC (ID #33)	Measurements (compressed)	
RGED (ID #65)	Measurements (compressed)	
REPB (ID #14)	Ephemeris	Required.
POSB (ID# 01)	Position	Recommended for GrafNet users.
MKTB (ID# 04)	Event Mark (time only)	Written to STA file.
MKPB (ID # 05)	Event Mark (time and position)	Written to STA file.
CLKB (ID# 02)	Clock Information	See Notes .

Notes

1. If using receivers with standard correlators, you should either request the CLKB record, or else re-calculate the position and clock information. The clock correction (offset) is needed for processing. This record is also suggested for users logging data right from power-up. Request the CLKB record before the measurement record.
2. Ensure that the baud rate is set high enough to properly handle 12 channels worth of measurement records, as well any additional records.
3. The GPS/GLONASS MiLLennium receiver has 24 channels.
4. Log MKTB or MKPB, but not both.

5.3.3.8 NovAtel OEM / SPAN

The following describes the options available for this converter:

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Decode RANGE_1B log

This is applicable only to SAASM receivers.

Verbose messaging mode

Displays additional warning messages.

Create separate file for each MARKNTIME record

Enabling this option decodes the event marks from multiple inputs into separate station files.

Create trajectory file (*.fsp) from following record

This option generates a separate FSP file for each supported position record that is logged. The files can be used to compare against the post-processed solution.

Ignore clock model status for MARKNTIME records

Decode MARKNTIME records regardless of clock model status. This option may be useful for indoor surveys with little GNSS.

L2C phase correction

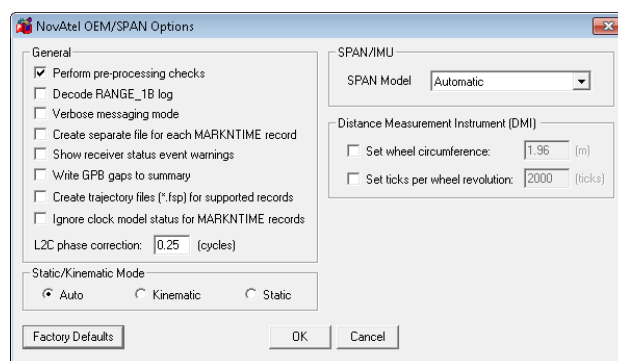
This correction value is inserted into the GPB header and can be used by the post-processing engine. OEMV firmware versions 3.0 and 3.1 use a correction of 0.50, while firmware versions 3.2 and later will use either -0.25 or 0.00. Generally, this value should occur on the $\frac{1}{4}$ cycle.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

SPAN/IMU and Distance Measurement Instrument (DMI)

These options are only for users of NovAtel's SPAN Technology and is only available in Inertial Explorer.



Logging data

See the *SPAN Data Logging for Inertial Explorer* application note (available at www.novatel.com/assets/Documents/Bulletins/APN-076-SPANLoggingEI8.7.pdf) for detailed instructions and examples for data logging.

Table 19: Records Supported for NovAtel OEM/SPAN below contains a full list of supported records, both for GNSS only and GNSS+INS (NovAtel SPAN) applications. Below are suggestions on how to request these logs from your NovAtel receiver or SPAN system.

Table 19: Records Supported for NovAtel OEM/SPAN

Record	Type	Comment
VERSIONB (ID #37)	Version information for all components of a system	Optional

Record	Type	Comment
RANGEB (ID #43)	Measurements (expanded)	One of these records is required. Do not request more than one as duplicate measurements will result.
RANGEB_1	Measurements (expanded)	
RANGECMPB (ID #140)	Measurements (compressed)	
RANGECMP2B (ID #1273)	Measurements (compressed)	
RAWEPHEMB (ID #41)	GPS Ephemeris	Required
GLOEPHEMERISB (ID #723)	GLONASS Ephemeris	Required if logging GLONASS data
BDSEPHemerisB (ID #1696)	BeiDou Ephemeris	Required if logging BeiDou data
GALEPHEMERISB (ID# 1122)	Galileo Ephemeris	Required if logging Galileo data
QZSSEPHemerisB (ID# 1336)	QZSS Ephemeris	Required if logging QZSS data
BESTPOSB (ID #42) RTKPOSB (ID #141) OMNIHPPOSB (ID #495) PSRPOSB (ID #47)	Position	Only required for comparison of real time trajectory to post-processed
MARKTIMEB (ID #231)	Event Mark Time	Written to STA file
MARKnTIMEB (ID #1130, 616, 1075, 1076)	Event Mark Time	Written to STA file
IONUTCB (ID #8)	Ionospheric Parameters	Optional. If present will be written to EPP file. This will be applied in single frequency processing but ignored in dual frequency processing.
RAWIMUSB (ID #325) RAWIMUSXB (ID #1462)	IMU Measurements	SPAN users only. RAWIMUSXB is recommended. Only one of these is required, do not log both as duplicate measurements will result.
BESTLEVERARMB (ID #674)	IMU to GNSS Lever Arm	SPAN users only. IMUTOANTOFFSETSB is recommended as both primary and (if applicable) secondary lever arms are logged. Lever arms must be set first through the SETIMUTOANTOFFSET and SETIMUTOANTOFFSET2 commands.
BESTLEVERARM2B (#1256)	IMU to secondary lever arm	
IMUTOANTOFFSETSB (ID #1270)	Primary and secondary lever arms	

Record	Type	Comment
BESTGPSPOSB (ID #423) BESTGNSSPOSB (ID# 1429) IMURATEPVAB (ID #1778) IMURATEPVASB (ID #1305) INSPVAB (ID #507) INSPVASB (ID #508) INSPOSB (ID #265) INSPOSSB (ID #321)	Position, velocity and attitude	Optional for SPAN users only. Can be used to compare real time and post-processed solutions.
SETIMUTYPE (ID #569)	IMU Type	Optional for SPAN users only. Recommended if RAWIMUSB is logged, not needed if RAWIMUSXB is logged.
VEHICLEBODYROTATION (ID #642)	Angular offset between vehicle frame and SPAN frame	SPAN users only. Allows vehicle body rotation to be automatically read by Inertial Explorer
MARKnPVAB (ID #1067, 1068, 1118, 1119)	Event Mark Time	Written to STA file
HEADINGB (ID #971)	Heading from dual antenna	Written to HMR file
SITEDEFB (ID #153)	Site definitions	
TIMEDWHEELDATAB (ID #622)	Odometer Measurements	SPAN users only. Written to DMR file.
WHEELSIZEB (ID #646)	Circumference of Wheel	SPAN users only. Written to DMR file.

5.3.3.9 RINEX

Receiver Independent Exchange (RINEX) data is a standard, manufacturer independent ASCII format for raw GNSS data. All GNSS manufacturers should provide tools to convert their native data to RINEX format. If your receiver type is not directly supported by GrafNav, first convert the data to RINEX using a utility supplied by the manufacturer and then import the RINEX data to GrafNav.

The following describes the options available for this converter:

General Options

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

Advanced Options

L2C phase correction

If the RINEX file contains L2C measurements, then the phase offset must be set.

Shift time to user interval

The decoder will attempt to determine the data interval by reading the header or scanning the observation file. If this fails, enable this option to force an interval.

Doppler Source

These options allow you to choose a method of obtaining Doppler measurements.

Automatic/use D1 value

Uses the D1 value, if present, from the RINEX file for Doppler. Otherwise, it uses *Calculate from CA code* for data intervals of 10 seconds or less, and *Use ephemeris (static)* for anything else.

Calculate from L1 phase

Select this option if the Doppler signal is missing or unstable.

Calculate from CA code

If the Doppler signal is missing or unstable, using the CA code will create fewer problems than using L1 phase, but velocity accuracies may be worse.

Use ephemeris (static)

Assumes static data and computes Doppler from satellite velocities.

Ephemeris

Prompt user if RINEX Nav file is missing

If a navigation file is either missing or has a different name than the observation file, you will be prompted to select a navigation file.



Use alternative ephemeris file

You may define a path to the navigation file manually. This will override the previous option.

Table 20: Files Supported for RINEX

File	Type	Comment
*.yyo, *.obs, *.rxo	Measurements	One of these files is required.
*.yyd	Measurements (compressed)	
*.yyN, *.yyp, *.nav, *.rxn	GPS Ephemeris	Required.
.yyg	GLONASS Ephemeris	Required only if logging GLONASS data.
.yyc	BeiDou Ephemeris	Required only if logging BeiDou data.



The yy in the file extensions found in the table above designate the last two digits of the year that the observations were collected in.

5.3.3.10 RTCM Version 3.0

The following describes the options available for this converter:

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Verbose messaging mode

Displays additional warning messages.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

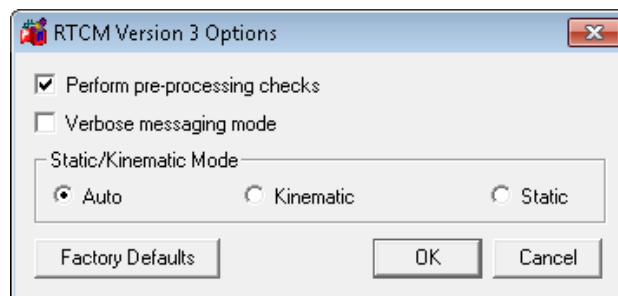


Table 21: Records Supported for RTCM Version 3.0

Record	Type	Comment
1002	L1 only measurements	One of these is required for GPS users.
1004	L1/L2 measurements	
1010	GLONASS L1 only measurements	One of these is required for GLONASS users.
1012	GLONASS L1/L2 measurements	
1013	System Parameters	Required to extract GPS week number.
1019	GPS Ephemeris	Recommended for GPS users.
1020	GLONASS Ephemeris	Recommended for GLONASS users.

The RTCM decoder has been expanded to support MSM5 and MSM7 messages, which can be used for multi-constellation operation. See *Table 22: Supported MSM Messages* below.



MSM7 messages are more precise than MSM5 messages, but are also larger.

Table 22: Supported MSM Messages

Record	Type	Comment
1075	MSM5 GPS L1 only measurements	One of these is required for GPS users.
1077	MSM7 GPS L1/L2 measurements	
1085	MSM5 GLONASS L1 only measurements	One of these is required for GLONASS users.
1087	MSM7 GLONASS L1/L2 measurements	
1095	MSM5 Galileo L1 only measurements	One of these is required for Galileo users.
1097	MSM7 Galileo L1/L2 measurements	
1115	MSM5 QZSS L1 only measurements	One of these is required for QZSS users.
1117	MSM7 QZSS L1/L2 measurements	

Record	Type	Comment
1125	MSM5 BeiDou L1 only measurements	One of these is required for BeiDou users.
1127	MSM7 BeiDou L1/L2 measurements	
1013	System Parameters	Required to extract the week number.
1019	GPS Ephemeris	Recommended for GPS users.
1020	GLONASS Ephemeris	Recommended for GLONASS users.
1042	BeiDou Ephemeris	Recommended for BeiDou users.
1044	QZSS Ephemeris	Recommended for QZSS users.
1045	Galileo F/Nav Ephemeris	Recommended for Galileo users.
1046	Galileo I/Nav Ephemeris	

5.3.3.11 Septentrio SBF

The following describes the options available for this converter:

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Verbose messaging mode

Allows you to see additional warning messages.

Extract multi-antenna data

For multi-antenna applications only.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

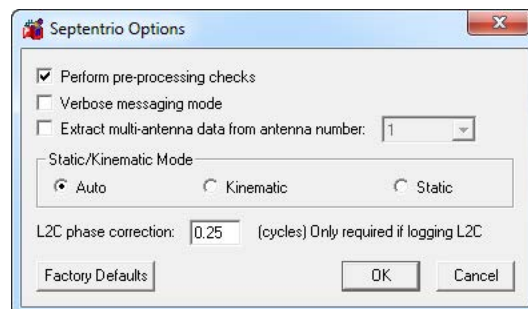


Table 23: Records Supported for Septentrio SBF

Record	Type	Comment
5889	Measurements	One of these records is required
5890	Measurements (compressed)	
5891	Ephemeris	Required
5904	Position	Recommended for GrafNet users
5924	Event	Written to STA file

5.3.3.12 Thales/Ashtech/Magellan B-File

The following describes the options available for this converter:

Thales (Ashtech) Receiver Type

Selects the receiver used to collect the data. If auto-detect does not work, then select the receiver manually.

General Options

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Detect static/kinematic from site name

Looks in B-file for data tagged as static or kinematic, using ??? site ID.

Ignore questionable L2 phase

Allows for processing of highest quality L2 data only. Should be enabled if ARTK is having difficulties.

Verbose messaging mode

Allows you to see additional warning messages.

Extract stations information from Ashtech 'D-File'

Various Thales hand-held controllers output a D-file containing features and antenna height information. Enable this checkbox to utilize this information.

Ignore SBAS Satellites

Newer versions of Thales firmware have resulted in the logging of raw data from SBAS satellites, which are not supported by the software. As such, this option should be left enabled to ensure the data is not written to the GPB file.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

UTC Options

Use the following UTC time

Changes the GPS to UTC time offset from the current nominal value to a user-defined value. Normally used for GLONASS processing if no UTC is contained in the data.

Correct GPS time in D-FILE for UTC offset

D-files can have GPS or UTC time. This option changes time from UTC to GPS.

Dfile Options

Chain Repeated Station Marks into 1 Static Session

Combines sessions that are repeated in the Seismark software into one session.

Do NOT Chain Marks that are more than n seconds apart

This value controls the time tolerance used in the previous setting. If two static periods are marked less than the amount apart, they will be combined.

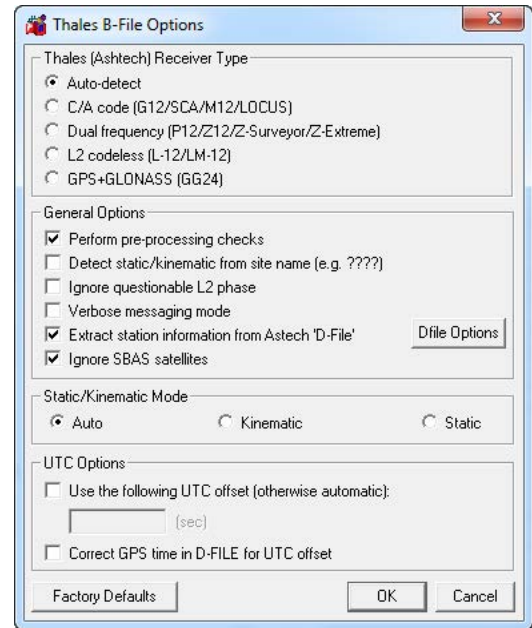


Table 24: Files Supported for Thales B-File

File	Type	Comment
BssssAyy.jjj	Measurements	Required.
EssssAyy.jjj	Ephemeris	Required.
SssssAyy.jjj	Static Station Information	Written to STA file.
DssssAyy.jjj	Kinematic Station Information	Written to STA file.
PHOTO.DAT	Event Mark	Read in directly by software.



Thales files follow a strict naming convention. In the table above, ssss is the site name, yy is the last two digits of the year, and jjj is the day of the year.



Antenna heights may need to be edited within the feature editor if not kept constant, as the Thales format only allows for one value.



You might need to select the receiver type manually.

5.3.3.13 Thales/Ashtech/Magellan Real-Time

This decoder converts Thales Real-Time (DG16, G12, or Super C/A) data. The real-time data forms when data is logged externally from the receiver using a custom data logger.

The following describes the options available for this converter:

General Options

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Decode MACM messages and ignore others

If both MBN/MCA and MACM records exist, only the MACM will be decoded.

Decode old-style MBN locktime

Some older units (for example, Sensor II) output locktimes with a different resolution. Enable this option to output the locktime value.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

Parthus MACM Settings

These settings are for logging MACM records:

Decode Parthus style MACM record

Parthus units (NS100, GSU-1, and GSU-2) utilize the MACM record. However, due to timing differences, its implementation is not compatible. Therefore, enable this option.

Data interval adjustment

The GSU-1 benefits greatly by having the correct data interval entered, while the GSU-2 is best processed using the raw time and having the base interpolated onto these times. See *Concatenate, Slice and Resample Files* on page 124 for help.

UTC Offset for GLONASS decoding

The following option is available for those users logging GLONASS measurements:

Use the following UTC offset for decoding

Allows you to define your own UTC offset rather than using the nominal or detected value. Important for GLONASS processing.

Alternate Ephemeris

Use alternate ephemeris

Enable this option if ephemeris data is missing (for example, Parthus, GSU-2) to specify an outside EPP file.

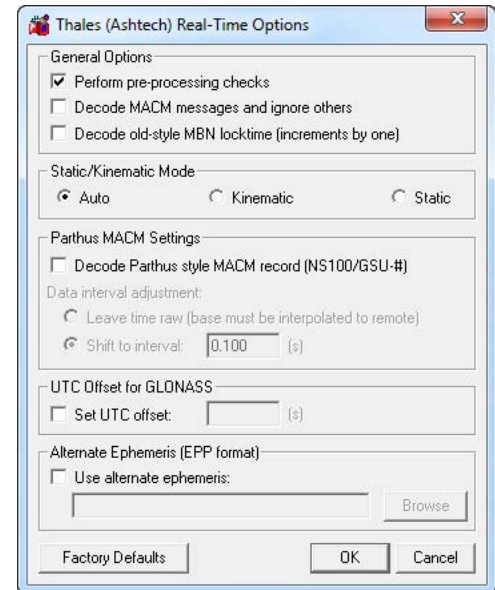


Table 25: Records Supported for Thales Real-Time

Record	Type	Comment
MBN	Measurements	One of these records is required; The MBN or MACM records are recommended for G12 receivers. The MACM record is designed for high-speed data output that is, 10Hz or 20Hz, under limited bandwidth conditions. The ITA record is for G8 receivers, while the MPC is for dual frequency receivers, such as those in the Z-series. The MCL record is an L2 codeless record.
MCA	Measurements	
MPC	Measurements	
MCL	Measurements	
MACM	Measurements	
ITA	Measurements (C/A Code Only)	
CT1	Measurements (C/A Code Only)	
CT2	Measurements (C/A Code and L1 Phase)	
CT3	Measurements (C/A Code, L1 Phase and C/A Code)	
SNV	Ephemeris	Required.
SNG	Ephemeris (GLONASS)	Required for GLONASS users.
PBN	Position	Marks the end of the record. Recommended for GrafNet users.

5.3.3.14 U-Blox

The following describes the options available for this converter:

Perform pre-processing checks

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 126 for more information.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

Verbose messaging mode

Displays additional warning messages.

Table 26: Records Supported for U-Blox

Record	Type	Comment
ID #10	Measurement	ANTARIS format
ID #15	Measurement	M8 format
ID #31	Ephemeris	ANTARIS format
ID #13	Ephemeris	M8 format
ID #02	Position	Recommended
ID #22	Clock	Recommended.
ID #3	Mark	If collecting time stamped events

APPENDIX A WPGCMD

This appendix documents the supported input parameters for the Waypoint GrafNav Command Line (WPGCMD), which is found within the *bin* sub-directory of the GrafNav installation directory. This feature is available with the purchase of a GrafNav term license.

A.1 Commands

Table 27: List of Available Commands

Command	Description
basefile#	Path to base station data file (raw or GPB)*
basetype#	Base station receiver type (NovAtel OEM6, Trimble DAT, etc)*
basecoord#	Coordinates of base station (latitude/longitude/height)*
baseant#	Base station antenna profile (using ATX format)*
baseht#	Base station antenna height*
remfile	Path to remote data file (raw or GPB)
remtype	Remote receiver type (NovAtel OEM6, Trimble DAT, etc)
remant	Remote antenna profile (using ATX format)
remht	Remote antenna height
remstatic	Convert remote in static mode
proccfg	Name of project CFG file to use for output
procmode	Processing mode (TC/ DGPS/PPP/etc)
procddata	Data processing type (C/A, L1, L1+L2)
procdir	Processing direction (both or multi-pass)
procdatum	Processing datum
procstatic	Static processing mode (float/ARTK or fixed static)
procprecise	Path to precise files (SP3/CLK)
procprofile	Name of processing profile
procglo	Turn ON/OFF the usage of GLONASS data
procmovbase	Turn ON/OFF moving baseline processing
procmovmode	Azimuth determination mode
procmovant	Distance between moving antennas
procmovantsd	Standard deviation of distance between moving antennas
procmsg	Write processing messages to disk
expprofile	Export Wizard profile
expfile	Export Wizard output file name

Command	Description
expsrc	Export Wizard source (epochs, static sessions, features)
exputmzone	UTM zone number to use for export
* This command can be used up for up to 8 base stations; use the # designator to uniquely identify the base station (# = 1...8)	



All commands must be preceded by a hyphen (-).

A.2 Base Station Commands

The following WPGCMD commands are related to the base station and therefore are only applicable if you are doing differential processing (i.e. DGPS).

Command	-basefile# [input]
Example	-basefile1 "C:\My Data\base.gpb"
Description	Specifies the location of the GNSS base station data file.
Input	Full file path to the GPB or raw data file.
Notes	If this file is not in GPB format, the command-line utility will convert it (see -basetype). Wrap the path in quotation marks if it contains spaces. The # designator must be 1...8 to uniquely identify the base station(s).
Required?	No. For differential processing, a base station file will be downloaded if this command is not present.

Command	-basetype# [input]
Example	-basetype2 GPS_LEICA1200
Description	Specifies the receiver/format used for the base station data.
Input	See <i>Table 28: List of Receiver Types (for -basetype and -remtype)</i> on the next page
Notes	Check with Waypoint Support if your receiver type is not listed here. Only applicable if the -basefile command is used. The # designator must be 1...8 to uniquely identify the base station(s).
Required?	No. If the file specified by -basefile is not already in GPB format and this command is not used, then the utility will attempt to auto-detect the receiver type. Use this command if auto-detection fails.

Command	-basecoord# [latitude] [longitude] [height]
Example	-basecoord1 36.161066211 -121.137349121 101.484
Description	Specifies the coordinates of the base station.
Input	Latitude (decimal degrees), longitude (decimal degrees), ellipsoidal height (metres)
Notes	These coordinates must be in the same datum specified by the -procdatum command. Only applicable if the -basefile command is used. The # designator must be 1...8 to uniquely identify the base station(s).
Required?	No. If the -basefile command is used but no coordinates are specified, the utility will automatically compute them using PPP.

Command	-baseht# [input]
Example	-baseht3 1.094
Description	Specifies the height of the base station antenna.
Input	Antenna height to ARP or absolute L1 phase center (metres).
Notes	This vertical height is measured relative to the coordinates passed by -basecoord. Only applicable if the -basefile and -basecoord commands are used. The # designator must be 1...8 to uniquely identify the base station(s).
Required?	No. If not used, then the coordinates specified by -basecoord will be assumed to represent the ARP if the -baseant command is set, or else the absolute L1 phase center if the -baseant command is not set.

Command	-baseant# [input]
Example	-baseant1 LEIATX1230+GNSS
Description	Specifies the antenna profile to be used at the base station.
Input	Name of the antenna profile (IGS format for absolute antenna calibrations).
	Consult the NGS or IGS website to find the proper name of your antenna's profile.
Notes	Only applicable if the -basefile and -basecoord commands are used.
	The # designator must be 1...8 to uniquely identify the base station(s).
Required?	No

Table 28: List of Receiver Types (for -basetype and -remtype)

Receiver Type	Input
NovAtel OEM/SPAN	GPS_NOVATEL_OEM4
NovAtel OEM3	GPS_NOVATEL_OEM3
NovAtel CMC	GPS_NOVATEL_CMC
Javad/Topcon	GPS_TOPCON_JAVAD
Leica System 500	GPS_LEICASR5
Leica System 1200	GPS_LEICA1200
NavCom	GPS_NAVCOM
NavCom Sapphire	GPS_NAVCOM_SAPPHIRE
RINEX	GPS_RINEX
RTCMV3	GPS_RTCM3
Septentrio	GPS_SEPTENTRIO
Thales B-File	GPS_THALES_BFILE
Thales Real-Time	GPS_THALES_REALTIME
Trimble DAT	GPS_TRIMBLE_DAT
Trimble Real-Time	GPS_TRIMBLE_REALTIME
Ublox	GPS_UBLOX

A.3 Remote Data Commands

The following WPGCMD commands are related to the remote data and are applicable to all projects.

Command	List of Receiver Types (for -basetype and -remtype)
Example	-remfile "C:\My Data\Rover.pdc"
Description	Specifies the location of GNSS remote file.
Input	Full file path to the GPB or raw data file.
Notes	If this file is not in GPB format, the command-line utility will convert it (see -remtype).
	Wrap the path in quotation marks if it contains spaces.
Required?	For NovAtel SPAN users, this file will contain GNSS, IMU and DMI (if applicable) data.
	Yes

Command	-remtype [input]
Example	-remtype [input]
Description	Specifies the receiver/format used for the remote data.
Input	See <i>Table 28: List of Receiver Types (for -basetype and -remtype)</i> on the previous page
Notes	Check with Waypoint Support if your receiver type is not listed here.
Required?	No. If the file specified by -remfile is not already in GPB format and this command is not used, then the utility will attempt to auto-detect the receiver type.
	Use this command if auto-detection fails.

Command	-remht [input]
Example	-remht 0.957
Description	Specifies the height of the remote antenna.
Input	Antenna height to ARP or absolute L1 phase center (metres).
Notes	By default, GNSS coordinates are computed at the L1 phase center. Using this command will result in a vertical shift in the computed trajectory.
	Inertial users should not pass this command (see -imula for information).
Required?	No

Command	-remant [input]
Example	-remant "ASH701941.B SCIS"
Description	Specifies the antenna calibration profile to be used for the remote.
Input	Name of the antenna profile (IGS format for absolute antenna calibrations).
Notes	Consult the NGS or IGS website to find the proper name of your antenna's profile.
Required?	No

Command	-remstatic [on/off]
Example	-remstatic on
Description	Specifies whether or not the entire file should be converted as static.
Input	on to have the entire file converted in static mode.
	off to let pre-processing checks determine the mode automatically.
Notes	This command is intended for customers performing static processing. It should be set to on if you are processing static baselines (see -procstatic) or doing static coordinate determination via PPP. It is only applicable if the remote file is being converted to GPB.
Required?	No. Default is off .

A.4 Processing Commands

The following WPGCMD commands relate to data processing and are applicable to all projects.

Command	-procmode [input]
Example	-procmode dgps
Description	Specifies the type of processing to be performed.
Input	dgps for GNSS-only differential ppp for GNSS-only Precise Point Positioning (PPP)
Notes	This command determines how the data will be processed. It also affects which commands are available for use. See <i>Table 29: List of Commands Supported for Each Processing Mode</i> on page 157.
Required?	Yes

Command	-proccfg [input]
Example	-proccfg "C:\My Data\Project.cfg"
Description	Specifies the project file to be created.
Input	Full file path and name of the CFG file to be created.
Notes	This command will be used to determine the name of the project file and all other files generated during processing.
Required?	No. If this command is not used, the project files will be given the same name as the remote data file and saved to the same folder.

Command	-procdata [input]
Example	-procdata L1L2
Description	Specifies the type of data to be processed.
Input	L1 for single frequency (L1) processing L1L2 for dual frequency (L1 & L2) processing CA for code-only (C/A) processing
Notes	Dual frequency processing is only available if L1/L2 measurements are available at the base station(s) and remote.
Required?	No. If not specified, the utility will scan the input file(s) to determine which data types are available for processing.

Command	-procdatum [input]
Example	-procdatum nad83
Description	Specifies the datum to be used for processing and output.
Input	The name of the datum.
Notes	If this command is not used, the utility will use the default datum. The default can be set via <i>Settings Preferences</i> within GrafNav or Inertial Explorer.
Required?	Only required if using -basefile and -basecoord.

Command	-procdir [input]
Example	-procdir both
Description	Specifies if data should be processed in both or multi-pass modes.
Input	both to process the data in the forward and reverse directions independently. multi to process in multi-pass mode.
Notes	both is applicable to all processing modes. multi is applicable to all modes except GNSS-only differential and LC differential.
Required?	No. The default is both .

Command	-procglo [on/off]
Example	-procglo off
Description	Specifies whether or not to use GLONASS data during processing.
Input	on to include GLONASS data during processing. off to ignore GLONASS data during processing.
Notes	Applicable to PPP users only if remote data and precise files contain GLONASS measurements. Applicable to differential users only if remote and base station data files contain GLONASS measurements.
Required?	No. By default, the utility will include GLONASS data (if available) during processing.

Command	-procprofile [input]
Example	-procprofile "SPAN Airborne (AG58)"
Description	Specifies the profile from which to load the processing settings.
Input	The name of the processing profile.
Notes	Processing profiles are loaded first and may have their settings overridden by other commands available here (i.e. -procglo).
Required?	No, but strongly recommended. If not used, the utility will attempt to detect the best profile based on the pre-processing checks performed during decoding.

Command	-procprecise [input1] [input2] ... [inputn]
Example	-procprecise "C:\My Data\COD17254.clk" "C:\My Data\COD17254.sp3"
Description	Specifies the precise clock and orbit files to use during processing.
Input	Full file paths and names of the SP3 and CLK files.
Notes	This command is mostly intended for PPP but is available to all projects. This command can read multiple input files for projects spanning more than one day.
Required?	No. If performing PPP processing and this command is not used, the utility will download the required precise files.

Command	-procstatic [input]
Example	-procstatic fixed
Description	Specifies the mode of processing to use for static data.
Input	float for float static processing. fixed for fixed static processing.
Notes	Only applicable for static data. See -remstatic for more information.
Required?	No. Default is to perform float static processing.

Command	-procmsg [on/off]
Example	-procmsg on
Description	Specifies whether or not to write all messages to disk.
Input	on to have all messages written to a file on disk (in addition to the console). off to have all messages written only to the console.
Notes	The output file name will use this convention: "<project name>_ProcMsg.log" Processing messages will always be written to the console.
Required?	No. By default, the messages will only be written to the console.

Command	-procmovbase [on/off]
Example	-procmovbase on
Description	Specifies whether or not to perform moving baseline processing
Input	on to enable moving baseline processing off to disable moving baseline processing
Notes	Only applicable when processing between two moving antennas
Required?	No. By default, moving baseline processing is disabled

Command	-procmovmode [on/off/compute/check]
Example	-procmovmode check
Description	Specifies options related to the azimuth computation between moving antennas off to disable azimuth determination on to perform azimuth determination and use distance constraint in ARTK compute to perform azimuth determination without using a distance constraint check to perform azimuth determine and only use distance constraint to re-engage ARTK if computed distance is outside tolerance
Notes	on and check are intended for applications where distance between antennas is fixed. on and check must be used in conjunction with -procmovant and -procmovantsd
Required?	No. By default, azimuth determination is set to off

Command	-procmovant [input]
Example	-procmovant 2.113
Description	Specifies the fixed distance between the two moving antennas
Input	Slope distance between the two antennas (meters)
Notes	This option is only applicable if the two antennas are mounted on the same body
Required?	Only required if -procmovmode is set to on or check

Command	-procmovantsd [input]
Example	-procmovantsd 0.04
Description	Specifies the estimated accuracy of the fixed distance between the two moving antennas
Input	Estimated error of the provided distance between the two antennas (meters)
Notes	This option is only applicable if the two antennas are mounted on the same body
Required?	Only required if -procmovmode is set to on or check

Table 29: List of Commands Supported for Each Processing Mode

	-procmode	
	DGPS	PPP
basefile#	X	
basetype#	X	
basecoord#	X	
baseant#	X	
baseht#	X	
remfile	X	X
remtype	X	X
remant	X	X
remht	X	X
remstatic	X	X
proccfg	X	X
procddata	X	X*
procdir		X
procdatum	X	X
procstatic	X	X
procprecise	X	X
procprofile	X	X
proglo	X	X
procmmsg	X	X
procmovbase	X	
procmovmode	X	
procmovant	X	
procmovantsd	X	
expprofile	X	X
expfile	X	X
expsrc	X	X
exputmzone	X	X
* PPP processing requires dual frequency carrier phase data.		

A.5 Export Commands

The following WPGCMD commands relate to the export of the final solution and are applicable to all projects.

Command	-expprofile [input]
Example	-expprofile Geographic
Description	Specifies the profile to be used when writing the formatted solution to disk.
Input	Name of the Export Wizard profile to be used.
Notes	You can use one of the software's built-in profiles or customize one through the interface.
Required?	No. If not used, no output file will be generated.

Command	-expfile [input]
Example	-expfile "C:\My Data\final_solution.txt"
Description	Specifies the name given to the output file.
Input	Full file path and name of the output file you wish to be created during the export process.
Notes	Only applicable if the -expprofile command is used. If the file already exists, it will be over-written.
Required?	No. If the -expprofile command is used but the output file name is not specified, the utility will use the project name (see -proccfg).

Command	-expsrc [input]
Example	-expsrc epochs
Description	Specifies the source to be used when generating the output file.
Input	epochs to output the trajectory at a fixed time interval. features to output data only for the loaded camera events/features. static to output data only for the static sessions.
Notes	Only applicable if the -expprofile command is used. In order to use the features option, there must be valid features/events loaded. The static option will not output solutions for any kinematic epochs.
Required?	No. If the -expprofile command is used but the output source is not specified, the utility will output in epochs mode.

Command	-exputmzone [input]
Example	-exputmzone 11
Description	Specifies the UTM zone number to be applied during export.
Input	0 to have the software automatically determine the zone number. 1...60 to force the UTM zone number to a specific value
Notes	Only applicable if the -expprofile command is used. Only applicable if the export profile contains UTM grid output variables.
Required?	No. If not specified, the software will use whichever UTM zone number was most recently used with the export profile.

A.6 General Notes

- The program returns *0* upon successful completion or *1* if an error is encountered. Note that a return value of *0* is not a guarantee of accuracy - only that the program did not encounter any serious errors. It is left to you to ensure that the final solution meets your requirements.
- If the input value for a command is a string containing spaces (i.e. file path or file name), it must be wrapped in quotation marks.
- Waypoint software contains many processing options, most of which are not available to be set via the command line. If you wish to customize the processing options, it is suggested that you create your own processing profile and pass it in using the `-procprofile` command. Processing profiles can be created within GrafNav under *Settings | Manage Profiles*.
- When downloading base station data, the utility will first search the Favorites for coordinates. If none are found, it will compute them using PPP. User-provided base station data will be processed with PPP if no coordinates are passed via the `-basecoord` command.
- You cannot load an existing project file (*.CFG) for processing.
- This utility supports the input of up to 8 base stations. However, for differential users who do not pass in their own base station data, only one base station will be downloaded. If you require more, it is recommended that you download the desired data first using the *Download Service Data* utility and then pass it in using the appropriate command.
- The commands themselves are not case-sensitive, but some inputs are (i.e. antenna profile names).
- All messages written to the console are preceded by a designator to indicate the nature of the message. See the table below for more information.

Table 30: List of Message Types

Message Designator	Description
MSG	General message; for informational purposes only
WARNING	Non-critical message; should be reviewed and addressed
ERROR	Critical message; only output if the utility cannot continue.

APPENDIX B Output Variables

Table 31: List of Output Variables

Variable	Description
Absolute ECEF-XYZ	XYZ coordinates in the Earth Centered Earth Fixed Frame which is a Cartesian frame centered at the ellipsoid origin
Antenna Height	Height of the pole or tripod above the station marker
Azimuth (1 \diamond 2)	Angle between true north and the baseline made between FROM and TO stations
Azimuth (2 \diamond 1)	Angle between true north and the baseline made between TO and FROM stations
Body Frame Acceleration - XYZ	Acceleration components in the vehicle body frame
Body Frame Velocity - XYZ	Velocity components in the vehicle body frame
Azimuth StdDev	Estimated error of the computed azimuth.
British-East, North	East and North coordinates in the British State Plane projection
C/A RMS	Root mean square of C/A code signal
Checksum (8-bit)	The absolute value calculated by using XOR, ADD, or NMEA methodology on the 8 data bits of each character in the sentence; decimal and hexadecimal formats may be selected (user will be prompted for these options after the profile is created)
Combined Scale Factor	Scale factor used by surveyors. It applies the map scale factor combined with the ellipsoidal height correction, which can be used to scale distances on the ellipsoid to the earth's surface.
Combined Standard Deviation	Combines east, north and up position standard deviations into one value. Same value is written by Write Coordinates.
Computed Azimuth	Azimuth from base antenna to remote antenna in moving baseline projects.
Convergence	Meridian convergence for the current location in the current map projection
Corrected GPS Time	GPS time corrected for receiver clock bias
Course Over Ground (Track)	Direction of travel indicated by velocity vector.
Date	Date of the epoch or feature
Description	Description of the station or feature from the STA file
Distance Error (Azimuth)	Error in the computed baseline length in moving baseline projects.
Double Difference DOP	Double Difference DOP which is approximately equivalent to PDOP ²
East, North, Height Fwd/Rev Separations	Separations between the forward and reverse solution in the east, north and height axes

Variable	Description
East, North, Height Fwd/Rev RMS	Root mean square of the separations between the forward and reverse solution in the east, north and height axes
East, North, Up Standard Deviations	Estimated east, north and up position standard deviations in the local level frame
East, North, Up Velocities	East, North and Up velocity components in the local level frame
East, North, Up Velocity Standard Deviations	Estimated east, north up velocity standard deviations in the local level frame
East, North, Up Offset Applied	When a 3-D offset is applied to camera event marks, this field can be used to verify that the proper offset is applied. This offset is oriented to local level that is, true-north.
ECEF Covariance Matrix	Estimated ECEF position covariance matrix
ECEF Vector XYZ	XYZ components of the vector between base and remote in the ECEF frame
ECEF Velocity Covariance Matrix	Estimated ECEF velocity covariance matrix
ECEF XYZ Standard Deviations	Estimated ECEF position standard deviations in the XYZ axes
ECEF XYZ Velocities	XYZ velocity components in the ECEF frame
ECEF XYZ Velocity Standard Deviations	Estimated ECEF velocity standard deviations in the XYZ axes
Ellipsoidal Height	Height above current ellipsoid; based on datum selected during processing
Ellipsoidal Height Scale Factor	Used to scale distances on the ellipsoid to the earth's surface.
End Time	End time of the static session
Error Ellipse Orientation	Orientation of the error ellipse (theta)
Error Ellipse Semi-Major	Estimated error along the semi-major axis of the error ellipse (a)
Error Ellipse Semi-Minor	Estimated error along the semi-minor axis of the error ellipse (b)
Extended Ambiguity Status	Indicates if KAR fixed the ambiguities
Field Separator	User can select what character separates each variable in a record
Float/Fixed Ambiguity Status	Indicates if carrier phase ambiguities have been fixed
Gauss Kruger-East, North	East and North coordinates in the Gauss Kruger projection
Geoidal Undulation	Height of the ellipsoid above or below the geoid
GPS Corrected Time	Exact time of measurement in the GPS time frame.
GPS Time/Date	Time of the epoch or feature; time format may be changed to user's preference
GPS Week Number	Week number for GPS data starting from January 4, 1980; Depending in the format, this week number may or may not reset after 1023
Heading Angle	Negative yaw (see IMU angle definition).
Height Difference	Vertical height difference between stations

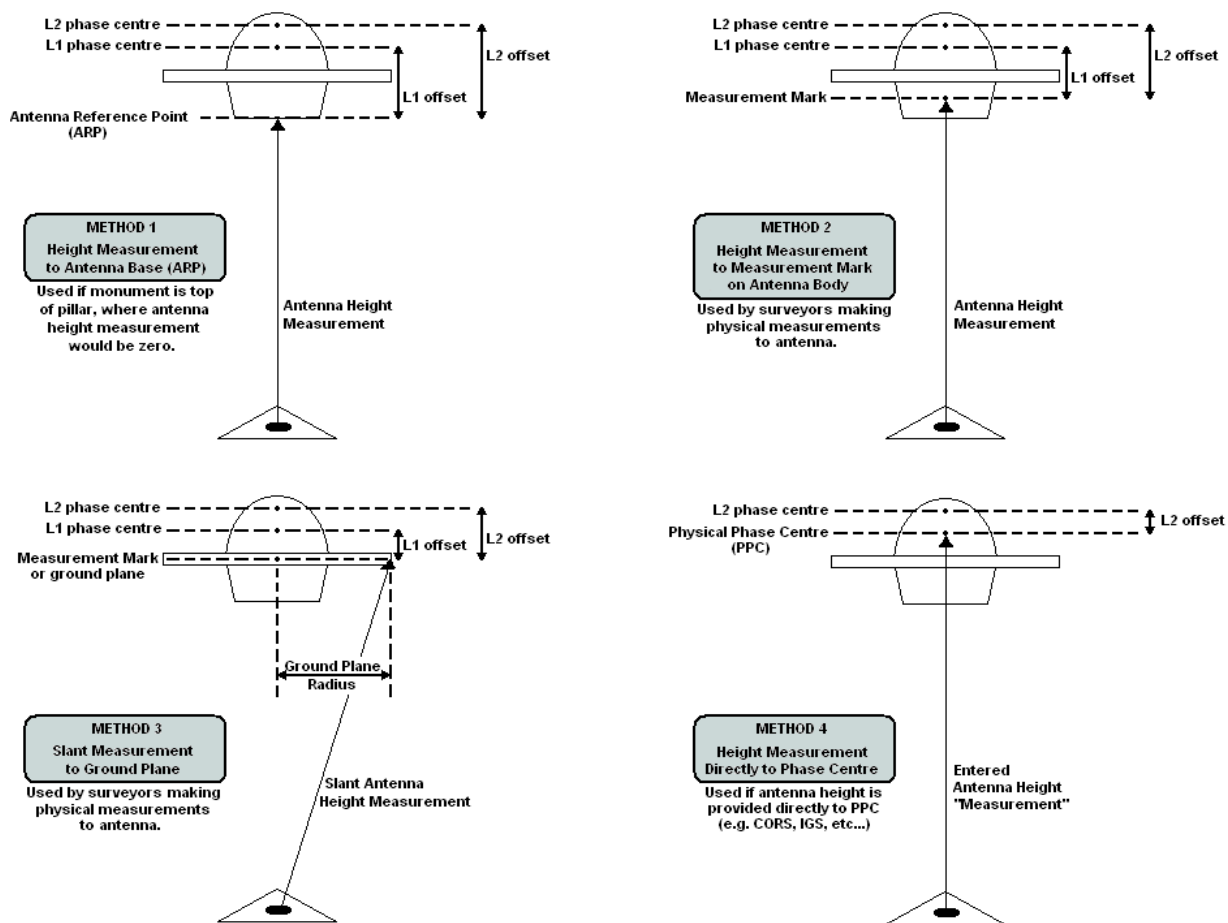
Variable	Description
Height Error Estimate	Estimated error along the vertical axis (dh)
Horizontal Distance	Horizontal distance on the ellipsoid between stations (geodesic)
Horizontal Standard Deviation	Estimated position standard deviation in the east and north axes of a local level frame
Irish-East, North	East and North coordinates in the Irish State Plane projection
L1 Doppler RMS	Root mean square of L1 Doppler signal; useful for INS integration
L1 RMS	L1, or Iono-free root mean square
Lambert-East, North	East and North coordinates in the Lambert Conformal projection
Latitude	North/South geographic coordinate
Local Level Covariance Matrix	Estimated local level position covariance matrix; needs extended output in GrafNav
Local Level Velocity Covariance Matrix	Estimated local level velocity covariance matrix; needs extended output in GrafNav
Local Level XYZ	Local level left hand side frame where the x axis is pointing east, the y axis is pointing north and the z axis is pointing up; the frame is centered at the master station
Local Plane XYZ	XYZ axes of a coordinate frame defined by two or more points (see local plane options)
Local Time/Date	GPS time and date with time-zone offset applied
Longitude	East/West geographic coordinate
Map Scale Factor	Map projection scale computed for a location
Master File Name	Name of Master GPB file
Num BEIDOU Satellites	Number of BeiDou satellites
Num Fwd+Rev or Comb Baselines	Number of baselines used in the combined solution.
Num GALILEO Satellites	Number of Galileo satellites
Num GLONASS Satellites	Number of GLONASS satellites
Num GPS Satellites	Number of GPS satellites
Num QZSS Satellites	Number of QZSS satellites
Number of Satellites	Total number of GPS and GLONASS satellites
Orthometric Height	Height above the geoid (mean sea level height)
PDOP, HDOP, VDOP	Position dilution of precision, horizontal position dilution of precision and vertical DOP. May be slightly different than values from other sources due to the differential computation
Pitch Angle	IMU pitch angle (see IMU angle definition)
Project Name	Name of current project
Quality Number	Quality factor; 1 (best) to 6 (worst)
Relative Azimuth	Azimuth between current and previous feature or epoch.

Variable	Description
Relative Height Difference	Relative height difference between current and previous epochs or features
Relative Horizontal Distance	Uncorrected horizontal distance on the ellipsoid between the current and previous epochs. Multiply by Combined Scale Factor to bring to mapping plane and surface
Relative Slope Distance	Free-air distance between neighboring epochs or features. Distance between current and previous.
Remarks	Remarks of the station or feature from the STA file
Remote File Name	Name of Remote GPB file
Roll Angle	IMU roll angle (see IMU angle definition)
Roll, Pitch, Heading Separation	The difference between the combined solutions in terms of Roll, Pitch and Heading.
Roll, Pitch, Heading StdDev	Estimated attitude accuracy.
Scale Factor	Horizontal distance ratio between the globe and the map distance for the current point in the current map projection.
Selectable Grid	Allows user to enter a north and east value for a user defined grid. Grids can be modified and added using the Grid Manager (see Tools Menu).
Sequence Number	Allows the user to number epochs in the data with a user defined start and end sequence number, as well as, an incremental value.
Slope Distance	Free air distance between stations
Solution Type	Type of solution used. In GrafNav, possible solution types include SF-Carrier, DF-Carrier, IonoFree, Rellono, CaOnly, SingPoint. In GrafNet, FixedSoln, FloatSoln.
Standard Dev. (NO PPM)	Trace of the covariance matrix expressed as a standard deviation; no distance dependent errors included.
Start Time	Start time of the static session.
State Plane-East, North	East and North coordinates in the US State Plane projection.
Static/Kinematic Status	Indicates if an epoch is static or kinematic.
Station Name	Name describing the station, feature or camera mark.
Surface Distance	Horizontal distance between the two stations on the surface (corrected geodesic).
Sun Angle	Angle of the sun above the horizon.
Time Length	Time length of the static session.
TM-East, North	East and North coordinates in the Transverse Mercator projection.
Total Slope Distance	Spatial distance between two points.
Total Horizontal Distance	The shortest path between two points on the surface of a sphere (for example, Great circle).
Transformed Grid	Allows for scaling, rotating and translating of a selectable grid.

Variable	Description
User Text String	String of text defined by user.
UTC Corrected Time	Same as UTC Time, but a correction for the receiver clock bias is applied. This is the most precise time. Only applicable for epochs.
UTC Date	Date in UTC time.
UTC Time	Time which is available in various format. This is the epochs or feature time offset from GPS seconds by the GPS-UTC time offset. This time is uncorrected for the receiver clock bias.
UTM-East, North	East and North coordinates in the Universal Transverse Mercator projection.
VSF Ellipsoidal Height	Ellipsoidal height corrected by the map scale factor.
VSF Orthometric Height	Orthometric height corrected by the map scale factor. Used in photogrammetry applications to create an elevation that is more compatible with measured ground coordinates.
XYZ Accelerometer Bias	This is the apparent output in acceleration when there is no input acceleration present. It is computed by the GNSS/INS Kalman filter and the effects may be sinusoidal or random.
XYZ Gyro Drift	This is the apparent change in angular rate over a period of time. It is computed by the GNSS/INS Kalman filter and the effects are usually random.

APPENDIX C Antenna Measurements

Figure 6: Antenna Measurements



Glossary

B

Baseline

Connection between two stations with one or more sessions. Normally, a session and a baseline can be considered the same. However, in some cases there may be more than one session per baseline. This is called a duplicate session baseline and it is plotted yellow on the screen.

C

Check Point

A station with known coordinates, but these coordinates are only used as a check against GrafNet's computed coordinates.

Control Point

See Station or GCP.

G

Ground Control Point (GCP)

A reference station with known latitude, longitude and height coordinates. The user may also assign horizontal and vertical standard deviations for these values. There can be horizontal, vertical or 3-D points, and there must always be at least one 3-D point or else one horizontal and one vertical point per project.

O

Observation

A raw measurement file collected from a receiver set up over a stationary point. GrafNet only accepts GPB files and, thus, other formats must be converted first. See the table Supported Data Formats for Post-Processing for supported formats. GrafNet also requires single frequency carrier phase data as a minimum, and accepts dual frequency if available. Users wishing to perform code-only processing should use GrafNav.

S

Session

Concurrent period of time between two observation files at two different stations. One of the two stations will be the remote and the other will be the master. The arrow on the screen will be pointing from the master to the remote. The direction is determined by GrafNet in order to form loop closures as well as to minimize the number of legs from a control point. Each session will be processed individually and combined in either a network adjustment or traverse solution. A session can have different statuses and colors depending on whether certain tests passed or failed.

Station

A point where the GPS receiver was setup over and there might be multiple observation files for a single station. However, one set of position values will be produced for each station as a final product of GrafNet. There are several types of stations.

T

Tie Point

Such a point may also be called a loop tie closure and is formed when two or more sessions point to it. Thus, there is a redundant determination at this point.

Traverse Station

This is a point with no tie or control information. It might have two stations connected to it, but one is pointing to it and the other is pointing from it.