



Carlson SurveyGNSS 2016

UserGuide v1.0.0



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1 Introduction

Carlson SurveyGNSS provides a robust post-processing environment for computing high quality vectors and resultant positions using simultaneous code and carrier phase observations of pairs of Global Navigation Satellite Systems (GNSS) receivers. Satellite constellations and signals provided by the United States NAVSTAR GPS, Russian Federation GLONASS, and various satellite based augmentation systems (SBAS) are supported using either single or dual frequency receiver equipment.

Carlson SurveyGNSS at a glance:

- Supports differential post-processing of RINEX GNSS observations in static, ‘stop and go’ and kinematic positioning modes.
- Accepts GNSS observations from any GNSS receiver in RINEX format.
- Accepts proprietary GNSS observations in the following formats:
 - Carlson **.log** and **.rw5**
 - NovAtel **.log**
 - NVS Technologies **.nvs**
 - Hemisphere GNSS **.bin**
 - Altus **.sbf**
 - Javad **.jps**
 - Sokkia **.pdc**
 - Leica **.m00, lb2**
 - Trimble **.dat, t00, t01, t02**
 - Conversion of other proprietary manufacturer formats has been externalized via shell scripts to allow users to configure and add support for command line RINEX conversion utilities.
- Provides a straightforward, workflow oriented user interface including an overview map and observation files, computed vectors, and positions presented in fully functional spreadsheet like grids.
- Incorporates a proven state of the science, highly autonomous baseline processor offering on the fly ambiguity resolution, automated cycle slip detection/removal, and more for baselines up to 200km (125mi).
- Automated search and retrieval of reference geodetic control and GNSS observations from organizations such as the US National Geodetic Survey and Continuously Operating Reference Station (CORS) networks.
- Rigorous least squares adjustment of all computed vectors.
- Seamless integration with downstream applications from Carlson and other vendors.

In spite of the popularity of real time GNSS surveys, post-processing field data is still in use for various reasons:

- As a back-up for RTK in case your data link fails (radio range).
- As a back-up when the RTK network in your area is temporarily out of order (GPRS/EDGE congestion).
- To carry out sub-centimeter geodetic surveys (i.e. deformation analysis).
- To improve the accuracy of real time single frequency GIS data.
- To have a backup for critical projects.
- As a means for Quality Control for real time surveys.

Carlson SurveyGNSS is a reliable and precise tool for all your post-processing applications.

1.1 New in SurveyGNSS 2016

- RINEX 3.x. SurveyGNSS 2016 introduces a second generation post processing engine which now accepts data in enhanced RINEX 3.x formats. In addition to other improvements, RINEX 3 accommodates observations from the Chinese Beidou, European Union Galileo, and possibly other future constellations. The post processing engine has been enhanced to be more robust when attempting to solve long “Stop+Go” (short duration) **Vectors** with few available satellites. GLONASS inter-frequency receiver biases formerly hard coded are now read from a configuration file delivered with the product as a simpler update mechanism for the rapidly expanding hardware market. This file may be found at <install path>/data/wa2.glo.
- “Active” (Online) Reference Networks. In previous releases direct embedded support of publicly accessible reference networks was limited to the Continuously Operating Reference System [CORS] of the United States. This release incorporates a protocol for the dynamic addition of many more global and national networks managed by the International GNSS Service [IGS] and the governments of Australia [ARGN], Brazil [RBMC], Canada [CACS], Germany [GREF], Spain [ERGNSS], European Union [EPN], France [RGP], Great Britain [GBOS], Mexico [RGNA], and the Netherlands [DPGA]. Additional reference network support will be added based on customer demand and protocol support. Users can view and select available reference networks via a list control shown in the **Preferences...General** tab. Command **Search...Published Observations** searches within the selected reference network.
- Detached Processing. Most if not all compute intensive tasks (RINEX conversion/validation, reference data downloads, **Vector**/VRS calculations, least squares adjustment) are now processed asynchronously, yielding control of SurveyGNSS back to the user. Asynchronous task progress is displayed and managed in the SurveyGNSS **Processes** panel, which is automatically redisplayed whenever an asynchronous process is started. For convenience the SurveyGNSS **Processes** panel also offers a context menu which offers a **Close All** command when all processes are inactive to clear it.
- Precise GNSS Space Segment Products. The use of precise ephemerides and/or global ionospheric models published by the International GNSS Service [IGS] can be enabled via check boxes added to the **Preferences...Vectors** tab. IGS publishes predicted and observed Ultrarapid, Rapid, and Final GPS Satellite Ephemerides/Satellite & Station Clocks with latencies of zero, 3-9 hours, 17-41 hours, and 12-18 days respectively. GLONASS Satellite Ephemerides are currently only available in Final form with a latency of 12-18 days. Ionospheric models are published in Rapid and Final forms with latencies of less than 24 hours and about 11 days respectively. Use of these precise space segment products can enhance **Vector** calculations for longer baselines and/or periods of active ionospheric activity (such as solar storms). Use of command **Search...Published Observations** automatically searches for and downloads available precise GNSS space segment products together with observations to the **Reference Data Relative Destination Folder** selected in **Preferences**. Command **Search...Published Space Segment** has been added to allow users to introduce such data to projects on demand.
- Observations. With the introduction of the precise GNSS space segment products, the “**Ephemeris**” column has been removed and replaced with the “**Type**” column indicating Static, Stop+Go, or Kinematic. Please consult the individual **Vector** processing transcripts for detailed information regarding specific space segment products used in a given **Vector** solution. An “**Interval**” column also shows the observational sample rate. The **Preferences...Vectors** tab has also been

modified to allow user selection of the amount of detail shown in these transcripts (**None, Brief, Detailed**).

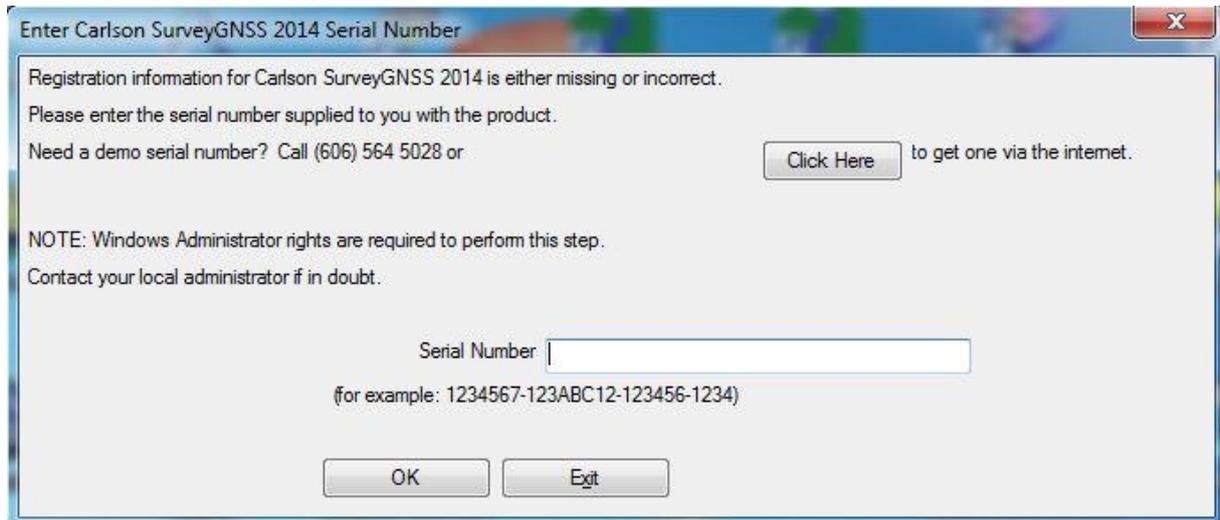
- Simultaneous Static Observations. Although the simultaneous observation duration required to achieve a fixed solution for a given **Vector** involves a rather complex combination of factors, this **Preferences** setting has been added as a coarse filter and basic criteria check for static Observations made using similar equipment and procedures in similar environments. SurveyGNSS computes and displays this criteria for candidate static **Vectors** and **GNSS Resections. Vectors** which do not meet these criteria are displayed accordingly (but not disallowed for calculation). Users are encouraged to review the computed values and compare to **Vector** solutions to adjust these values for commonly used equipment and procedures.
- Automated Static Vector Processing. For static observations typically involving multiple receivers and observation sessions, SurveyGNSS adds command **Compute...Candidate Static Vectors**. This command queries the available **Observations** and **Vectors** in the project, and displays all static **Observation** pairings which may yield a static **Vector** solution which are not already resident in the **Vectors** tab. Individual candidate rows may be selected followed by a context sensitive **Compute Vectors** command which will initiate their calculation.
- GNSS Resection. This command combines the **Search...Published Observations, Compute Vectors, and Compute...Network Adjustment** for one or more static **Observations** into one. It replicates the functionality of some non interactive online services (OPUS in US) without imposing the reference network, occupation duration, constellation restrictions, or other requirements some of these do.
- Virtual Reference Station (VRS). Optional module SurveyGNSSVRS eliminates the need for users to operate a local base receiver to be used as a basis for computing precise positions of a moving or stationary rover. In many cases where users do not wish or do not have the ability to establish a local base receiver to be used as the basis for computing precise rover positions, the distance to operating GNSS reference stations is too far for centimeter level positioning within the short observation periods typical of 'stop and go' and kinematic rovers. In such cases a user supplied local base receiver can be substituted by a Virtual Reference Station (VRS) which is computed from the observations of surrounding (actual but distant) reference stations. With this optional module SurveyGNSS can automatically compute virtual observations from the observations of at least 3 GNSS reference stations within the **Active Reference Network**, thereby creating virtual local base observations which form the basis on which to post process precise rover positions. In case of wide area stop and go or kinematic applications, the VRS must be able to both adapt to the changing position of a moving rover receiver and be kept fixed to a reference position in order to be usable as a viable post processing reference. These requirements are fulfilled by computing a semi kinematic VRS which provides optimum reference observations for a moving rover.
- Least Squares Network Adjustments. **Compute...Network Adjustment** command has been enhanced to respect user selection of a subset of the **Vectors** and associated **Positions** to consider for adjustment. **Vectors** may be selected in the usual ways or via the check boxes at the extreme left of the grid. In this way users may experiment with multiple adjustment strategies and withhold/isolate problematic **Vectors** which may require further intervention. The adjustment **Summary** report has been expanded to include the distribution and dimensional expansion factors used to compute confidence regions at the selected level. Those passing Chi-Square test of a posteriori variance apply the Normal distribution (irrespective of degrees of freedom), those failing apply the Fisher-Snedecor distribution, dependent on degrees of freedom). **File...Save Adjustment** has also been enhanced to allow posting of any selected adjustment

result from the **Reports** pane to the project (in previous versions, only the most recent adjustment result was available for posting).

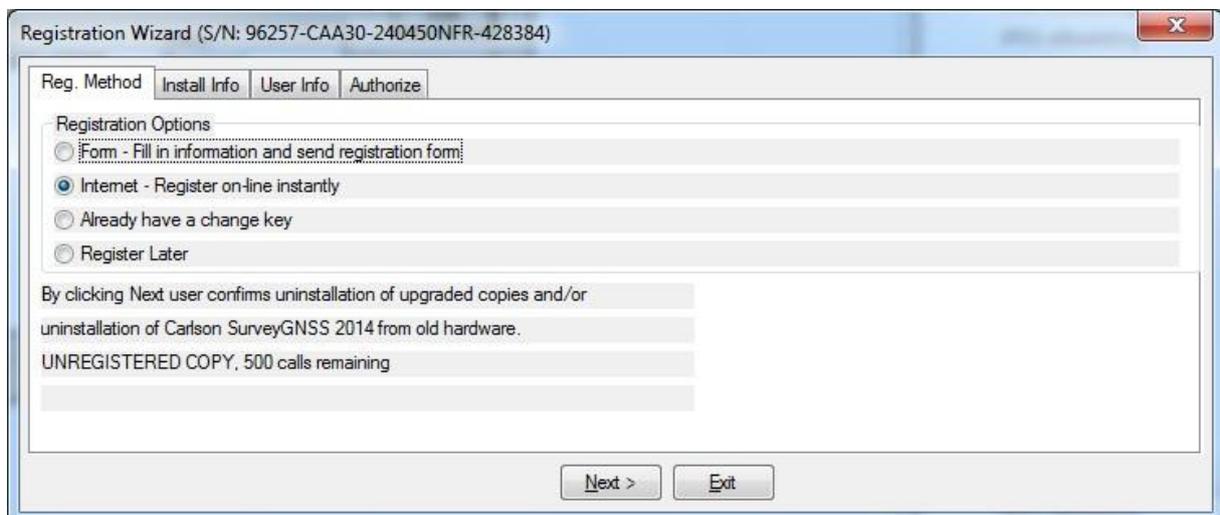
- **Vectors in .RW5.** **File...Save As Carlson .RW5** has been modified to include **Vectors** as well as **Positions**.
- **Recompute Vectors.** The **Vectors** tab context menu adds the **Compute...Vectors** commands to allow selection and recalculation of an arbitrary set of **Vectors** using different **Preferences** options. The menu bar version of these commands continue to apply to the **Observations** tab.
- **Compute...Vector(s) With Options** duration chart has been enhanced to display a rectangle indicating the time restriction associated the candidate **Vector**. It will continue to display when the form is resized. Users can continue to click-drag a different time restriction within the chart, or change the **From** and **To** times as before. Additionally they may define a **Duration** (which will compute a new **To**).
- **Edit Antenna(e).** Some receiver drivers/**RINEX** converters either fail to assign or assign incorrectly a calibrated antenna model defined in the **RINEX ANT # / TYPE** header record. If SurveyGNSS antenna phase center (APC) corrections are enabled (**Preferences...General**), this is considered an error by the post processor and vector calculation will fail. Previously users were required to **Edit...Observation Details** for each offending observation to modify this record to a known antenna model, which is typically required for precise work. Command **Edit...Antenna(e)** has been added so that users may select one or more **Observations** to conform all selected **Observations** to a given antenna model with a single command. For additional information on the status of individual manufacturer antenna calibrations and updates to the comprehensive ngs08.atx ANTEX composite absolute calibration file (delivered by SurveyGNSS to <install path>/data/ngs08.atx, please see <http://www.ngs.noaa.gov/ANTCAL/>.

2 Registration

Each Carlson program is licensed for use on one workstation which must be registered. The registration records your company name and serial number. To register your copy, install and then start Carlson SurveyGNSS. When you start the software for this first time after installation a window will pop up asking you for your serial number. The serial number consists of a 4 groups of characters separated by a dash (-).



Enter your serial number and press **OK**.



There are four registration options.

- Fax: This method allows you to print out the required information on a form which you then fax to Carlson Software. The fax number is printed on the form. The change key will be faxed back to you within 72 hours.
- Internet: Register automatically over the Internet. Your information is sent to a Carlson Software server, validated and returned in just a few seconds. If you are using a dial-up connection, please establish this connection before attempting to register.
- Enter pre-authorized change key: If you originally chose the Fax method above, you will need to choose this method now to enter the change key that is faxed back to you.

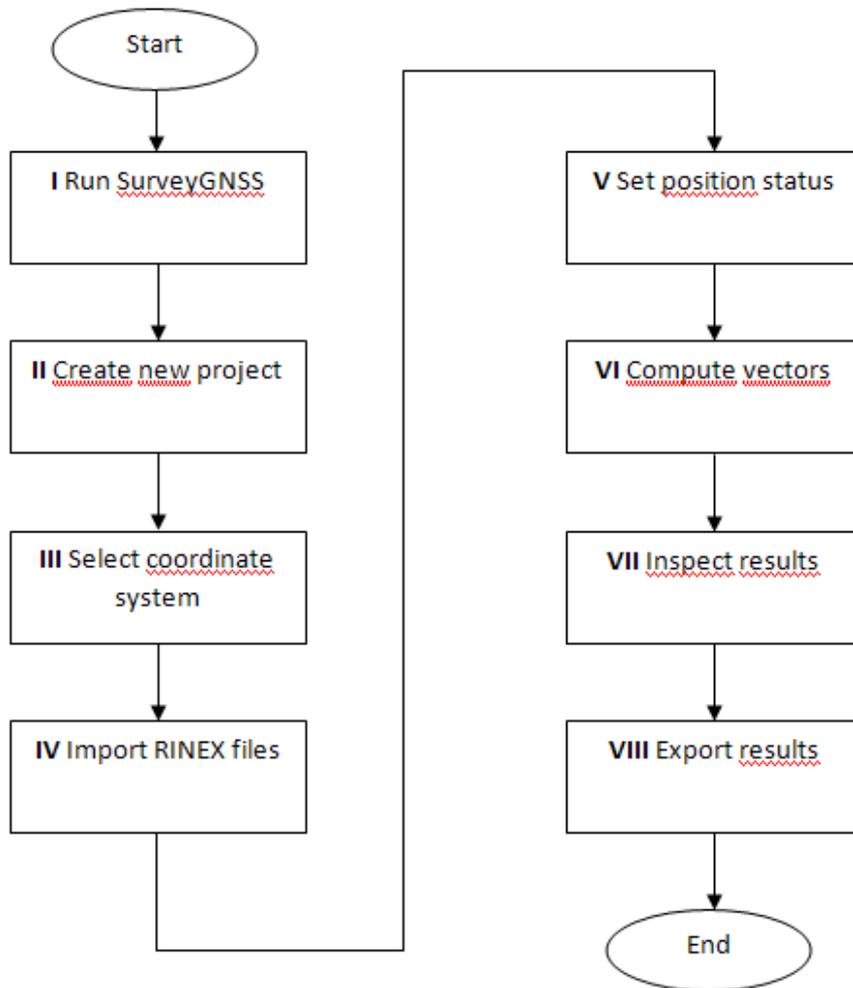
-
- Register Later: If you wish, you may defer registration up to 30 days. After this time, Carlson will enter demo mode which displays a message each time a Carlson command is run.

After you select the registration method, choose **Next** and select the type of installation you are performing, choose **Next** again to review the copyright information and to fill out the required information. At this point, if you are using the Fax method, press the Print Fax Sheet button. If you are registering using the Internet method, press Next and the process will start. The process has ended successfully when you have received your Change Key. Make sure you keep your serial number and change key in a safe place.

Tip: If Carlson SurveyGNSS is running, you may access the registration dialog by choosing **Product Registration** from the **Help** menu.

3 Carlson SurveyGNSS Workflow

The illustration below shows the general workflow for using Carlson SurveyGNSS.



See below for a further explanation.

I : Run SurveyGNSS

II : Create a new project

Go to **File** and select **Open** to create a new project. Project files have the extension '.sgp'.

III : Select a coordinate system

This is an optional step. When a coordinate system is selected, the coordinates of the site positions in the **Positions** tab will be presented in the selected coordinate system. Go to **Search** and then **Set Spatial Reference...** In the **Define Spatial Reference** window select your coordinate system. Note that you have to be on line to make this selection.

IV : Import RINEX files

To import RINEX (or proprietary) files select the **Observations** tab and drag your RINEX files from the data folder where you have stored the files onto the tab. When this is done you maybe review the sites and vectors by picking the **Map** tab. Note that all observations must be given in RINEX format (up to version 2.11) with each file containing data of a single receiver deployed.

V :Set the position status

Usually one of your stations will be the reference point for which the coordinates are kept fixed. Go to the **Positions** tab, right-click on the status icon of the reference station (by default 'Approximate') and change the position status to 'known'.

VI : Compute vectors

First select the vector to compute in the **Observations** tab by Ctrl+left-clicking on the observations. The line with the selected observation will change color. Then either right-click and select and select **Compute Vector(s)** from the menu, or select **Compute>Vectors(s)** from the main menu tab.

VII : Inspect results

Go to the **Vectors** tab to inspect the results. Newly computed vectors will be added to the list.

VIII : Export results

Go to **File>Export** on the main menu bar to export the results. By default, a text file with detailed results about the processed vector is created in the project folder. For each vector there is a separate file. The filename is a combination of the station names.

4 Conversion of Receiver Files to RINEX

SurveyGNSS support a number of proprietary GNSS receiver formats. The processing engine of SurveyGNSS works exclusively with RINEX files. RINEX is the Receiver Independent EXchange format for raw GNSS data. Therefore all proprietary GNSS files are converted into RINEX directly following the import.

The pre-defined auto-conversion to RINEX in SurveyGNSS is only possible when the conversion tool from the proprietary format to RINEX is made available by the manufacturer for free distribution. Some RINEX converters are only available to authorized users of certain manufacturers' GNSS equipment and cannot be redistributed/installed by SurveyGNSS.

Open source support has been incorporated together with additional shell scripts which support additional proprietary receiver formats. The shell scripts are redistributed in the Carlson SurveyGNSS install folder **sup\RINEX** and take the form of standard Windows batch (.bat) script files.

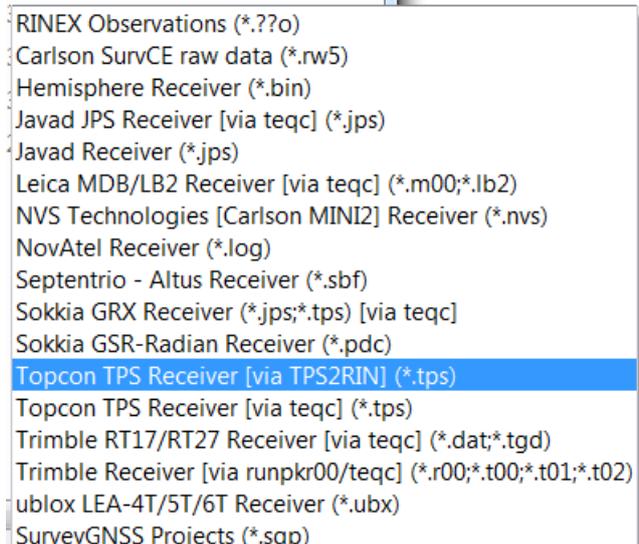
What to do if your GNSS receiver files are not in the list of supported proprietary files? If you have a RINEX converter, then you can convert your files to RINEX prior to running SurveyGNSS and then import your files as RINEX. However, to simplify the import procedure and to make the process more user friendly, you can now create a custom batch file which includes your RINEX conversion executable.

For example, if you want to use the Topcon tps2rin.exe (not distributed by Carlson, only available to Topcon customers), follow these steps:

- Go to the Carlson SurveyGNSS install folder **sup\RINEX\sample**, here you will find a number of sample files which you can edit and use.
- One of the sample files is called Topcon_sampe.bat, open this file in the Windows editor (or any other ascii file editor).
- Go to line number 41 and replace 'REM' by 'SET' and replace <PATH TO tps2rin.exe> by the folder location of your tps2rin.exe file.
- If you have your exe file stored in the folder **\tools\converter\topcon** then the modified line should look like this:

```
41 SET RINEXCommandLine="\tools\converter\topcon\tps2rin.exe" -o "%_DATAPATH:~0,-1%" %1 -e -l
```

- Save and close the editor, rename the file to Topcon.bat and copy the file from the **sample** folder to **sup\RINEX**
- The conversion from Topcon tps file to RINEX via tps2rin is now available in SurveyGNSS through **File> Open**



5 Guidelines for Evaluating Results

Whether the post-processing result is acceptable depends on the accuracy which we want to achieve, but let's assume we are aiming for cm-accuracy. The SurveyGNSS Vector view starts by listing three very basic but also very important items; baseline **Length**, **Solution** and **Quality**.

Both in case of RTK and post-processing the baseline **length** is an important factor. When the baseline length increases, the influence of the ionosphere increases as well. For longer baselines (>20km) it will be increasingly difficult to get a fixed solution and cm precision. The quality of the data (cycle slips, multi-path, PDOP, number of SVs, observation time) plays a role in this as well. The specs of geodetic GNSS receivers usually show precision values such as: 5mm+1.0ppm horizontally and 10mm+1.0ppm vertically. This means that for a 20km baselines the expected precision under good conditions will be around 2.5cm horizontally and 3.0cm vertically. These values are nothing more than an indication and require 'good conditions' but can be useful as a rule of thumb.

We should aim for either a FixedL1 **solution** for short baselines (<10km) or a ionosphere free L0 solution for longer baselines, both with 'high' Quality. Then we have an optimum cm-level result. The software will always try to compute a FixedL1 solution since this will give the most accurate result. The definition of 'short baseline' is not strict. If the quality of the data is sufficient, then baselines of 10km will be FixedL1. On the other hand if the quality is poor, baselines of just 5km will be hard to be fixed with L1 data.

For long baselines the software will produce a FixedL0 solution. If the quality of the data is high then 'long' could mean 100km or more. The result will be on the cm-level, taken into account what is mentioned above about precision in relation to baseline length.

If our solution is float (FloatDGNSS) then the software was unable to fix any ambiguities. The percentage of fixed ambiguities will be 0. The accuracy in this case will usually be on the dm-level.

When we have a fixed solution it is useful to check the percentage of Fixed Ambiguities. The higher this value the better. When our data is of high quality, this value should be well above 95%. The percentage of **Reweighted Observations** on the other hand should be as low as possible. After ambiguity fixing all the residuals in the solution are checked for outliers. The large residuals are weighted lower in the final estimation process. This value is a measure of how well the solution fits the actual data. In case of high quality data this value should be close to 0.0 .

The **pdop** value should be as low as possible. When using a modern GPS+GLONASS receiver which is tracking sufficient satellites, this value will be well below 3 or even 2. The **pdop** value can still be a useful parameter to monitor i.e. in a GNSS-hostile environment such as an urban canyon. Even while having a short baseline with a FixedL1 solution based on good quality data, the precision of our solution could be worse than expected because of the bad satellite geometry. The **pdop** will then increase to 6 or more.

Note that the standard deviation of the rover position which is also presented ($\sigma_x, \sigma_y, \sigma_z$), is only a measure of the internal precision. Very often this value is over-optimistic and should be corrected i.e. by a factor 4 or more. A better indication of the actual precision of the rover positions is by carrying out a least squares adjustment. This requires a network with sufficient redundancy.

The σ_0 **Vector** value is the standard deviation of unit weight, and is similar to the a posteriori standard error of unit weight in a network least squares adjustment. Ideally this value is 1.0. When the value is lower than 1.0 the accuracy of the solution is better than expected; the a priori accuracies were too pessimistic. When the value exceeds 1.0, the a priori accuracies were too optimistic.

When using a GPS+GLONASS receiver, the GLONASS ambiguities can only be solved when SurveyGNSS has the correct information about the antenna and receiver type. The reason is that the receiver bias depends on the satellite signal frequency. All GPS satellites transmit on the same frequency so they all create the same receiver bias. GLONASS satellites transmit on different frequencies; each GLONASS satellite generates a different receiver bias. In technical terminology GLONASS satellites cause inter-channel biases which, if not taken into account, can significantly degrade position accuracy. SurveyGNSS will take the biases into account when it has knowledge about the receiver type.

Therefore it is important that both the antenna and receiver type are listed in the RINEX header. For instance:

```
4612206760    TRIMBLE NETRS    1.3-0    REC # / TYPE / VERS
0220367016    TRM29659.00    SCIT     ANT # / TYPE
```

SurveyGNSS will identify the receiver by the a 3 letter code. i.e.:

- TRI (Trimble)
- ASH (Ashtech)
- TPS (Topcon)
- JAV (Javad)
- LEI (Leica)
- NOV (Novatel)
- SEP (Septentrio)

Full list of all receiver types used by SurveyGNSS is in the file wa2.glo in the data folder of the SurveyGNSS installation.

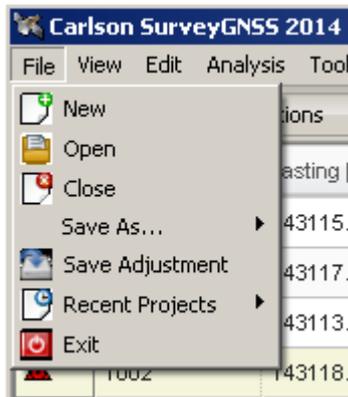
Everytime a baselines is successfully processed, a plain text log file of the processing is created (basefilename-roverfilename.txt). This file includes valuable information about the processing.

6 SurveyGNSS Main Menu

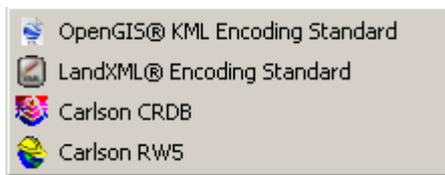
See below a description of the SurveyGNSS main menu options.

6.1 File menu

SurveyGNSS provides a logical and easy-to-use system for creating, opening and saving project files.



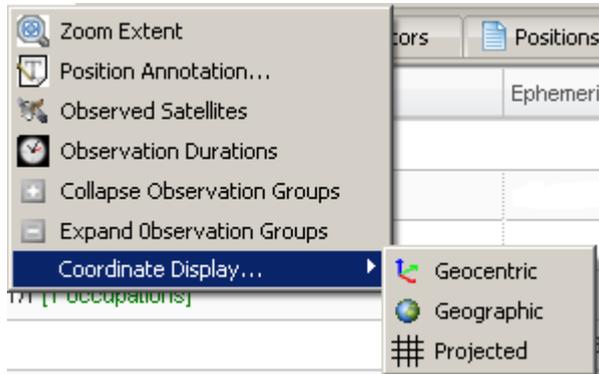
- **New** will create a new SurveyGNSS project.
- **Open** will open an existing SurveyGNSS project or when a project is already then this option can be used to add data files as an alternative to drag and drop.
- **Close** will close the current SurveyGNSS project.
- **Save As...** offers four different file formats to save your data in:



- The **KML Encoding Standard** allows you to save files in the format accepted by Google Earth, Google Maps and some of the Marble software. KML became an international standard of the Open Geospatial Consortium.
- **LandXML**
- **Carlson CRDB** is the Carlson coordinate format. This format allows alphanumeric combinations of point number and descriptions up to 255 characters in length.
- **Carlson RW5** is Carlson's raw data format. SurveyGNSS will store the station's geographic coordinates in this format. This allows for further processing of the station coordinates in other Carlson products. For instance, when you need the position of a station to be expressed in a specific (local) coordinate system or geoid which is not available in SurveyGNSS, then the RW5 format will be the exchange format to products such as Carlson SurvCE, X-port or Survey.
- **Save Adjustment** allows you to accept and the adjustment results from **Compute> Network Adjustment**.
- **Recent Projects** presents a list of projects that have recently been opened.
- **Exit** ends SurveyGNSS and exits.

6.2 View menu

The options in the **View** menu will work jointly with the four SurveyGNSS views: **Map**, **Observations**, **Vectors** and **Positions**.

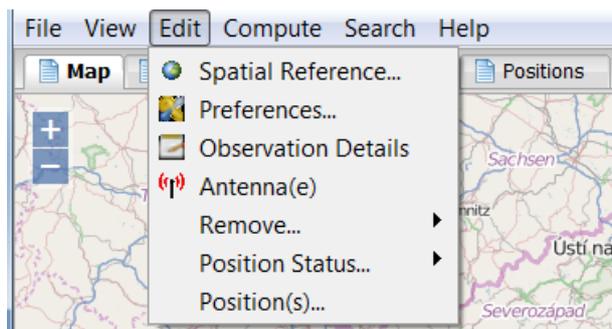


The following options are available:

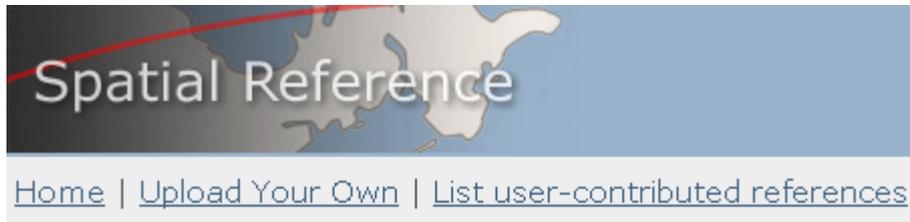
- **Zoom Extent** will activate the zoom extent in the **Map** view. This option is also available by right-clicking on the **Map** view.
- **Position Annotation...** will activate a menu that allows you to change the font, size and color of the text on the **Map** view.
- **Observed Satellites** works best in combination with the **Observations** view. This option will provide a graphical overview of the tracking of each observed satellites. This overview consist of a horizontal bar chart with each satellite observed (GPS and if available GLONASS), represented as a horizontal bar spanning the time during which the satellite was observed. Satellites are marked by their identification number. By analyzing the overview you can check on anomalies in your raw data (data gaps caused by bad tracking) that may affect the post-processing result. You can only view one file at the time.
- **Observation Durations** shows you the overlap in observation duration between stations. Only stations which have overlapping observation periods are candidates for baselines processing. Make sure you select two or more stations for which you want to evaluate the overlap.
- **Collapse Observation Groups** reduces the **Observations** view.
- **Expand Observation Groups** expands the **Observations** view.
- **Coordinate Display** allows you to change the representation of the coordinates in the **Positions** view: **Geocentric**, **Geographic** or **Projected**.

6.3 Edit Menu

The **Edit** menu offers the following options:



- **Spatial Reference...** allows you to select a coordinate system from the on line Spatial Reference List. You may use a search reference to find a suitable coordinate system and then pick it from the list. Exit with the OK button and the name of the active coordinate system will appear on the bottom right of the SurveyGNSS screen. See below an example for the available coordinate systems in Poland.



Search References:

- [SR-ORG:102](#): Poland 1942 strefa 3
- [SR-ORG:103](#): Poland 1942 strefa 4
- [SR-ORG:107](#): PND1925
- [EPSG:2171](#): Pulkovo 1942(58) / Poland zone I
- [EPSG:2172](#): Pulkovo 1942(58) / Poland zone II
- [EPSG:2173](#): Pulkovo 1942(58) / Poland zone III
- [EPSG:2174](#): Pulkovo 1942(58) / Poland zone IV
- [EPSG:2175](#): Pulkovo 1942(58) / Poland zone V
- [EPSG:2176](#): ETRS89 / Poland CS2000 zone 5
- [EPSG:2177](#): ETRS89 / Poland CS2000 zone 6
- [EPSG:2178](#): ETRS89 / Poland CS2000 zone 7
- [EPSG:2179](#): ETRS89 / Poland CS2000 zone 8
- [EPSG:2180](#): ETRS89 / Poland CS92
- [EPSG:3120](#): Pulkovo 1942(58) / Poland zone I

Once a coordinate system is active, you can review the station coordinates in the **Positions view** in the Projected Easting, Northing, Height.

Note that since SurveyGNSS release 1.0.5, support has been added for introducing datum shift/distortion grids to spatial reference definitions. Such grids provide the most accurate way to introduce datum shifts from WGS84/GRS80, and can also model distortions inherent in certain spatial references. Typical coordinate transformation accuracies are on the order of a few centimeters. When you select a coordinate system which requires a distortion grid, SurveyGNSS will notify you and prompt you to define the Datum Shift/Distortion Grid. The Datum Shift/Distortion Grid data should be in NTV2 Binary format (*.gsb), NTV1 Binary format (*.dat) or CTable Binary format (*.*) . Information and downloads for these files can be found here:

<https://trac.osgeo.org/proj/wiki>

- **Preferences** allows you to set the preferences for the processing: **General**, **Vectors** and **Adjustment**.
 - **General** includes **Data Resources** and **Reference Data**.
In **Data Resources** you can set the Gravity Model and the Antex file with the Antenna Definitions.
The default Gravity Model is the worldwide EGM2008 model in the binary GTX format. Textual Carlson geoid grid files, such as the files used by Carlson SurvCE and SurvPC, are accepted as well. Note that when this option is enabled the projected coordinates presented in the **Positions** tab are showing 'orthometric' heights.

By default two ATX files are supplied; from the NGS (National Geodetic Survey) and the IGS (International GNSS Service).

SurveyGNSS will read the antenna type and from the RINEX header. If the antenna type is not found in the current Antex ATX file, an error message is displayed and the RINEX file will not be processed. To solve this, select an ATX file which includes the proper antenna type or edit the RINEX header of your observation file; go to the **Observations** view and right-click on the observation and select **Observation Details** or **Edit Antenna(e)** (see Tutorial 4 for an example).

It is also possible to disable this option (tic **Enable** off). Note: disabling the Antenna Definition and thus not using the antenna calibration may degrade the accuracy of the processing result.

In **Reference Data** you can select a Reference Network and the search range for **Published Observations**. See the **Search** menu.

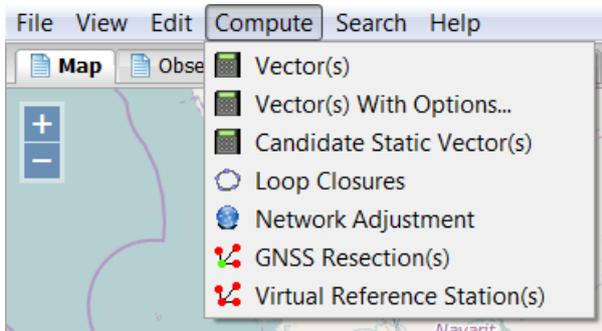
The following Reference Networks are now supported:

Continuously Operating Reference Stations [CORS]		
Network	Region ▲	Operator
 Australian Regional GNSS Network [ARGN/AuScope]-South Pacific Region	Australia and South Pacific	Geoscience Australia
 Rede Brasileira de Monitoramento Contínuo dos Sistemas GNSS [RBMC]	Brasil	Geodésia
 Canadian Active Control System [CACS]	Canada	Canadian Geodetic Survey (CGS)
 Integrierte Deutsche Geodätische Referenznetz [GREF]	Deutschland	Bundesamt für Kartographie und Geodäsie (BKG)
 International GNSS Service [IGS]	Earth	International Federation
 La Red de Estaciones Permanentes GNSS [ERGNSS]	España	Área de Geodesia
 EUREF Permanent Network [EPN]	Europe	European Federation
 IGN Réseau GNSS Permanent [RGP]	France	Service de Géodésie et de Nivellement de l'IGN (SGN)
 OS Net	Great Britain	Ordnance Survey
 Red Geodésica Nacional Activa [RGNA]	México	Instituto Nacional de Estadística, Geografía e Informática (INEGI)
 Actief GNSS Referentie Systeem [AGRS]	Netherlands	Technische Universiteit Delft
 Continuously Operating Reference Stations [CORS]	United States of America	National Geodetic Survey

- **Vectors**, see the **Compute** menu option **Vector(s) With Options...**
 - **Adjustment**. See the chapter on least squares adjustment for details.
- **Observation Details** will show more detailed information on the observation currently selection in the **Observations view**. The displayed information is based on what is available in the RINEX header. **Observation Details** also allows you to edit the station position, i.e. updating the know station coordinates.
 - **Antenna(e)** gives you immediate access to the antenna type of the selected observation.
 - **Remove** will permanently delete the selected observation or vector from the project.
 - **Position Status...** allows you to change the position of a station in the **Positions** view from **Known** to **Approximate** and vice versa.
 - **Edit Position(s)...** makes it possible to edit the coordinates of a station in the **Positions** view. This is useful when the coordinates of a point in the RINEX header are just approximate. By using the options the coordinates of a known point can be updated, whether geocentric, geographic or projected.

6.4 Compute Menu

The **Compute** menu offers the following options:

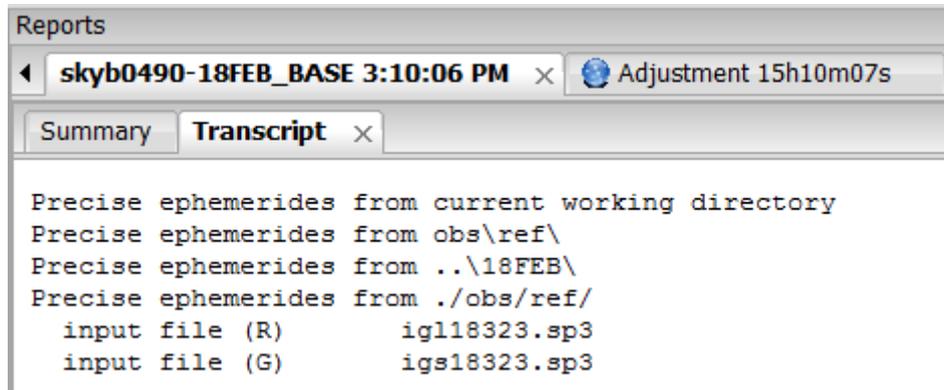


- **Vector(s)** invokes the SurveyGNSS post-processing engine. You can only select and process one vector at the time. To process multiple baselines, see **Candidate Static Vector(s)**.

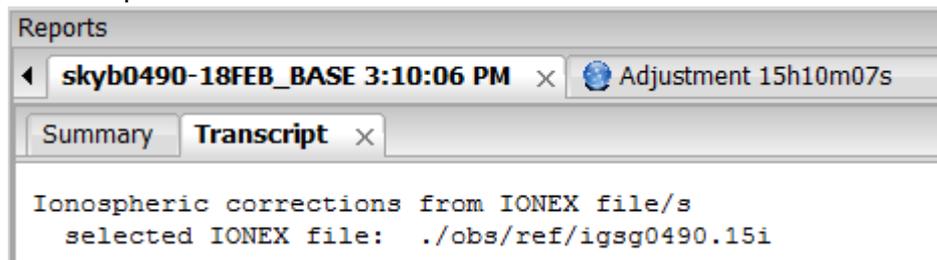
- **Vector(s) With Options...** allows you to set a number of processing parameters:

- **Use Precise Ephemeris** will automatically import a SP3 file and use the ephemeris in this file in the processing. The SP3 file is placed in the folder specified under **Edit> Preferences** (Relative Destination Folder). Note that precise ephemeris will only contribute to the solution for long baselines with an observation duration of several hours.

The transcript of the processing and the associated TXT file will confirm the use of precise ephemeris:



Use Global Ionosphere Model will automatically import an IONEX ionospheric model stored in IONEX format (extension by default '.YYi'). The file is placed in the folder specified under **Edit> Preferences** (Relative Destination Folder). The transcript of the processing and the associated TXT file will confirm the use of the ionosphere model:



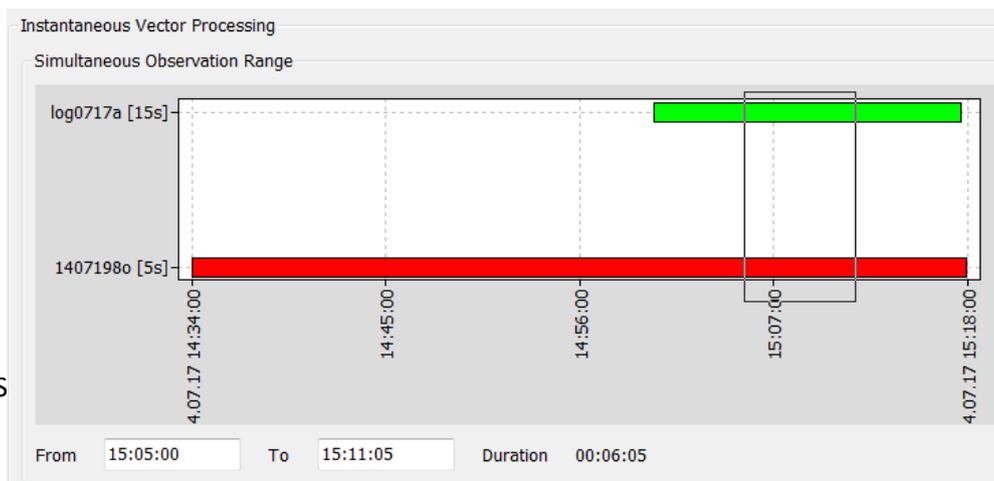
- **Transcript Content Level** controls the amount of detail shown in the transcripts which are produced after data processing. The transcripts are shown in the Report window (bottom left) and available as a plain text log file (basefilename-roverfilename.txt) in the raw data folder.
- **Elevation Mask** specifies the minimum mask angle in degrees to be used. A low angle allows the use of more satellites, but at the same time increases the potential of processing bad data (multipath effects and cycle slips). Low observations usually result in more noise. When the data is a good quality the mask should be between 10 and 15 degrees. Of course the mask value should not be lower than the mask used during data collection by the receiver.
- **Interval** specifies the processing data interval to a value greater than the interval used during recording of the data. This options can be used to synchronize the data, i.e. if the base logged at a 15 second interval and the rover at a 10 second interval, then the common inval value to be set is 30.
- **Constellations** allows you to set a GNSS constellation. SurveyGNSS will be ready to process data from new GNSS systems as soon as these become available for commercial use.
- **Frequencies** allow you to set the frequencies: **L1**, **L1+L2** and **L1+L2+L5** (depending on the L5 availability).
- **Simultaneous Static Observations** sets a minimum observation duration for vectors. The setting used in **Compute> Candidate Static Vector(s)**. The duration can be set as a constant value, or a relative value depending on the baseline length.

Simultaneous Static Observations seconds + seconds/km >= seconds

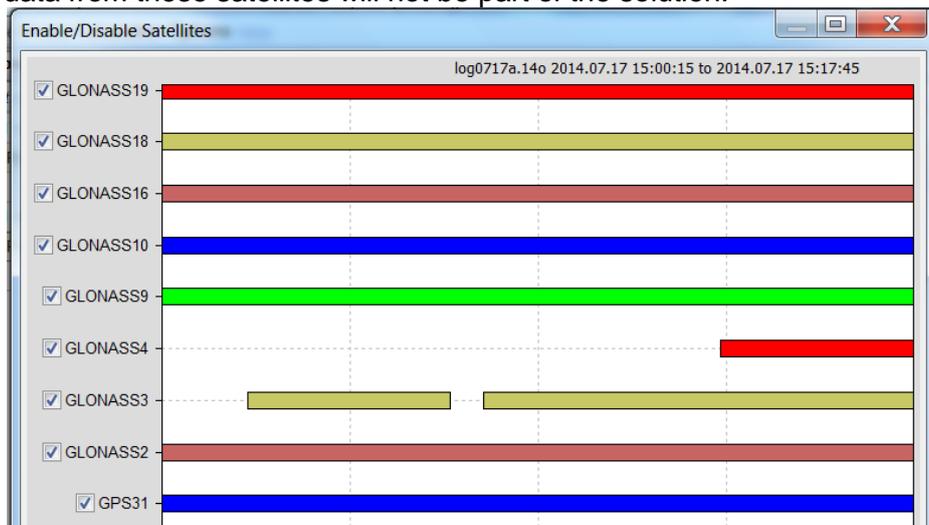
In the example above the minimum duration of 600 seconds (10 minutes) is set for static vectors. This means a minimum observation time of 600 seconds is advised for both stations (base and rover). If the vector is 3km long then the minimum duration based on the relative setting is $60+3 \times 120=420$ seconds (7 minutes). Since this duration is shorter than the 10 minutes, the latter is used. In case of a 5km vector, the relative setting (660 sec/11 min) exceeds the 10 minutes setting. Now 11 minutes is used as minimum duration.

Note that the duration setting is just an indication of the required observation time. The actual required observation time depends on the type of receiver (e.g. L1 only or L1/L2) and on the conditions. Vectors which do not meet the duration settings are marked in the candidate static vector list but can still be processed.

- **Kinematic Position File Format** defines the output of processed kinematic data in terms of the format of Position and Date & Time. Kinematic data is exported in an ascii file with the extension 'pos'.
- **Instantaneous Vector Processing** allows you to reduce the duration of an observation. You can reduce the duration by typing in the **From** and/or **To** times or reduce the duration graphically by an overlapping rectangle. See example below.



- **Enable/Disable Satellites...** allows you to deselect satellites individually so that data from these satellites will not be part of the solution.



- **Candidate Static Vector(s)** makes it possible to select candidate vectors for processing. This allows you to process multiple vectors at once (as opposed to one vector at the time). A new window is opened showing all candidate vectors. With the tick boxes on the left, all or a subset of the vectors can be selected for processing. Right-click to start the processing.

<input type="checkbox"/>	Status	From	From File	Status	To	To File	Length [km]	Duration	Criteria
<input checked="" type="checkbox"/>	▲	BRUG146G	BRUG146G.12o	▲	RUIS	RUIS146G.12o	15.0	0 01:00:00.000	0 00:31:03
<input type="checkbox"/>	▲	BRUG146G	BRUG146G.12o	▲	GENT146G	GENT146G.12o	41.0	0 01:00:00.000	0 01:23:00
<input checked="" type="checkbox"/>	▲	BRUG146G	BRUG146G.12o	▲	DIKS146G	DIKS146G.12o	27.1	0 01:00:00.000	0 00:55:13
<input type="checkbox"/>	▲	RUIS	RUIS146G.12o	▲	RUIS	RUIS146G.12o	12.4	0 01:00:00.000	0 00:25:52
<input type="checkbox"/>	▲	RUIS	RUIS146G.12o	▲	RUIS	RUIS146G.12o	43.1	0 01:00:00.000	0 01:27:16

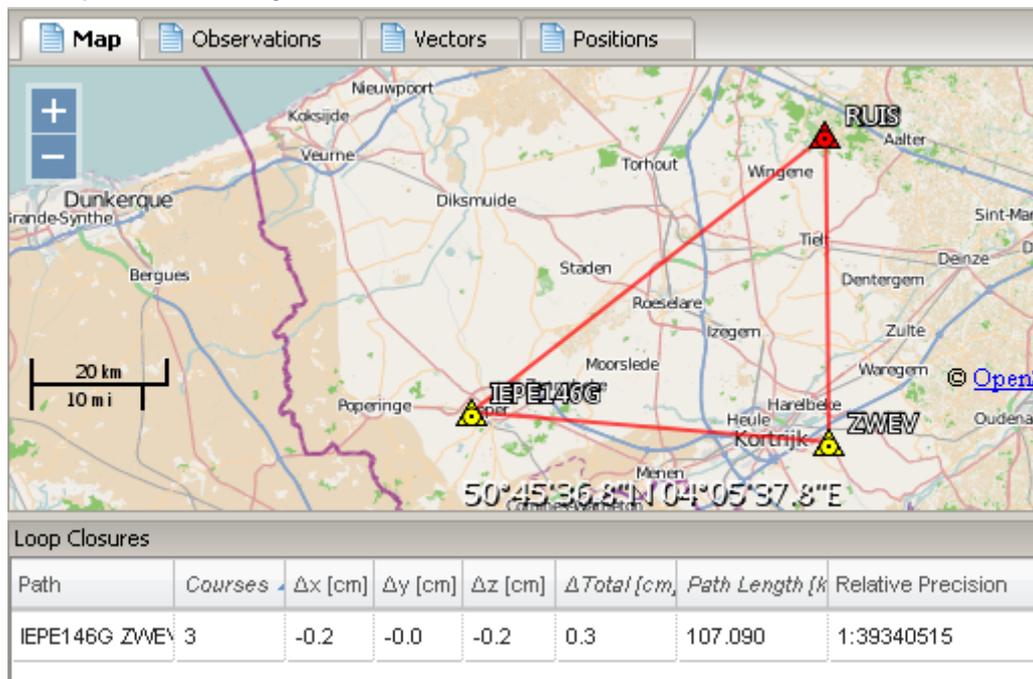
The duration of the vector observation is compared to criteria based on the settings in **Edit> Preferences**. See **'Simultaneous Static Observations'** under **Vectors**. If the condition for minimal observation duration is not met, the observation is shown in grey, but can still be selected for processing. In the example above, the actual observation duration for the 15.0 km baseline was 1 hour which was more than enough to meet the 31 minutes condition. The second baseline (41.0 km) does not meet the preset condition and is shown in grey.

There two ways to influence the selection of candidates:

1. Select one or more stations from the **Positions** tab; only vectors to the selected station(s) and the rest of the network will be in the candidate list.
2. Select a **Position Proximity** in **Edit> Preferences**; only vectors which do not exceed the Proximity setting length are selected as candidates.

Assume you have an existing network and you have added a new station. You don't want to recomputed the entire network and you don't want to compute all vectors to the new station. Select the new station in the **Positions** tab and set the **Position Proximity** to 25km. Running **Candidate Static Vector(s)** will now present you with a list of vectors <25km from the existing network to the new station.

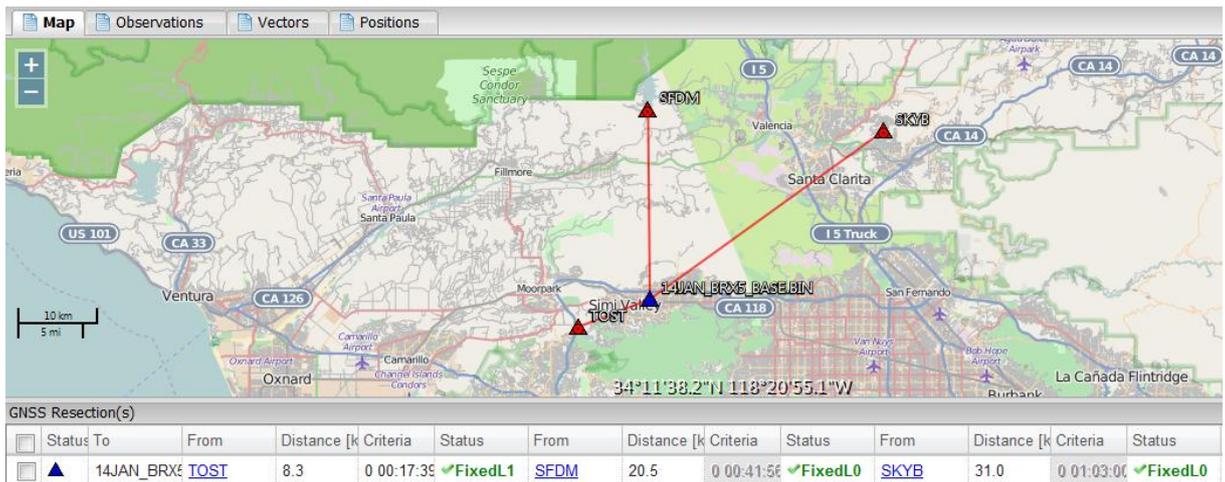
- **Loop Closures** allows you to view the closure errors in your network. This options works best with the **Map** view selected, and of course only works when you have a closed figure (a loop) in your network. First select the stations which form the loop; left-click on the station symbol while holding the Shift key. Alternatively you may select all stations at once by holding the Ctrl key while creating a selection window.



Then select **Loop Closures**, either from the **Compute** menu or by right-clicking and selecting **View Closures** from the popup menu.

The closures errors (Δ) are presented in x, y and z direction separately, as well as in a combined $\Delta Total$ value. The **Relative Precision** is a measure of the total closure error versus the Path Length.

- **Network Adjustment** will carry out a least-squares network adjustment. To accept the adjustment results and store them internally, go to **File> Save Adjustment**.
- **GNSS Resection(s)** is a quick way to calculate a precise position for a station using the 3 closest reference stations. You may select more than one unknown station. A new window is opened showing the resection vectors. Select the tick box of the resection you to process (or select them all) and right-click to start the computation. The resection computation is automatically followed by an adjustment.



In the example above the GNSS Resection identified TOST, SFDM and SKYB as the 3 closest CORS stations to the 14JAN_BRX5 station and processed the 3 baselines.

- **Virtual Reference Station(s)** will create a virtual RINEX station using data from the 3 closest reference stations. This is similar to the working of a VRS RTK network, however in this case we are not working real time and SurveyGNSS creates a local base RINEX file for post-processing. This option only works for stop and go and kinematic surveys.

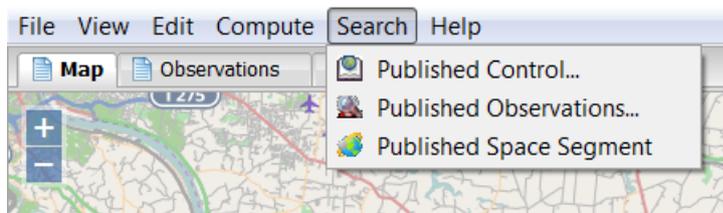
Select a stop and go occupation from the **Observations** tab and run **Virtual Reference Station(s)**. Make sure that the **Antenna Definitions** are enabled under **Edit>Preferences...**

Note: **Virtual Reference Station(s)** is a separate option in SurveyGNSS and is grayed out when it is not included in the installation.

Note: Every time a baselines is successfully processed, a plain text log file of the processing is created (basefilename-roverfilename.txt). This file includes valuable information about the processing. This file is displayed on the right side of the screen in **Transcript** tab of the **Reports** window.

6.5 Search Menu

The **Search** menu offers the following options:



- **Published Control...**
- **Published Observations...**

The options **Published Control...** and **Published Observations...** allow you to download know station coordinates in the area of your survey, as well as RINEX data from local active reference stations. An internet connection is required. Also note that

this service is not available in all parts of the world. For details on the working of these tools see Tutorial 2.

- **Published Space Segment** has been added to allow you to introduce Precise Ephemeris and Ionosphere Model data to the project on demand. The associated SP3 and YYi files are placed in the relative destination folder as set in **Edit> Preferences...**

6.6 Help menu

The **Help** menu include the SurveyGNSS 'about' information as well as the Product Registration, see also Chapter 2.

7 SurveyGNSS Views

SurveyGNSS allows you to inspect your raw and or processed data in four different tabs or views. The SurveyGNSS views are:

- **Map** view
- **Observations** view
- **Vectors** view
- **Positions** view

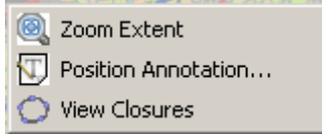
7.1 Map View

The **Map** view presents the positions and observations on a worldwide background map. SurveyGNSS uses OpenStreetMap© for this purpose, a collaborative project that creates and distributes free geographic data for the world. An internet connection required to view the map.

Initially only the positions of RINEX stations are shown, baseline vectors are shown after computation. The colors of the station symbol indicates the position status: approximate-blue (not yet processed), known-red, (kept fixed) and processed-yellow. See also the **Positions View**.

Note that positions of kinematic points are not shown on the **Map**. Create a Google KML file via **File> Save as...> Open GIS® KML Encoding Standard** to view these positions.

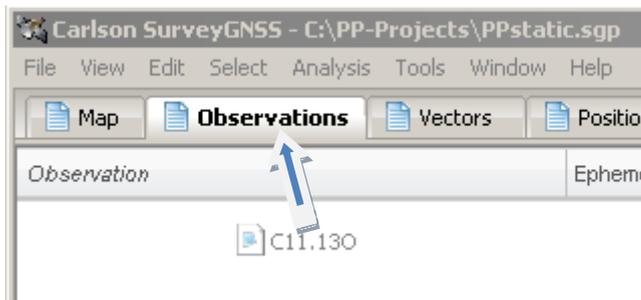
Right-clicking on the map brings up a menu with 3 options:



- Use **Zoom Extent** for a complete view of you network. You can also use the '+' and '-' buttons on the top left for zooming. Your mouse can be used to zoom and pan as well.
- **Positions annotations** brings on a standard Windows screen for changing the font on the station name.
- **Loop Closures** will open a windows and show the closure errors. To view the closures it is necessary to define a closed figure (loop) on the map. See **Compute>Loop Closures** in the main menu.

7.2 Observations View

The **Observations view** allows you to import RINEX and other supported observation files into the SurveyGNSS project. To import a file, select the filename from your Windows document browser and drag the file onto the **Observations** tab. SurveyGNSS will open a Report window on the right of the screen with information about the import and about the conversion to RINEX (in case of a proprietary observation file format).

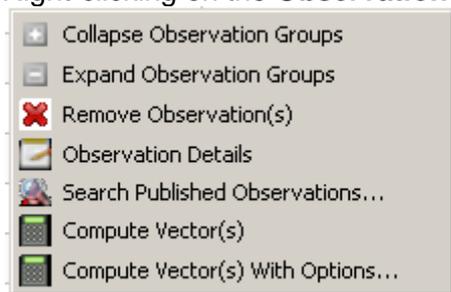


If the file is accepted, SurveyGNSS will display information about the file and all observation files imported into your project.

Observations are listed in the view along with the following information:

- **Observation** shows the station name and the associated file name
- **Ephemeris** shows the ephemeris file that is used, this can be the standard broadcast ephemeris file or file with a precise ephemeris
- **Antenna height** shows the antenna height in meters found in the import file
- **Start Time** shows the data and start time of the observations
- **Durations** shows the duration (observations time) in hh:mm:ss
- **Measurements** shows the number of measurements based on the duration and the measurement rate, i.e. 1 hour of data with a 15 sec rate is $60 \times 4 = 240$ measurements.

Right-clicking on the **Observations view** brings up a menu with a number of options:



- Use **Collapse/Expand Groups** to minimize or maximize the listed observations.
- Use **Remove Observation(s)** to permanently remove an observation from the project. First select the observation, then remove.
- **Observation Details** opens an editor to edit the RINEX header details.
- **Search Published Observations.../Compute Vector(s)/Compute Vectors With Options...** offer a quick way to access the same options under **Compute**.

See the **View** menu option for information on graphical display of observations and durations.

7.3 Vectors View

In the **Vectors view** the post-processing results are listed. By default, a text file with detailed results about the processed vector is created in the project folder. For each vector there is a separate file. The filename is a combination of the station names.

See an example for the SurveyGNSS output below.

From ▲	From File	From Antenna Height	To ▲	To File	To Antenna Height
alm1035k	../Almere Static 2013/alm1035k.1	0.000	1000	../Almere Static 2013/1000.130	0.000

Length	Solution	Quality	PDOP	σ_0 Vector	σ_0 Solution	Satellites	Fixed Ambiguities	Reweighted Observations
27101.5	FixedL0	high	0.9	0.004	0.400	16	99.8	0.0

Δx	Δy	Δz	σ_x	σ_y	σ_z	$\rho\Delta x\Delta y$	$\rho\Delta x\Delta z$	$\rho\Delta y\Delta z$
15391.432	-19060.540	-11588.505	0.0008	0.0002	0.0009	0.0130	0.8774	0.0139

Under **From** the name of the base station in the base RINEX file is shown, under **To** the rover name is shown.

From File and **To File** show the associated based and rover RINEX files.

The antenna height in **From Antenna Height/To Antenna Height** should be the true antenna height i.e. the height from the marker on the (ground) surface to the antenna phase center. This is conform the RINEX specifications.

The **Length** is the baseline length (m). The baseline length is an important factor in the selection of the solution type, i.e. for longer baselines an ionosphere-free solution is selected. This is done automatically.

Each coordinate solution is accompanied by its **Solution** type (DGNSS, FloatDGNSS, FixedLW, FixedL1, FixedL2, FixedLN, FixedL0) and static solutions by a **Quality** indicator (low, medium, high).

Solution quality "high" is only given to those FixedL1 or ionosphere-free FixedL0 solutions which fulfill certain requirements with respect to percentage of fixed ambiguity, standard deviation of unit weight, number of satellites, and PDOP. Solutions of the type FixedLW are always of "medium" quality.

FloatDGNSS solutions may be either of "medium" or of "low" quality, mainly depending on the amount of observation data.

The quality indicator of a DGNSS solution is always set to "low".

pdop is the Position Dilution of Precision, a measure of the quality of the satellite geometry.

The **σ_0 Vector** is the standard deviation of unit weight.

The **σ_0 Solution** is the standard deviation of a single observation (m).

Satellites lists the number of satellites (GPS & GLONASS).

Fixed Ambiguities shows the percentage of fixed ambiguities for the data. The DGNSS or FloatDGNSS solutions are not included in this number.

Reweighted Observations show the percentage of re-weighted observations.

Δx , Δy , Δz are the vector elements (m) of the baseline to the rover position.

The σ_x , σ_y , σ_z are the standard deviations of the rover position in Cartesian coordinates (cm).

$\rho\Delta x\Delta y$, $\rho\Delta x\Delta z$, $\rho\Delta y\Delta z$ are the correlation coefficients for the XY, YZ, ZX vector element combinations.

Tip: Right click on one of the column headers. This will allow you to make a selection of the displayed items.

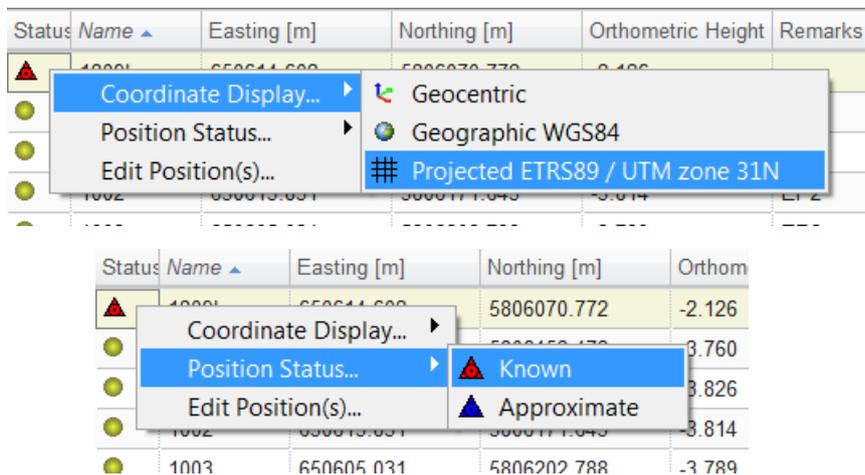
To save the view to a file or print the view, use the appropriate icon on the bottom right;



7.4 Positions View

The **Positions** view lists the stations and their coordinates as well as their status. The coordinates are expressed in the coordinate system which was chosen in **Search>Set Spatial Reference...**

Right-clicking on the status of a station will bring on a menu:



Coordinate Display... will set the coordinates to **Geocentric** (Earth-centered Cartesian XYZ), **Geographic** (latitude, longitude, height) or **Projected** (e.g.UTM). The projected coordinates are based on the coordinate system projection selected in **Search>Set Spatial Reference...**

The **Position Status...** is either **Known** or **Approximate**. Usually the network will include a reference position which should be marked as **Known**. The other stations are then **Approximate**. This is the default value. The known station is kept fixed in the processing, the rover position is processed relative to the known station.

There is no use in marking more than one station as **Known**. Constraints on the network which are imposed by multiple known stations should be handled by the least squares adjustment following the post-processing.

Edit Position(s)... can be used to edit the coordinates i.e. of a known station. The three position formats (geocentric, geographic, projected) in the **Edit Position** window are linked, so when making a change all formats are updated simultaneously.

Edit Position 1809base						
Geocentric	X	3885077.395	Y	354462.918	Z	5029039.199
Geographic	Latitude	52°23'2.95000"N	Longitude	05°12'47.02968"	Ellipsoidal Height	41.01
Projected	Northing	5806070.772	Easting	650614.602	Orthometric Height	-2.126
		Save		Next		Cancel

Tip: Right click on one of the column headers. This will allow you to make a selection of the displayed items.

To save the view to a file or print the view, use the appropriate icon on the bottom right;

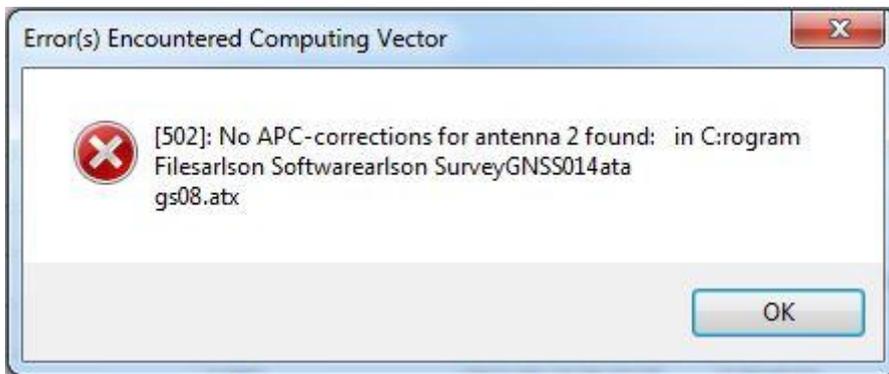


8 SurveyGNSS and SurvCE

For the post-processing of stop and go surveys, SurveyGNSS assumes there is a RW5 as produced by SurvCE available. The RW5 file holds the markers (the 'stop and go points') and this is vital information for the processing.

To import the rover part of a stop and go survey, the RW5 file must be dragged and dropped onto the **Observations** view. The rover raw data file is then automatically added. SurveyGNSS will merge the RW5 file and the rover raw data file, which could be in one of the supported proprietary format, into a new RINEX file. The new RINEX file now includes the stop and go markers.

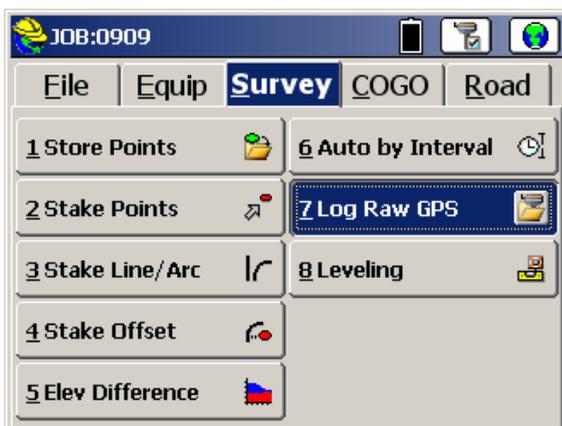
The new RINEX file should also import information about the antenna type from the proprietary log file. If this info is not available (e.g. not entered in SurvCE or the log file has no record for the antenna type) then SurveyGNSS will generate a [502]: No APC-corrections error message:



In this case the antenna type must be picked manually from a predefined list. This is important for a correct processing of the offset to the antenna phase center. See Tutorial 4 for an example.

Some receiver brands might produce RINEX files which already hold the stop and go markers. There is no guarantee that these RINEX files are accepted by SurveyGNSS.

See the Carlson SurvCE Reference Manual for further information about logging raw data from your GNSS receiver for post-processing. Note that this option is not supported for all receiver brands.



Note that in SurvCE 4.0 new records have been introduced to facilitate the processing of raw data: GNSSLOGRCVR and GNSSLOGANT. When using SurvCE for static or kinematic datalogging in the receiver, it is advised to use SurvCE 4.0 . Carlson cannot guarantee proper import results of raw data with SurvCE 2.x and 3.x .

See an example of the use of the new records in a SurvCE 4.0 RW5 file below:

```
--GPS Log File: 1802rov.log rover open Carlson,Surveyor+ GPS
```

```
--GNSSLOGRCVR,FL1802rov.log,SRROVER,RNBFN12100140  
D2LR0G55R,RMNOVSurveyor+ GPS,RFOEM060100RN0000 2011/Jun/28
```

```
--GNSSLOGANT,FL01802rov.log,AN,AMNOV702GG    NONE,LI1000,AG2.000,PA0.067
```

```
--GPS Log File: 1802rov.log rover close Carlson,Surveyor+ GPS
```

9 Least Squares Adjustment

SurveyGNSS includes an adjustment tool, based on SurvNet, Carlson's network least squares adjustment program. This tool performs a least squares adjustment and statistical analysis on a network of known points and GNSS vectors (total station measurements not included).

The preferences for the adjustment are found under **Edit> Preferences**.

The screenshot shows the 'Preferences' dialog box with three main sections:

- General:** Contains four input fields: 'Confidence Level' (95.0 %), 'Convergence Limit' (0.0001 m), 'Iteration Limit' (10), and 'Centering Error' (3 mm).
- GNSS Vector Weighting:** Features a sub-section 'A Priori Method' with three radio buttons: 'Variance Factor' (selected), 'Standard Deviation', and 'Standard Deviation Scale'. Below are two input fields: 'A Priori Variance Factor' (32.0) and 'A Priori Standard Deviation' (5 mm + 1 ppm).
- Compute Relative Ellipses:** Includes a checked checkbox for 'Observations' and an input field for 'Stations Within' (50000 m).

The **General** Section includes:

- **Confidence Level:** This setting is used when calculating the size of error ellipses, and in the Chi-square testing.
- **Convergence Limit:** The adjustment is carried out in a series of converging iterations. During each iteration corrections are computed. When the corrections are below the convergence limit, we have found our solution.
- **Iteration Limit:** This settings defines the maximum number of iterations of the adjustment process. The iteration process is stopped when either the convergence limit or the iteration limit has been reached. A high number of iterations could indicate bad data (slow or in extreme case no convergence). Typically if there are no blunders in the data the solution will converge in less than 5 iterations.
- **Centering error:** This option is used to specify the precision associated with centering a GPS receiver over a marker.

The **GNSS Vector Weighting** presents three options for settings the a priori standard precision of the vectors. The three vector elements DX, DY, DZ are correlated so we are

actually dealing with a full 3x3 matrix including the off-diagonal correlation coefficients. The standard deviation of the rover position calculated by the post-processing is only a measure of the internal precision. Very often this value is over-optimistic which results in incorrect weighting in the adjustment. Incorrect weights will make the statistical testing unreliable.

- By selecting **Variance Factor** and entering an **A Priori Variance Factor** value, we are scaling the a priori precision to a more realistic value. It is not uncommon to scale the standard deviations by a factor 4 or 5 or even more (16 or 25 Variance Factor). This method works well when all vectors are equally over-optimistic, i.e. when all vectors are of similar length.
- By selecting **Standard Deviation**, the precision of the vectors is subject to the entered values for the **A Priori Standard Deviation** model (i.e. 5ppm + 1 ppm). This model is in line with what most GNSS receiver manufacturers list in their specs as static performance. This method works well when the network includes vectors of various lengths. The drawback of this model is that the correlation between the vector elements is ignored. This simplification might influence the reliability of the statistical testing.
- The **Standard Deviation Scale** method is a combination of the two methods above. The 'mm + ppm' model is used to set the a priori precision and then each vector is scaled individually to this model value. This is a more refined method compared to the Variance Factor method which applies a single scale factor to the complete network. The advantage over the A Priori Standard Deviation model is that correlations are taken into account.

The adjustment will **Compute Relative Ellipses** for stations which are within a certain distance of each other. The distance can be entered in the **Stations Within** field.

SurveyGNSS uses the **Chi-square test** for the statistical testing. This is a so called overall model test which does not test individual observations, but either accepts or rejects our complete network. Simply said: the null-hypothesis which is tested is H_0 : our network is correct. Correct means that:

- The a priori standard deviations for our vectors have been correctly estimated; they all have realistic values.
- The model chosen to relate the observations to the unknowns parameters (station coordinates) is complete and true, and the vectors are free of bad observations (outliers).

When the **Chi-square test** is accepted, we can accept the processed positions with the option under the **File** menu; **File> Save Adjustment**. Then for each new position in the **Position View**, the a posteriori standard deviations σ_x , σ_y , σ_z and their correlations ρ_{xy} , ρ_{xz} , ρ_{yz} are added. In the **Observations View** for each vector the least squares corrections $v\Delta x$, $v\Delta y$, $v\Delta z$ and the normalized or standard residuals $nv\Delta x$, $nv\Delta y$, $nv\Delta z$ are added. Ideally, the latter values should be close to 1.0 .

On the other hand, if we have a rejected **Chi-square test**, we must go back to our GNSS vector weighting, or go back to our post-processing result. When we are able to identify a

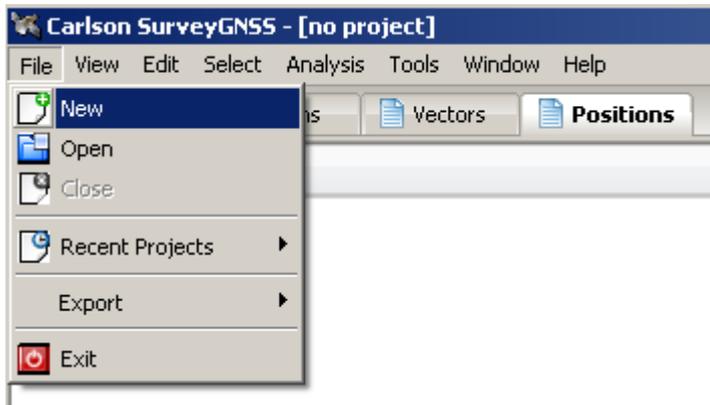
suspect vector in our post-processing results we have the option to re-process, to remove (if we have enough redundancy) to re-measure the vector.

10 Tutorials

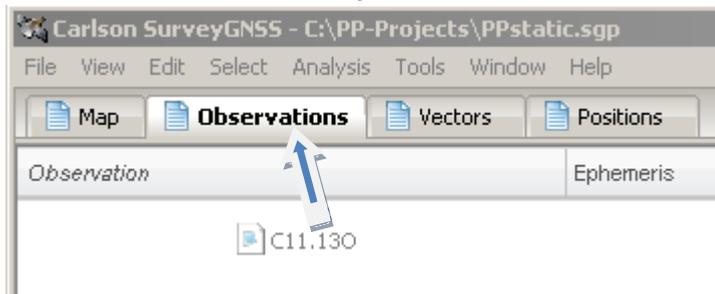
10.1 Tutorial 1: Processing Static Data

In this tutorial you will process 2 baselines with SurveyGNSS and will learn about the basic settings in the software. An internet connection is required.

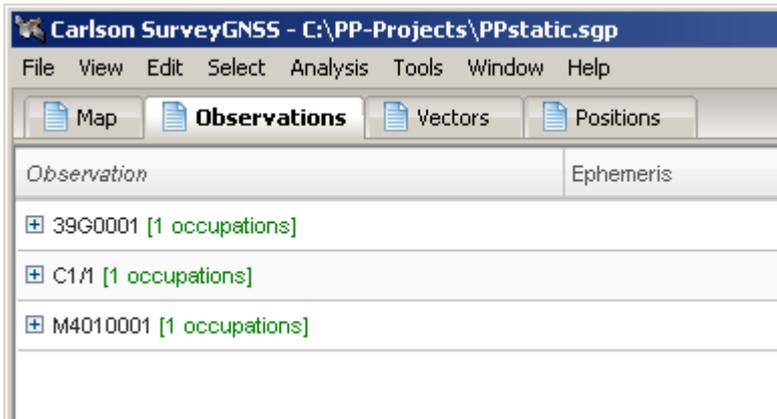
1. Start SurveyGNSS and select **File > New** to open a new project. SurveyGNSS projects will have the extension 'sgp'. Call the project 'ppstatic' or another appropriate name.



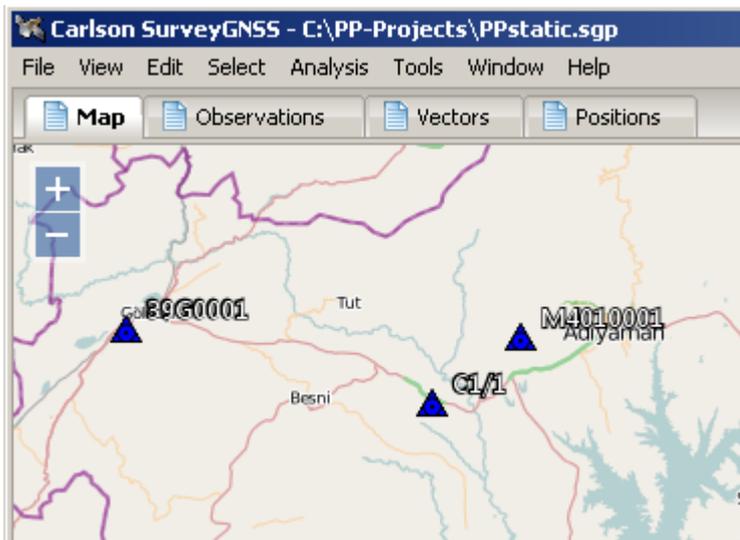
2. We will import 3 static files. To import a file, select the filename from your Windows document browser and drag the file onto the **Observations** tab.



Import all three files: C11.130, 39G001.130, M4010001.130 . Note that you only have to import the RINEX 'O' files; the associated files will be added automatically. Your screen should look like this:



- To review the location of the three markers go to the **Map** tab. Right-click on the map and select **Zoom Extent**.



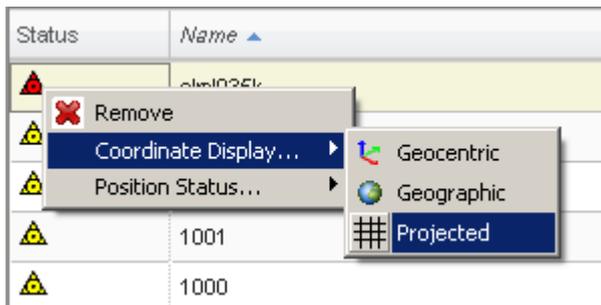
The sample data that we use in this tutorial is in the South-East of Turkey.

- The next step is to select a plane coordinate system. Go to **Edit>Spatial Reference...** This will bring you to an online database of coordinate systems. In this tutorial we will use a standard UTM projection; in the **Search References** Field enter 'UTM Zone 37N' and then select **Search**. Pick the coordinate system from the list (7771) and select **OK**.

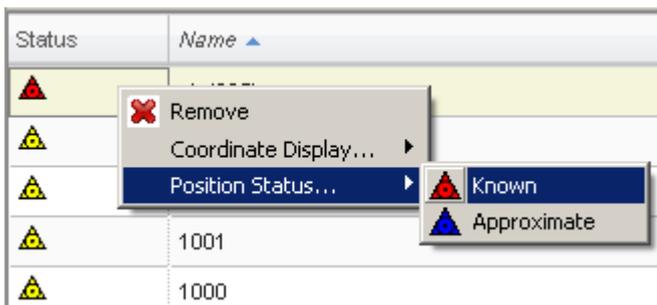
In the bottom right of the screen you should now see the selected coordinate system. This coordinate system is now active.



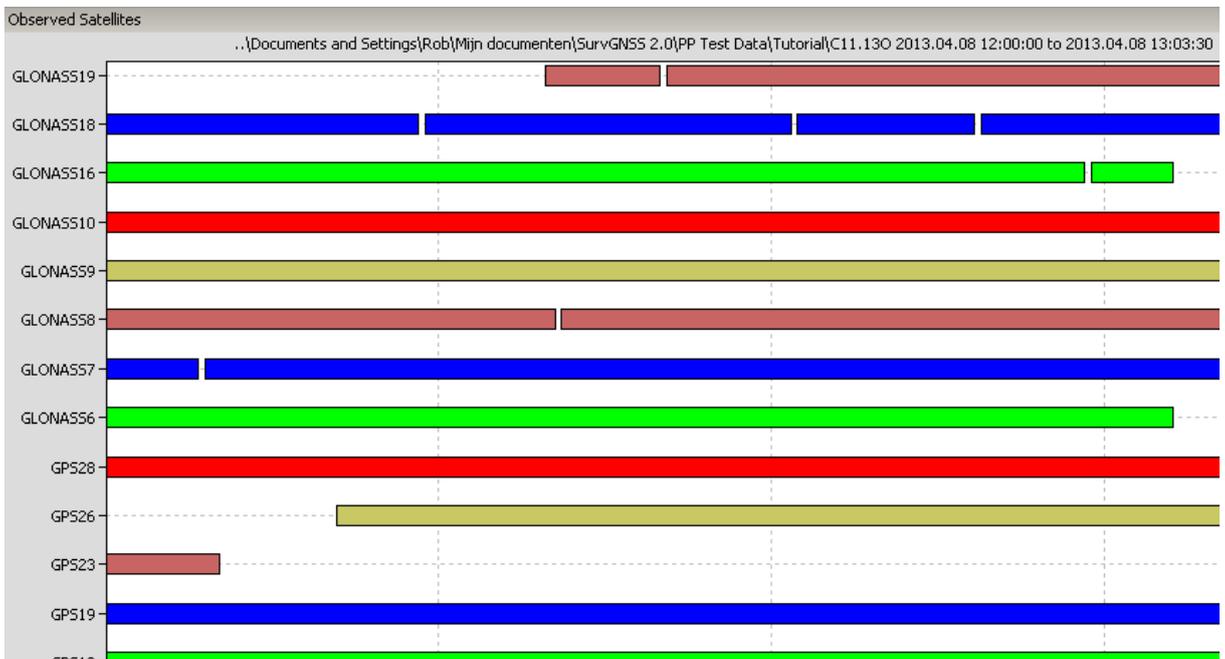
- Now go to the **Positions** tab. By default the coordinate system displayed is Geocentric (XYZ, Earth-centered). Right-click on the blue triangle, select **Coordinate Display...** and then **Projected**. Now you will see the coordinates displayed in UTM projection.



One of the markers will be our reference point, the position of the other two markers will be calculated from this fixed reference point which we assume to be known. Marker C1/1 will be our reference point; right-click again on the blue triangle and select **Position Status... > Known**.



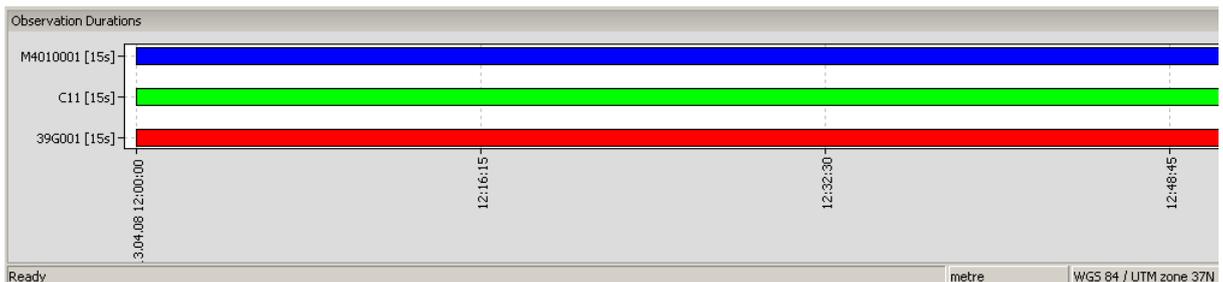
- We have now entered some basic settings for the processing but we have not yet looked at our data. Go back to the **Observations** tab. From the main menu select **View > Observed Satellites**. Now pick C1/1, our reference station, by left-clicking on the line with the filenames while pressing the Ctrl key (make sure the observation groups are expanded). The selected line will change color and on the right side of the screen a graphics overview of the observed satellites is shown.



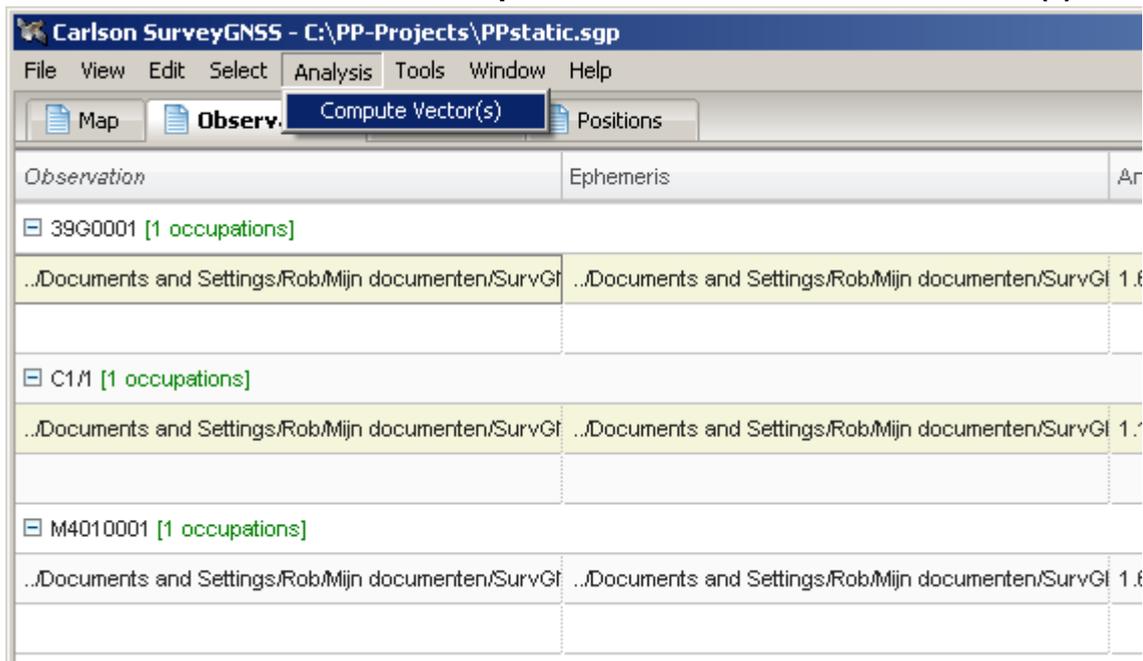
The view can be expanded by dragging the display window to the left. Our data looks good: we a combination of GPS and GLONASS data and the apart from a view cycles

slips (sections where the colored lines are broken) the quality seems satisfactory. You can review the data of the other files as well.

Another useful display is the observation durations; this will show how much overlap we have between our files. If we have no overlap or the overlap is too short, the data processing will fail. From the main menu select **View> Observation Durations**. Now pick all three observation lines by left-clicking while pressing the Ctrl key. The graph will show that we have overlapping data for about an hour which should be sufficient for our baselines. In the **Observations** tab you can also review the duration of the observation and also the number of measurements. The data was taken at a 15 second rate so in our case we have well over 240 measurements for each file.



- Now we are ready for the actual processing of the data. In the **Observations** tab select C1/1 and 39G0001. Go to **Compute** in the main menu and select **Vector(s)**.

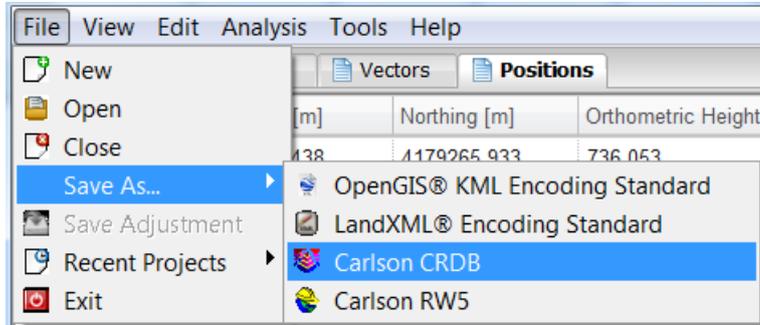


Go to the **Map** tab and note that a baselines is now drawn from C1/1 to 39G0001. Then go to the **Vectors** tab to review the processing result. As you can see we have 37km baselines with a FixedL0 solution of high quality.

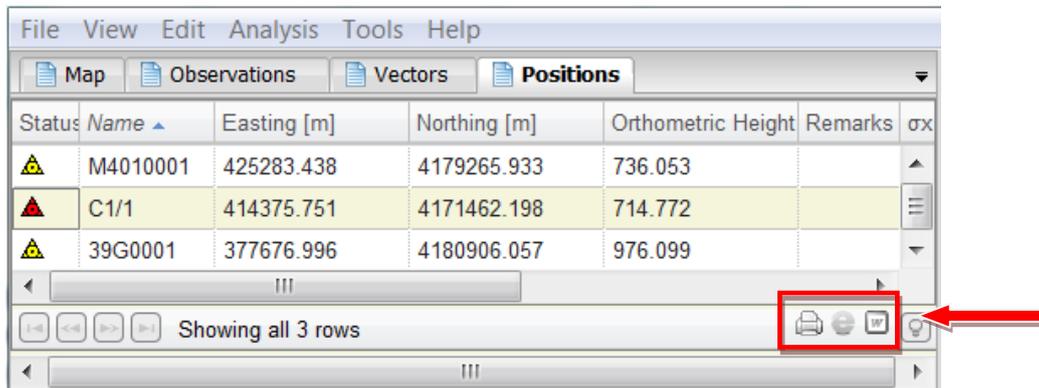
Length [km]	Solution	Quality	PDOP	σ_v Vector [cm]	σ_s Solution	Satellites	Fixed Ambiguities
37.911	FixedL0	high	0.9	0.82	0.800	16	100.0

Now process the other baseline: C1/1 to M4010001.

8. A text file with details of the processing is created for every processed baseline in the data folder of the RINEX files. The files are named after the markers, so in this case look for the files C11-39G0001.txt and C11-M4010001.txt .
To save the processed positions you can create a Carlson CRDB file (for further processing with Carlson office products) via **File> Save As...>Carlson CRDB**



It is also possible to create printer output, a HTML file or a Word Doc using the buttons on the lower left.

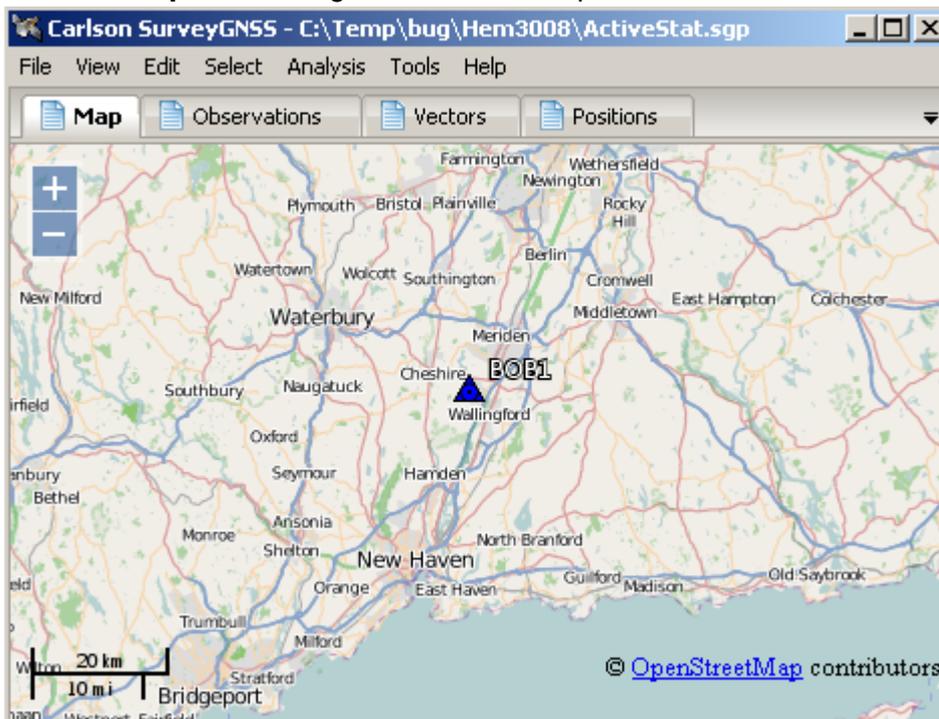


Tip: To control which parameters are to be send to the printer/Doc/HTML, position the mouse on one of the column headers (in either the **Observations**, **Vectors** or **Positions** tab) and right-click. This will bring on a set of tic boxes which let you switch parameter on or off.

10.2 Tutorial 2: Downloading active and passive reference stations

In this tutorial you will download RINEX data from reference stations near your base and rover points. You will also locate control points in your area. Reference stations which produce live RINEX data are referred to as active stations, while known points (i.e. first or second order control points) are called passive stations. For this tutorial an internet connection is required.

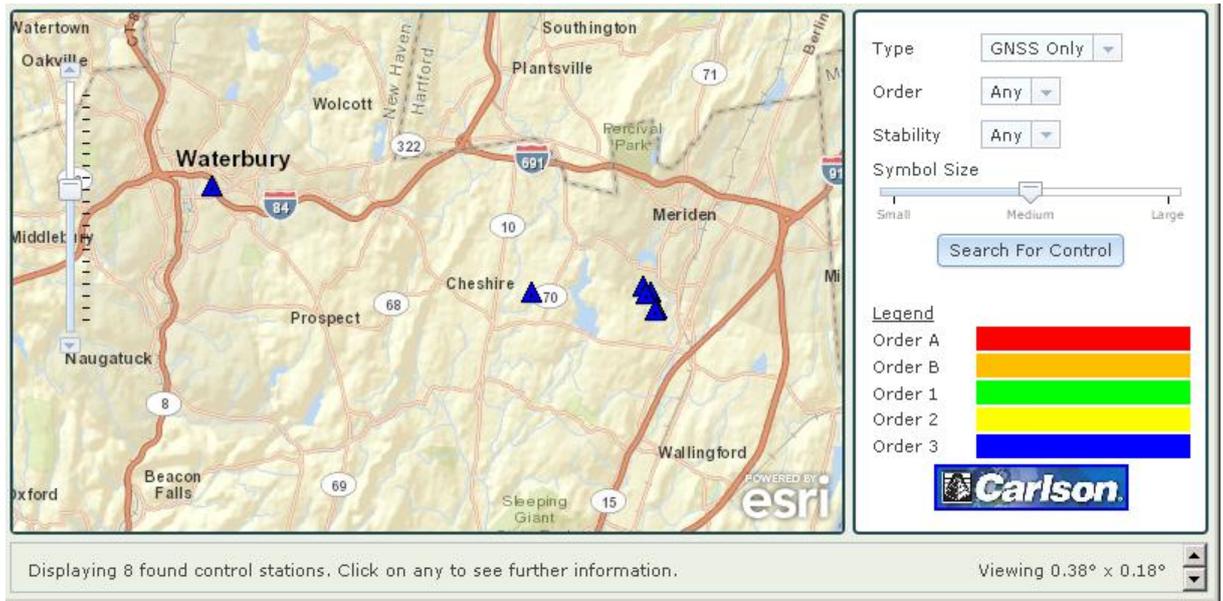
1. Start SurveyGNSS and select **File > New** to open a new project. SurveyGNSS projects will have the extension 'sgp'. Call the project 'Activestat' or another appropriate name (see also Tutorial 1).
2. We will import a single static file and then add data from 3 active stations. Drag the file BOB1196A.13O from your Windows browser to the **Observations** tab in SurveyGNSS.
3. Go to the **Map** tab and Right-click on the map and select **Zoom Extent**.



Our station BOB1 is located in Connecticut, north of New Haven.

You may skip Step 4 when you are not interested in passive published control points and to go directly to CORS station selection.

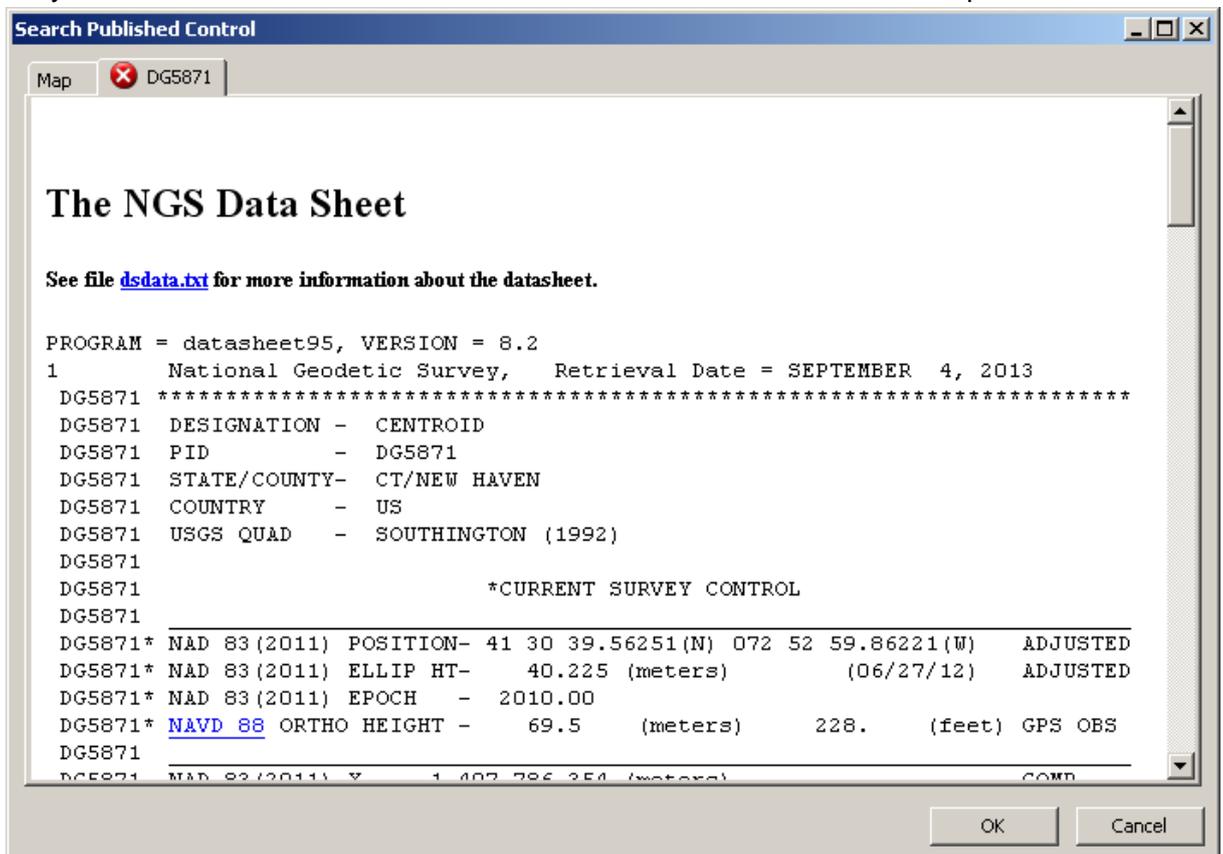
4. We would like to find control points in our area. We can use these points as base stations for our own GNSS receiver, or add one or more points to our network for QA. Go to **Search>Search Public Control...** You will see a map of the U.S. (more active reference networks will be added to SurveyGNSS at a later stage). Follow the given guideline: *Zoom to maximum 2°x 2° x area of interest...*



Once you have zoomed to an acceptable level, select **GNSS Only** as the type of control point, and then press **Search for Control**.

The number of located stations depends on your zoom-level. For the 0.38° x 0.18° area above, 8 stations were found.

Left-click on the station near Route 70. You will see it has the identifier DG5871. When you close the pop up, you will note that a tab DG5871 has been created. In the tab you will find the NGS data sheet with full information about the control point.



When you exit the DG5871 tab by pressing OK, the control point will be added to the project as a known point. This was merely an illustration of the use of passive control points. We will not use this point in this tutorial.

- We will now locate the active stations (CORS) near our BOB1 marker. We will search in a radius of 105km. This radius exceeds the 100km default, so go to **Edit> Preferences...** and then change the **Proximity** value under **General Settings** to 105km.

Make sure you have the BOB1 observation selected in the **Observations** tab (with Ctrl-left click). This observation will be the center of the search area. Now go to **Search>Search Published Observations...** A list of available reference stations around BOB1 is presented. The list is sorted by distance to BOB1.

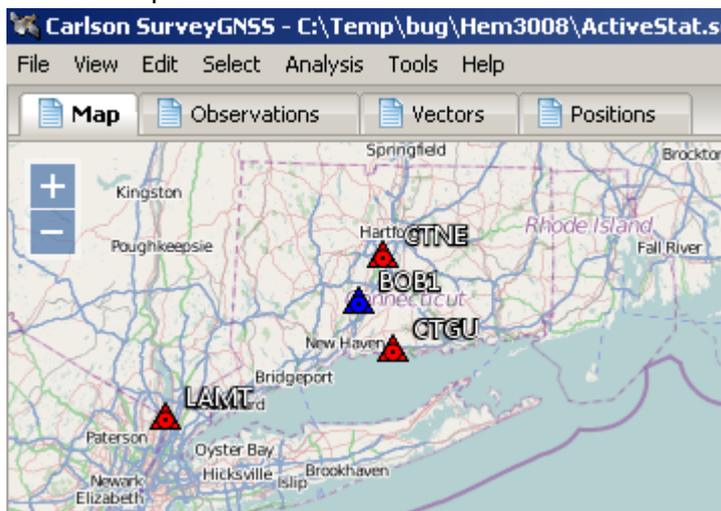
Available Reference Stations Near BOB1							
Station	Identifier	Distance [km]	Territory	Place	Operator	Status	Interval [s]
CTNE	DH7113	24.0	CT	Hartford	Connecticut Department of Transportation		5
CTGU	DH5833	26.5	CT	Guilford	Connecticut Department of Transportation		5
CTBR	DH5825	47.3	CT	Brookfield	Connecticut Department of Transportation		5
CTVM	DH5839	49.4	CT	Winchester	Connecticut Department of Transportation		5
CTEG	DH5829	50.4	CT	East Granby	Connecticut Department of Transportation		5

Showing all 46 rows

- Right-click on one of the stations and then select **Acquire** to bring in the RINEX file from that station. SurveyGNSS will automatically make sure that the correct data, time and observation interval is chosen. Select the stations CTNE at 24.0km, CTGU at 26.5km and LAMT at 103.4km. The LAMT station exceeds the 100km default search range. If this station is not in the list, go to **Edit> Preferences...** and then change the **Proximity** value under **General Settings** to 105km.

When you download a station RINEX file the Status field will show a green bar showing progress.

- After downloading the data from the 3 reference stations, we now have 4 occupations and our Map should look like this:



Note that the reference stations are automatically marked as Known (in red).

8. Go back to the **Observations** tab and select the observations to BOB1 one by one. Process each observation with **Compute>Vector(s)**.
9. Go to the **Vectors** tab and review the processing result. Even the long 100km baseline is fixed with more than 99% of fixed ambiguities. This indicates high quality data.

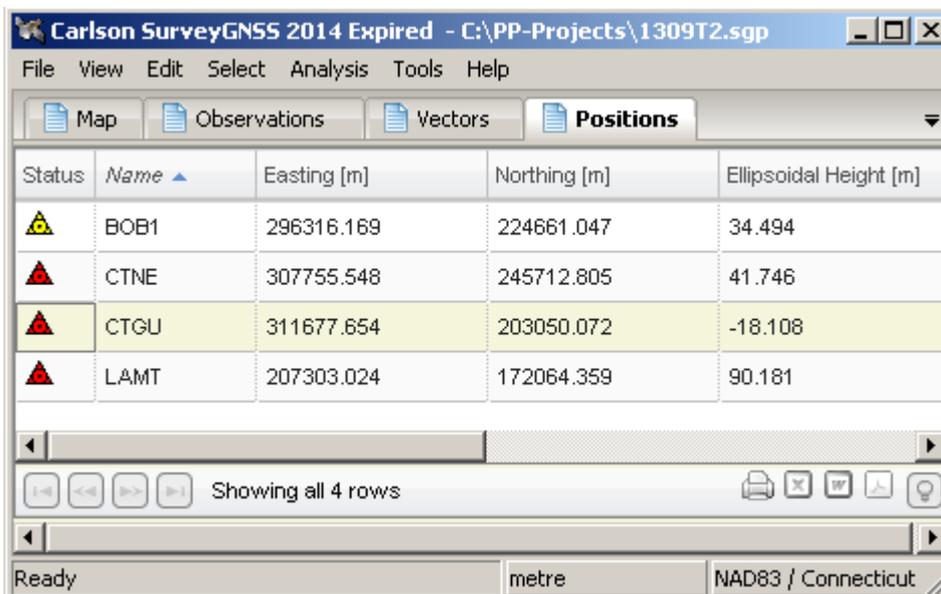
<i>From</i> ▲	From File	From Antenna Height [m]	<i>To</i> ▲	To File	To Antenna Height [m]	<i>Length [km]</i> ▲	Solution	Quality	PDOP
CTGU	.obs/ref/ctgu1960.13o	0.000	BOB1	...Documents and Settings\R	1.446	26.515	FixedL0	high	2.1
CTNE	.obs/ref/ctne1960.13o	0.000	BOB1	...Documents and Settings\R	1.446	23.960	FixedL0	high	2.1
LAMT	.obs/ref/lamt1960.13o	0.000	BOB1	...Documents and Settings\R	1.446	103.391	FixedL0	high	2.1

The network configuration is a typical resection. The next step is to carry out a least-squared adjustment, See Tutorial 3.

10.3 Tutorial 3: Least Squares Adjustment

In this tutorial you will carry out a least squares adjustment using the processed baselines from Tutorial 2.

1. In Tutorial 2 we have concentrated on processing the raw data. For this purpose it is not required to have a plane coordinate system active. Now that we want to calculate the final position of our new station we need a coordinate system. Go to **Edit> Spatial Reference**, search 'Connecticut' and pick 'EPSG:26956: NAD83/Connecticut'. Exit the screen with **OK**.
2. Go to the **Positions** view and right-click on one of the yellow or red status icons (triangle). Then select **Coordinate Display...> Projected** Your view will look like this:



Status	Name ▲	Easting [m]	Northing [m]	Ellipsoidal Height [m]
	BOB1	296316.169	224661.047	34.494
	CTNE	307755.548	245712.805	41.746
	CTGU	311677.654	203050.072	-18.108
	LAMT	207303.024	172064.359	90.181

Note that the heights are either ellipsoidal heights or if a Gravity Model has been enabled under **Edit> Preferences...> General**.

The reference station coordinates have all been marked as known (red); these stations will be kept fixed in the adjustment. Station status of BOB1 is now yellow instead of blue. This which means it has been processed but is not yet adjusted.

3. Go to **Edit> Preferences...** and then to **Adjustment**. This will open the windows with settings for the adjustment. We will leave the **General** settings as they are (see below). The **GNSS Vector Weighting** setting is an important setting because we need realistic precision values for our input observations in order to achieve a realistic precision for our adjusted coordinates. The precision values (the 3x3 covariance matrix) from the post-processing are often over-optimistic and require a correction. In this case we will introduce a **Variance Factor** of 32 to scale the precision of our vectors. Our correlation coefficients will stay intact. See the required settings below.

General

Confidence Level %

Convergence Limit m

Iteration Limit

Centering Error mm

GNSS Vector Weighting

A Priori Method

Variance Factor Standard Deviation Standard Deviation Scale

A Priori Variance Factor

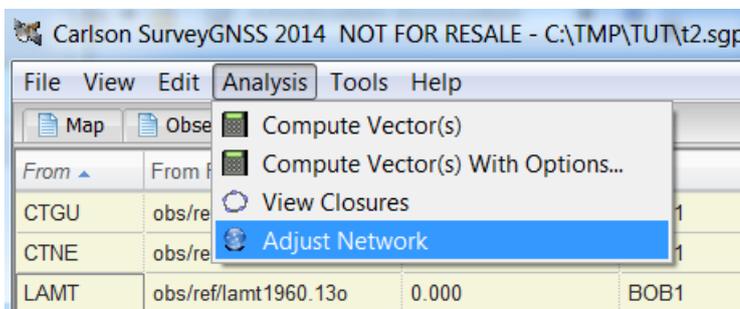
A Priori Standard Deviation mm + ppm

Compute Relative Ellipses

Observations

Stations Within m

4. Select **OK** to leave the **Adjustment** window and go to the **Vectors** view and select all 3 vectors. Then go to **Compute> Network Adjustment**.



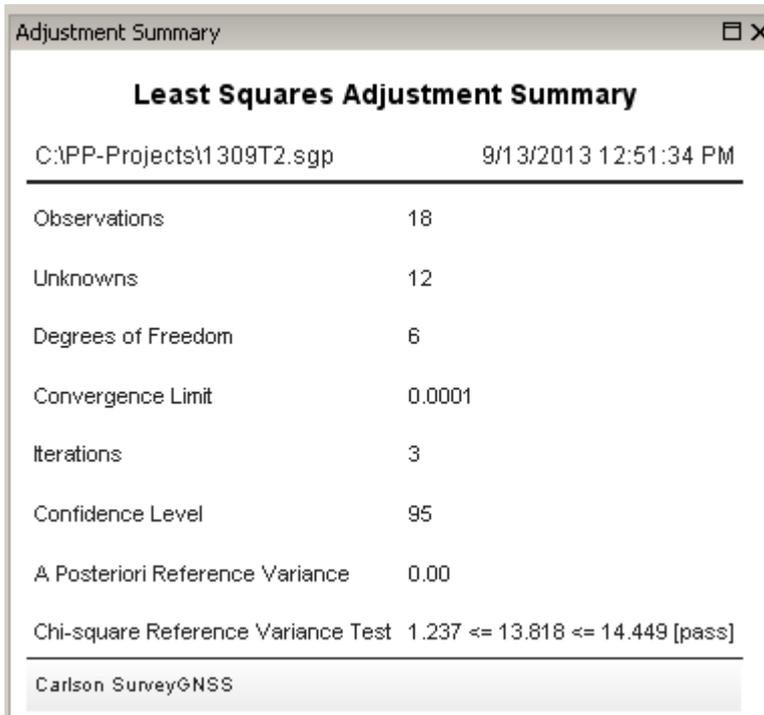
SurveyGNSS will present the results in the **Least Squares Adjustment Summary** below. The Chi-square statistical test has accepted our model.

5. Now go back to **Edit> Preferences...> Adjustment** . Change the **Variance Factor** value to 25, and rerun the adjustment; **Compute> Network Adjustment**.

If you check the **Least Squares Adjustment Summary** you will see that the Chi-square test has now failed. By decreasing the variance factor to 25 we are too optimistic in describing the accuracy of our input data. Set the factor back to 32, rerun the adjustment. To accept the adjustment result select **File> Save Adjustment**.

Note that the Chi-square will also fail when observations are incorrect or the network contains a blunder. In that case increasing the factor is not a proper solution. A better

scenario is to try to identify a faulty observation or known station and rerun the adjustment.



- Go to the **Positions** view. The status icon of BOB1 has now turned green, indicating we have an accepted adjustment result.

Status	Name	Easting [m]	Northing [m]	Ellipsoidal Height [m]	σ_x [cm]	σ_y [cm]	σ_z [cm]
	BOB1	296316.171	224661.042	34.481	2.761	2.251	2.660
	CTNE	307755.548	245712.805	41.746			
	CTGU	311677.654	203050.072	-18.108			
	LAMT	207303.024	172064.359	90.181			

The indicated standard deviations are well below 3cm. If we take as a rule of thumb that are baseline accuracy will be around $1\text{cm}+1\text{ppm}$, then with baselines of around 25 and 100km (3.5cm and 6.0cm respectively) we have a proper result.

- Go to **File>Save As...Carlson RW5** and select a name for the RW5 file i.e. BOB1. You have now created a RW5 file with geographical coordinates for the station points. The RW5 file can serve as an exchange format to other Carlson Software products.

For example, to change the ellipsoidal height to orthometric (leveling) heights and to change the units from meters to feet, import the RW5 file in Carlson X-port and process with the settings below.

Projection: USA/NAD83/Connecticut
Geoid: GEOID99
Alignment File: NONE

Point No.	Latitude Northing	Longitude Easting	GPS Elev Elevation	Rod Height Description	Geoid
BOB1	41°29' 02.20459"	-72°51' 05.72873"	34.481	0.000	-96.341
BOB1	737075.436	972163.972	209.468		
CTNE	41°40' 24.71719"	-72°42' 52.25224"	41.746	0.000	-96.146
CTNE	806142.761	1009694.660	233.107		

GPS Settings [X]

Projection Type: More Pre-Defined/User-Defined [v]

Zone: [v]

System: USA/NAD83/Connecticut [Setup]

Use Alignment File For Localization

Horizontal Transformation: Plane Similarity [v]

Vertical Transformation: Tilted Plane [v]

One Point Alignment Azimuth: State Plane Grid [v]

Two Point Align Method: Fit & Rotate [v]

Geoid To Apply: USA (Geoid99) [v]

Project Scale Factor: 1.000000000

Decimals for Report: 0.000 [v] Units: US Feet [v]

Multiple Measurement To Same Point: Use Last [v]

Create Point Notes

[OK] [Cancel] [Help]

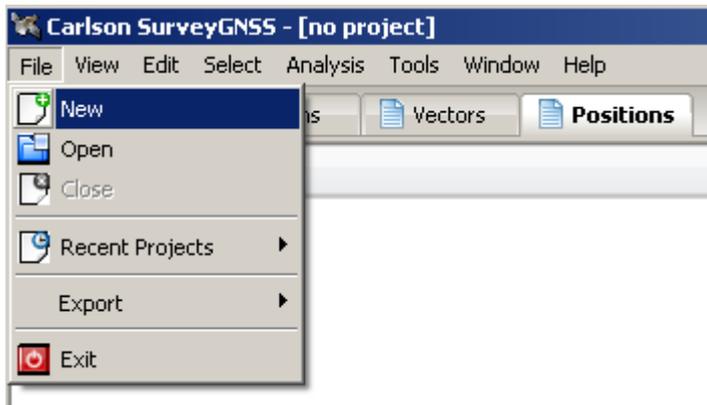
0.000 -98.622

0.000 -102.639

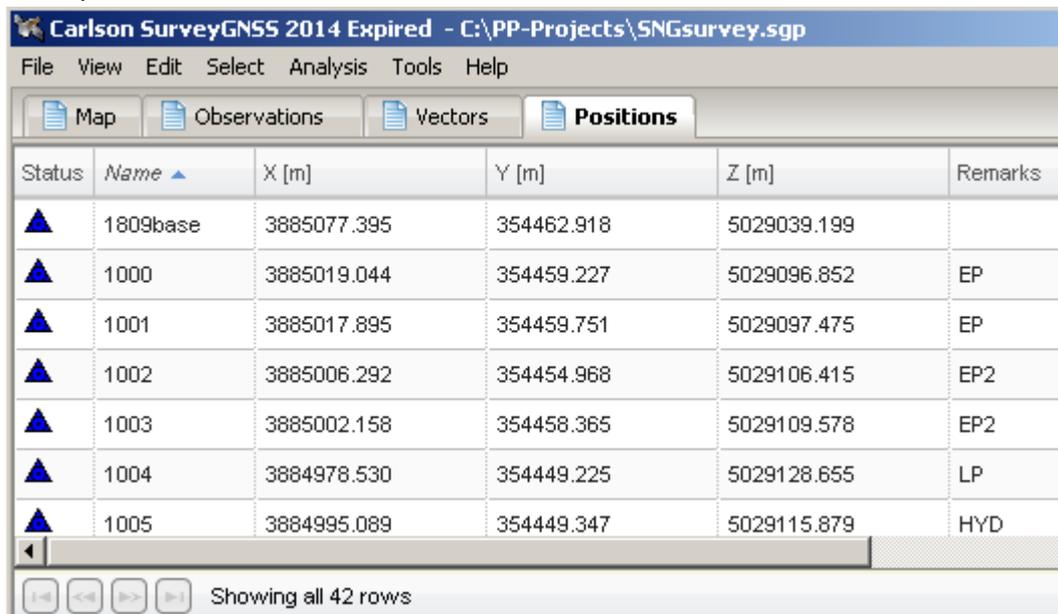
10.4 Tutorial 4: Processing of Stop and Go Data

In this tutorial you will process data from a Stop and Go survey that was carried out with Carlson SurvCE.

1. Start SurveyGNSS and select **File > New** to open a new project. SurveyGNSS projects will have the extension 'sgp'. Call the project 'SNGsurvey' or another appropriate name.



2. We will import the base and rover file. The base file is in RINEX format. Drag the file 1809base.13O from your Windows browser to the **Observations** tab in SurveyGNSS. The rover part of the stop and go data consists of the SurvCE RW5 file and the rover raw data LOG file in a proprietary format. Drag and drop the 1802rov.RW5 file onto the **Observations** tab, the rover raw data file is now automatically loaded.
3. Go to the **Positions** tab. You should see a base point and 41 rover points with their descriptions.

A screenshot of the Carlson SurveyGNSS 2014 software interface. The title bar reads 'Carlson SurveyGNSS 2014 Expired - C:\PP-Projects\SNGsurvey.sgp'. The menu bar includes File, View, Edit, Select, Analysis, Tools, and Help. There are tabs for 'Map', 'Observations', 'Vectors', and 'Positions'. The 'Positions' tab is active, displaying a table with the following data:

Status	Name ▲	X [m]	Y [m]	Z [m]	Remarks
▲	1809base	3885077.395	354462.918	5029039.199	
▲	1000	3885019.044	354459.227	5029096.852	EP
▲	1001	3885017.895	354459.751	5029097.475	EP
▲	1002	3885006.292	354454.968	5029106.415	EP2
▲	1003	3885002.158	354458.365	5029109.578	EP2
▲	1004	3884978.530	354449.225	5029128.655	LP
▲	1005	3884995.089	354449.347	5029115.879	HYD

At the bottom of the table, there are navigation buttons and the text 'Showing all 42 rows'.

Right-click on the Status icon of the 1809base station and change the **Position Status...** to **Known**. This will change the icon from blue to red.

- To set the plane coordinate system, go to **Edit> Spatial Reference...** . This will bring you to an online database of coordinate systems. In this tutorial we will use a standard UTM projection; in the **Search References** Field enter '31N' and then select **Search**. Pick the 'ETRS /UTM zone 31N' coordinate system from the list (EPSG25831) and select **OK**.

Right-click on any blue triangle, select **Coordinate Display...** and then **Projected**. Now you will see the coordinates displayed in UTM projection.

On the bottom right of the screen you should now see the selected UTM coordinate system. This coordinate system is now active.

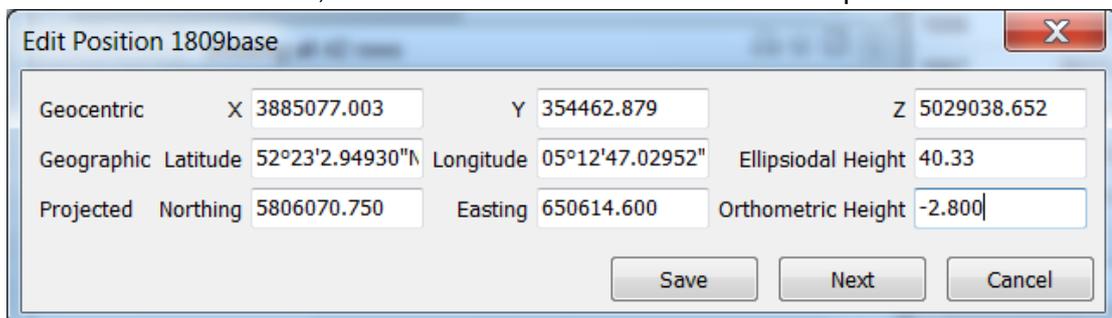
- Let's assume that during the stop and go survey we only had approximate coordinates for our base point, and that we now have more precise coordinates available. We want to edit the base position and enter the known coordinates. In the **Positions** view righty click on the Status icon of the 1809base station and select **Edit Position(s)...**

In the **Edit Position** window, change the projected coordinates to:

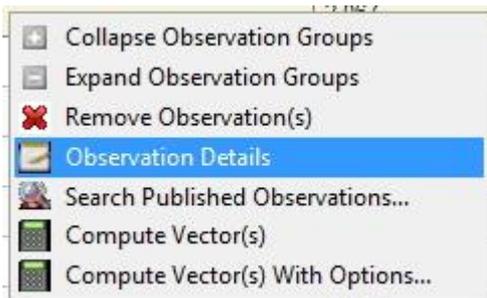
Northing: 5806070.750m
 Easting: 650614.600m
 Height: -2,800m (Ortho)

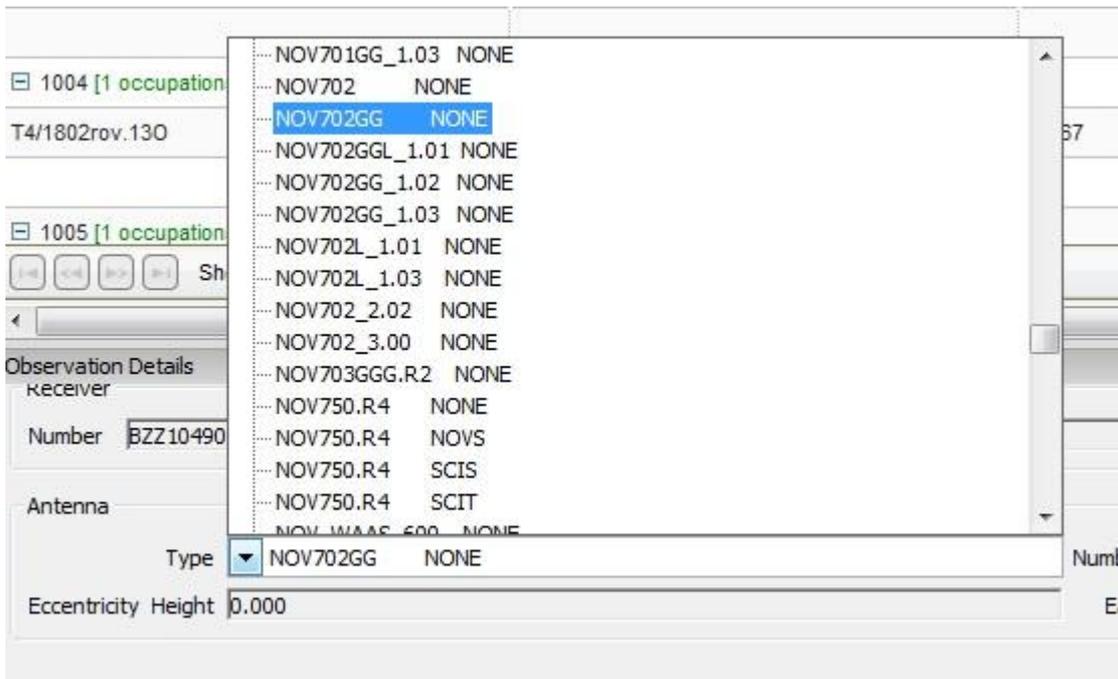
Exit with **Save**.

Note that the for the actual post-processing in the next step, the new base coordinates will be used, but the base RINEX file header is not updated.



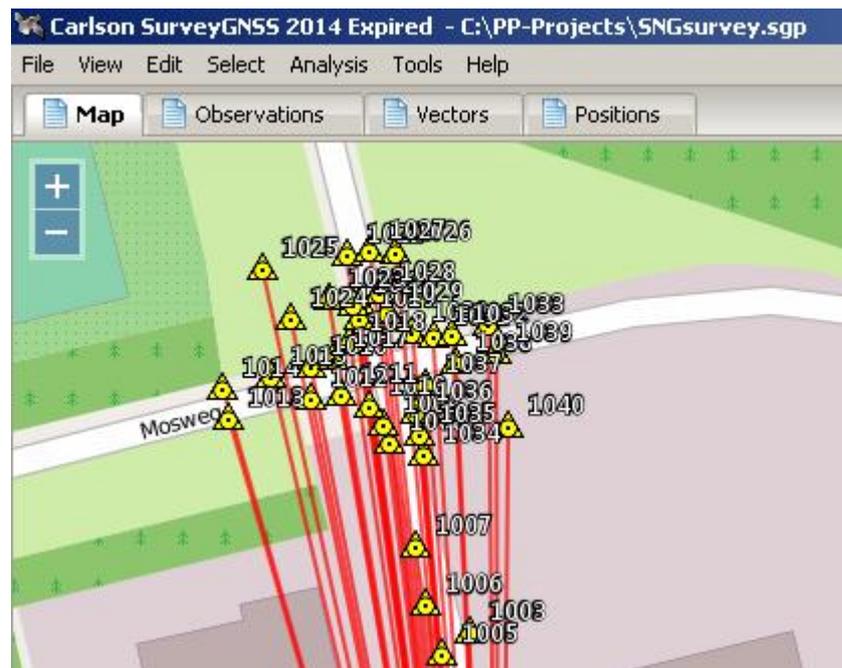
- In the **Observations** tab, Ctrl-left click on '1802rov.130' below the first stop and go point (point 1000) and then right-click to bring up the menu. Select **Observation Details** from the menu. The **Observation Details** window will open at the bottom of the screen. It is important for the processing that the correct rover antenna type is known so that the correct height offset is applied. Scroll down to **Antenna Type** and select 'NOV702GG None', then **Save Changes** and exit.



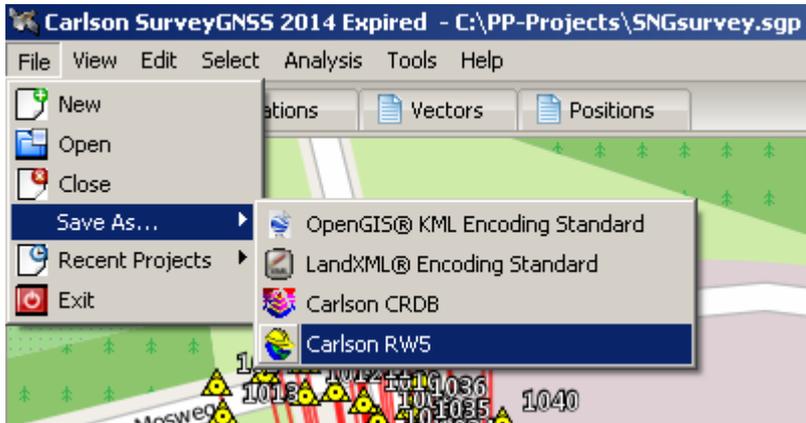


7. Make sure the base station observation at the bottom of the observations list is selected as well by Ctrl-left clicking. Now both the base station and the first stop and go point are selected (to process all stop and go points only the first points needs to be selected). Right-click to bring up the menu and pick **Compute Vector(s)**.
8. Go to the **Vectors** tab to review the processing result. All the stop and go points have a fixed solution and high quality. If you don't get a fixed solution, go to **Edit>Preferences...** and make sure that the Elevations Mask under **Vectors** is 15 deg and run **Compute Vector(s)** again.

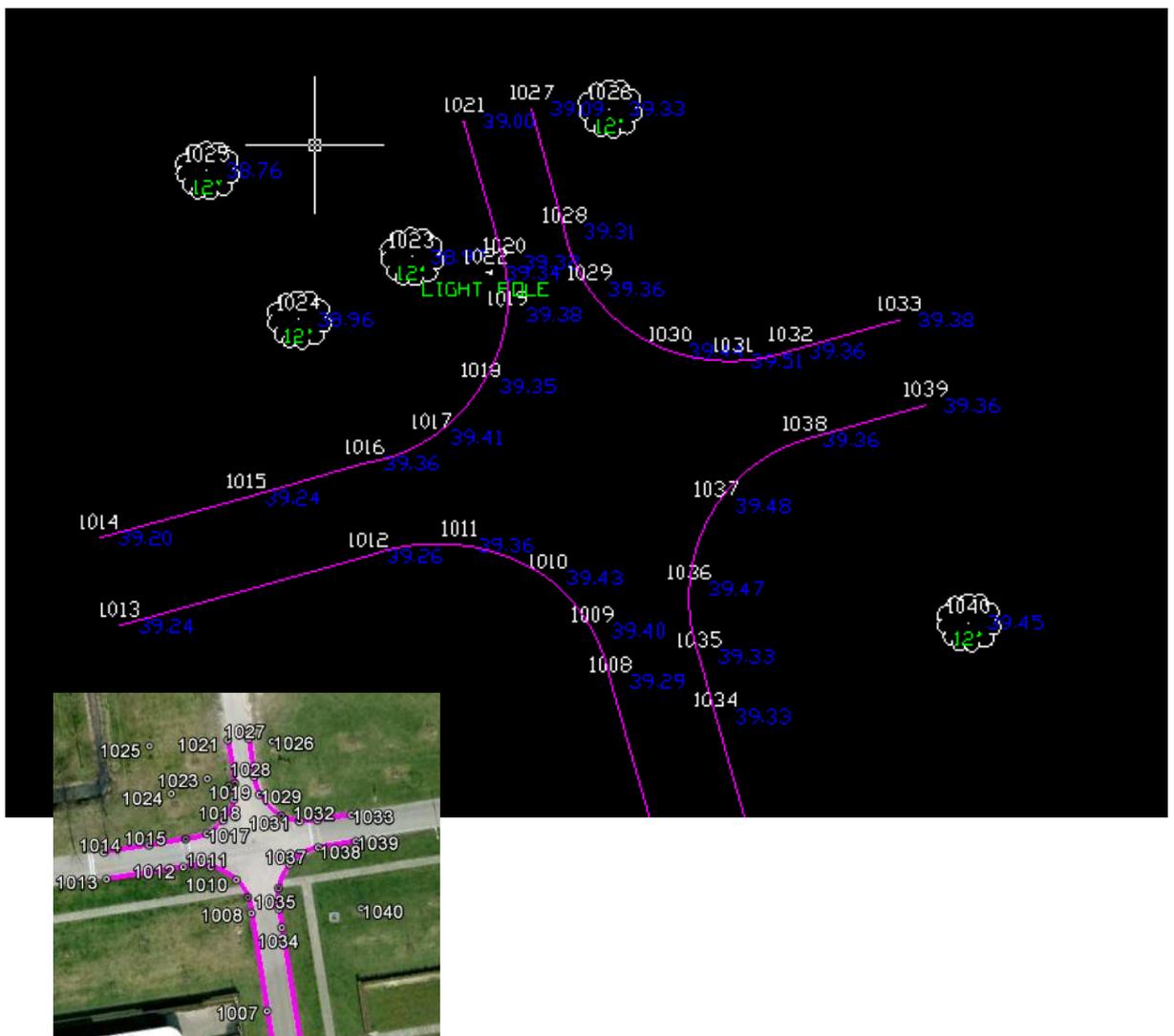
9. Go to the Map view and right-click to select **Zoom Extent**. You will see the cluster of stop and go points, all marked yellow (successfully processed).



- Go to the **File** menu and select **Save As...** and then either the **Carlson CRDB** or **RW5** format.



The CRDB and RW5 format can now be imported in Carlson Survey and then processed by Field to Finish. The result will then look like this:



10.5 Tutorial 5: Processing of Stop and Go Data with VRS

In this tutorial we will use the Virtual Reference Station(s) option. This option is available if you purchased the optional module SurveyGNSSVRS.

The module creates a Virtual Reference Station (VRS) which is used as a local base for the 'stop and go' survey. The module offers a solution in case you do not wish or do not have the ability to establish a local base, or in case the distance to operating GNSS reference stations is too far for centimeter level accuracies. In such cases a user supplied local base receiver can be substituted by a Virtual Reference Station which is computed from the observations of surrounding, actual but distant, reference stations (three in total).

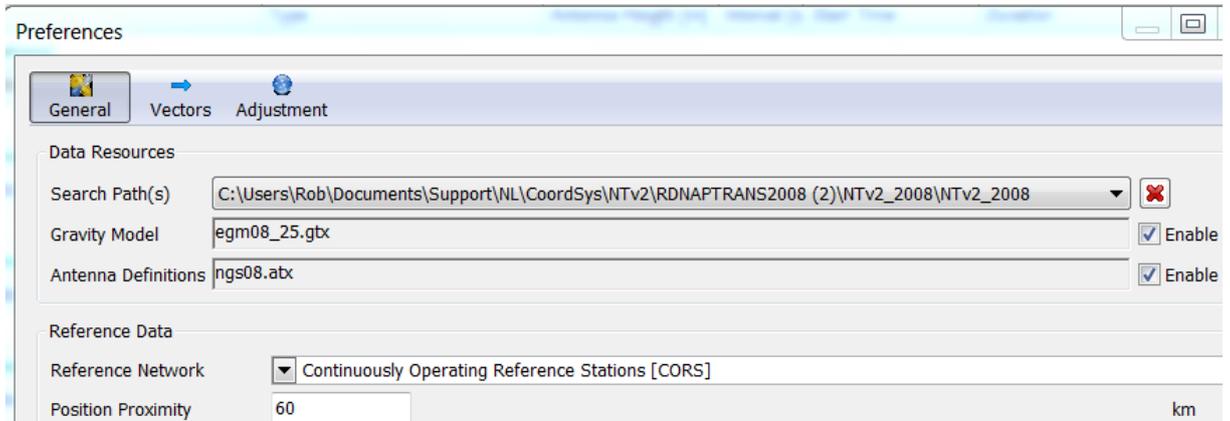
Note: the VRS option is a very powerful option but cannot perform miracles with your data. If the rover data is of bad quality, then the VRS option will not do any good. The VRS is based on a network solution and less sensitive to the baseline length than an actual reference station. However, the distance from the rover to the three closest reference stations is still an important factor in the computation. Here are few guidelines:

- Distances to the three reference stations which form the VRS network should be small. Accuracy will degrade when the distance to all reference stations exceeds 50km.
- The three reference stations should form a triangle surrounding the rover station. A bad reference station geometry, i.e. three stations on a line, will have a bad effect on the accuracy.
- The accuracy of the reference station position must be accurate on the millimeter level. This is the case for the reference networks used in SurveyGNSS.
- The ionosphere is an important factor in VRS calculations. Strong variations in the ionosphere will influence the accuracy. An Ionosphere Model should be used at all times (see the **Compute** menu).
- The observation rate of the 'stop and go' rover is normally 1 second, which means that the observation rate of the reference stations should ideally be 1 second as well. Since the VRS module will carry out an interpolation, even a 30 second reference station observation rate can lead to correct results. The observation rate for the reference stations is not critical but a short rate is advisable.

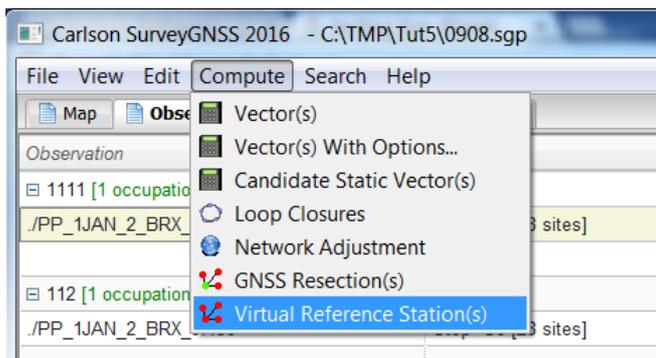
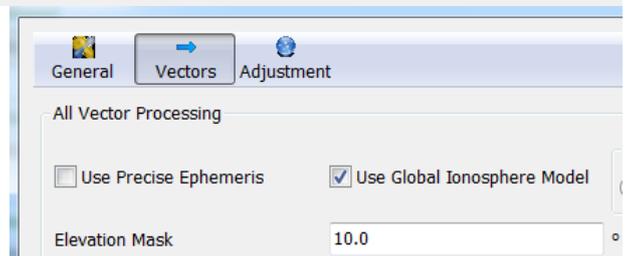
We will now process a 'stop and go' survey. Note that we will work with just two files: the Carlson SurvCE RW5 file (with the 'stop and go' point numbers) and the Carlson BRx5 rover file, no base files required.

1. Start SurveyGNSS and select **File > New** to open a new project. SurveyGNSS projects will have the extension 'sgp'. Call the project 'VRSsurvey' or another appropriate name.
2. Drag and drop the PP-1Jan-2.RW5 file onto the **Observations** tab, the rover raw data file is now automatically loaded (28 points in total).

- Go to **Edit>Preferences...** and make sure you have **Antenna Definitions** enabled, as well as 'CORS' with a '60km' proximity. In the **Vectors** tab switch 'Use Global Ionospheric Model' on. (see below).



- By Ctrl-left clicking, select one of the occupations in the **Observations** tab, then go to the **Compute** menu and select **Virtual Reference Station(s)**.



- SurveyGNSS will now locate the three closest reference stations and will list these in a separate window. Select the tick box on the left and right-click and select **Compute VRS Observation(s)**. This will start the actual computation of the VRS. The computation may take several minutes.

Virtual Reference Station(s)									
<input checked="" type="checkbox"/>	Type	To File	Antenna Height [m]	From	Distance [k]	From	Distance [k]	From	Distance [k]
<input checked="" type="checkbox"/>		.PP_1JAN_2_BRX_5.15e	1.931	P224	7.1	BRIB	8.6	CAPO	15.9

- When the computation is finished, the **Vector Status** in the window above should say 'Fixed L1' and in the **Vectors** tab all points should have a fixed L1 solution. Note the small baseline length in this window. This is the length to the newly created VRS.

7. The VRS is also listed in the **Positions** tab. The name of the VRS is equal to the rover filename with 'VRS' added to the end.

Status	Name	Longitude	Latitude	Ellipsoidal Height [m]
▲	BRIB	122° 09' 09.13920" W	37° 55' 09.84602" N	263.691
▲	CAPO	122° 13' 19.44532" W	37° 42' 51.02056" N	-20.327
▲	PP_1JAN_2_BRX_5VRS	122° 08' 32.85528" W	37° 50' 33.54862" N	250.567

