P4

User Guide

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Pseudorange & Phase Post-Processor

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to download demonstration versions of GRINGO and P4.

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INTRODUCTION

P4 is a Pseudorange and Phase Post-Processor which is distributed free-of-charge to purchasers of GRINGO. P4 was originally developed for the task of handling RINEX files of pseudorange data. It provides all the options necessary to compute Differential (DGPS) or stand-alone positions, whether the receiver is static or mobile. It provides a statistical and graphical analysis of the resulting positions, as well as providing details of the observations used in the computations (such as the DGPS corrections and the range residuals).

Since the development of a carrier phase version of GRINGO, P4 has been developed to cope with carrier phase data. The phase data can be used in two ways:

- To smooth the pseudorange data, and thereby improve the precision of the pseudoranges.
- To process a single static baseline using purely the carrier phase data, offering the possibility of measuring relative coordinates to a decimetre or better.

P4 is a Windows 95/98/NT/2000 program, with an easy-to-use graphical interface. Its operation is straightforward, and involves 6 steps (7 for carrier phase processing), which are represented by the tabs at the top of the main program window.

1. Choose a RINEX file for the 'Roving' receiver
2. Choose a RINEX file for the 'Reference' receiver (optional)
3. Choose a satellite 'Ephemeris' file
4. Define the session times and satellite constellation
5. Select the Pseudorange processing and output options, and process the Pseudorange data
6. Select the Carrier Phase processing and output options, and process the Carrier Phase data (optional)
7. View the results

Each of these steps is described in more detail in the following sections.

INSTALLATION

Although distributed free-of-charge, unless P4 is installed in the same directory as an activated copy of GRINGO, it will only run in demonstration mode. In this mode you will only be allowed to process the first minute from the roving receiver. The setup program for P4 is configured on the basis that you already have an installed copy of GRINGO, and it leaves out installation files which are common to both programs. Unless you have installed GRINGO already, P4 may not work, even in demonstration mode.

To install P4, download the P4 Setup disk file and unzip it to a temporary location. Run SETUP.EXE.

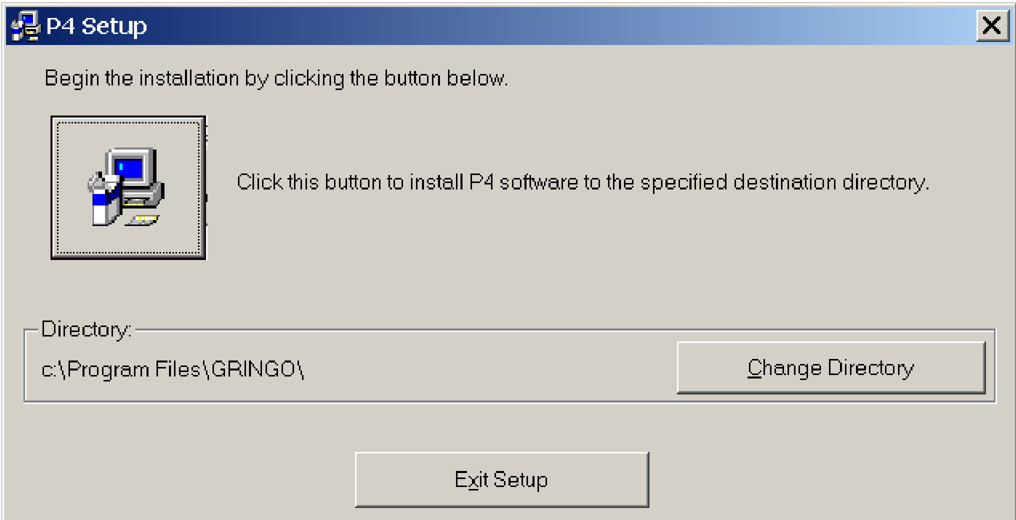


Figure 1 – P4 Setup screen

> *Tip: Be sure to use the* 'Change Directory' *button to specify the directory containing your copy of GRINGO as the installation directory for p4.*

If you have already installed P4, you can upgrade to the latest version by downloading just the P4 executable, which should be unzipped and copied to your GRINGO/P4 installed directory.

STARTING P4

The installation process should place a shortcut to P4 on your Start button, under Programs. You can 'drag and drop' this shortcut onto your desktop if you wish. When the program starts, it initially displays the following 'splash' screen.

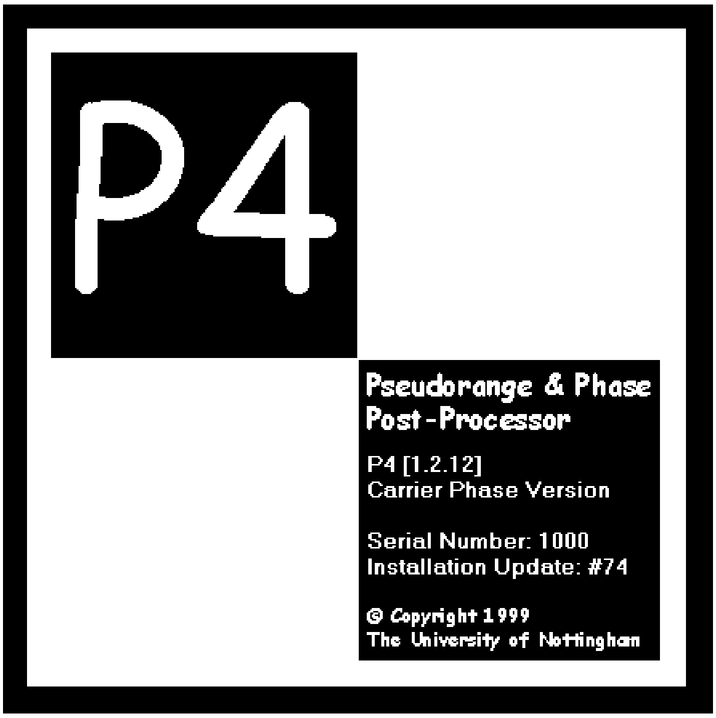


Figure 2 – P4 'Splash' Screen

This splash screen shows the Version number - [1.2.12] above - and the type of installation - Carrier Phase Version above, or Pseudorange Version. It will also display the Serial Number of your copy, and an Installation Update number. These two numbers may be required for certain operations involving your installation. If you do not have an activated copy of GRINGO, or P4 is not installed in the same folder as your activated copy of GRINGO, the splash screen will be preceded by the following warning screen.

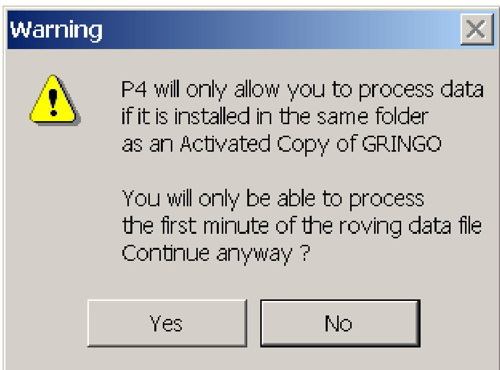


Figure 3 – Demonstration mode warning

To proceed, you need to click on the splash screen to clear it, and then accept the terms of the software licence. P4 will then display its main window. The processing steps are logically set out on 7 tabs across the top of the window.

Figure 4 – Processing Tabs

These 7 steps are described in the following sections.

STEP 1

CHOOSE A RINEX FILE FOR THE 'ROVING' RECEIVER

The 'Roving' receiver is usually a receiver for which you have recorded a RINEX file with GRINGO. The term 'roving' does not imply any receiver dynamics - it could have been static over a single point, or mobile - it simply denotes the receiver for which you require post-processed coordinates.

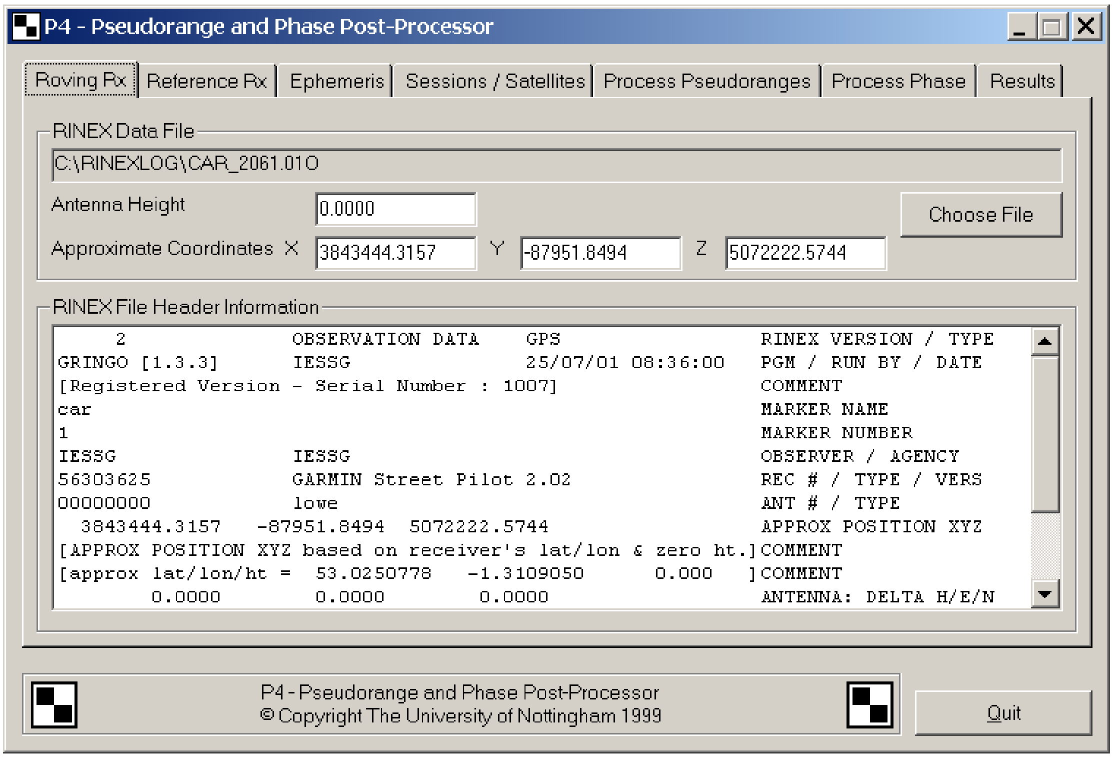


Figure 5 – 'Roving' Receiver File Selection

Select the 'Roving Rx' tab, and use the 'Choose File' button to bring up a file selection dialog box. Use this to locate and open the RINEX file for the roving receiver. Once a file has been opened, the grey box at the top of this page will be filled with the full path and filename. This filename will be recorded in the `P4.INI` file, and will be used as the default roving receiver filename the next time P4 is executed (it will still need to be 'opened' explicitly, using the 'Choose File' button). When a file is opened, P4 will carry out a number of steps:

- The 'RINEX File Header Information' box will be filled with any header lines from the RINEX file, to allow you to confirm that the selected file is the intended one.
- The receiver's approximate coordinates, if included in the RINEX header, will be extracted into the 'Approximate Coordinates' boxes below the selected filename. You can update these approximate values at this time if you wish,

but in practice there is usually no need, unless they are not found in the header.

- The receiver's antenna height, if included in the RINEX header, will be extracted into the 'Antenna Height' box below the selected filename. You can update this value if you wish, if, for instance, you know that your antenna was at a specific height above the ground point you wish to survey. The output coordinates will then relate to the ground point, and NOT the antenna.
- The RINEX file will be scanned to determine which satellites were observed, and the times of the first and last observations. The progress of the file scan will be shown in the frame at the bottom of the program window.

> *Tip:* *P4 only allows you to select a single file of roving data. However, if your data set spans two or more RINEX files, you can combine these files into one and process the combined file with P4. Use the DOS* '`copy`' *command to combine files. For example, if you had RINEX files from a site named 'NOTT' for 2 consecutive days (269 and 270), you could use the following DOS command to create a file named* `NOTT2DAY.01O` *which contained the data from both days:*
>
> ```
> copy NOTT2691.01O+NOTT2701.01O NOTT2DAY.01O
> ```
>
> *(note that the data files which are combined in this way should be listed in chronological order in the* '`copy`' *command. P4 will generate errors if the RINEX data is out of order)*

STEP 2
CHOOSE A RINEX FILE FOR THE 'REFERENCE' RECEIVER

The 'Reference' receiver is the receiver which will provide the differential corrections in a DGPS solution, or carrier phase data at a known point. If you simply wish to produce a stand-alone pseudorange solution, you do not need to specify a reference receiver.

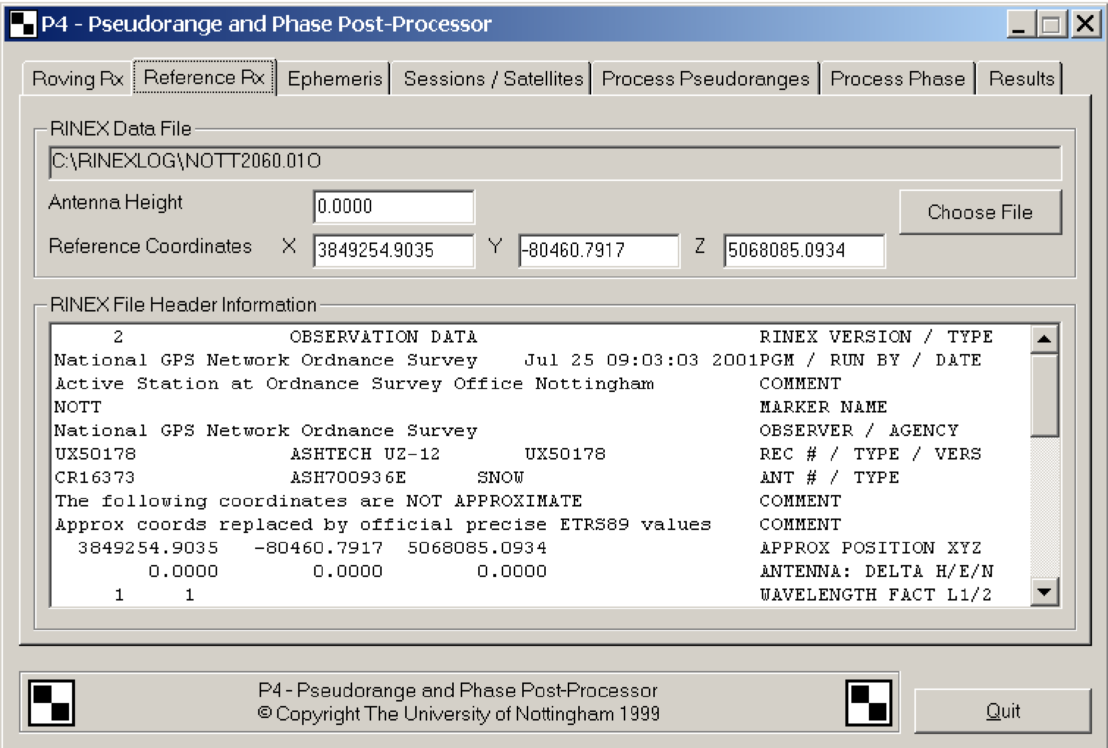


Figure 6 – 'Reference' Receiver File Selection

Select the 'Reference Rx' tab, and use the 'Choose File' button to bring up a file selection dialog box. Use this to locate and open the RINEX file for the reference receiver. As with the roving receiver, once a file has been opened, the grey box at the top of this page will be filled with the full path and filename. This filename will be recorded in the `P4.INI` file, and will be used as the default reference receiver filename the next time P4 is executed (but, as before, it will still need to be 'opened' explicitly, using the 'Choose File' button). When a file is opened, P4 will carry out the same steps as it does for a roving receiver, ie. the header box will be filled, the approximate coordinates and antenna height will be extracted, and the file will be scanned.

Tip:	*Assuming that this RINEX file is from a receiver at a known location, the known* 'Reference Coordinates' *should be typed in at this stage, into the boxes below the filename. If you do not know them, the approximate coordinates found in the RINEX header will be used as the reference coordinates for the DGPS or carrier phase processing, with potentially misleading consequences. Different reference receivers and organisations have different strategies for recording the approximate coordinates in a RINEX file. It is possible that the approximate coordinates in the RINEX header may be many metres different from the correct coordinates (for instance, if they are based on the receiver's instantaneous stand-alone solution). All post-processed coordinates will then be in error by the same amount.*

If you do know the correct Reference Coordinates, and you enter them in the reference coordinates boxes, P4 will take steps to ensure that you don't have to re-enter them every time you use data from the same station. P4 will create a section in the `P4.INI` file to record the manually entered coordinates. The name of the ini file section will be the first 4 characters of the RINEX file name. Since the normal RINEX file naming convention is to use the name of the survey marker to create the first 4 characters of the filename, this means that the `P4.INI` section should reflect the name of the survey marker. Whenever a reference file with the same initial 4 characters is opened in future, P4 will ask if you wish to update the reference coordinates with those found in the `P4.INI` file.

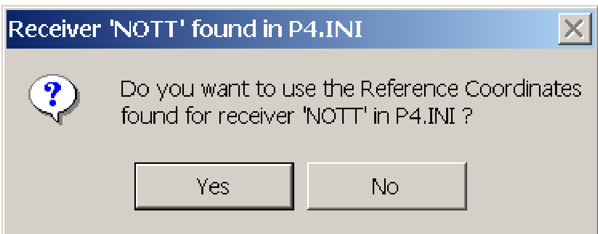


Figure 7 – Reference Coordinate Update

This feature of P4 is included as a convenience. If you regularly use the same reference receiver in your processing, and this reference receiver is known to be at a permanent location, this feature will save you the task of finding and entering the known coordinates every time you process a new data file.

> *Tip: If for some reason your reference file has the same initial 4 characters in its filename as a previously used reference file, but it is not at the same location, then the reference coordinates would be updated with the WRONG values. This is the reason that P4 asks you, before updating the coordinates, whether you want values from the ini file to be used.*

To indicate that the reference coordinates are NOT those found in the RINEX header, the values are displayed in bold type whenever you change them manually, or they are updated from the ini file. This is simply to alert you.

As with the roving receiver, P4 only allows you to select a single file of reference data. You can use the DOS '`copy`' command to combine several RINEX files, but remember to combine them in chronological order.

STEP 3
CHOOSE A SATELLITE 'EPHEMERIS' FILE

The satellite ephemeris file contains the information required to compute the coordinates of the GPS satellites whenever a pseudorange or carrier phase measurement is being processed.

P4 can accept either a

- **Broadcast Ephemeris**, which is the same ephemeris that GPS receivers use in real-time to compute positions, or a
- **Precise Ephemeris**, which is normally computed within one or two days from global tracking data, and used for high precision post-processing.

A Broadcast Ephemeris must be supplied in RINEX format. RINEX broadcast ephemeris files usually have a filename extension of the form 'yyN', where 'yy' represents the last two digits of the year, and 'N' is used to denote a 'Navigation' data file. The US NGS CORS web site previously included RINEX broadcast ephemeris files with a .ORB extension. Both of these extensions are supported by P4. Precise ephemeris files are supported if they are in SP3 format. These usually have the extension .SP3, which is also supported by P4.

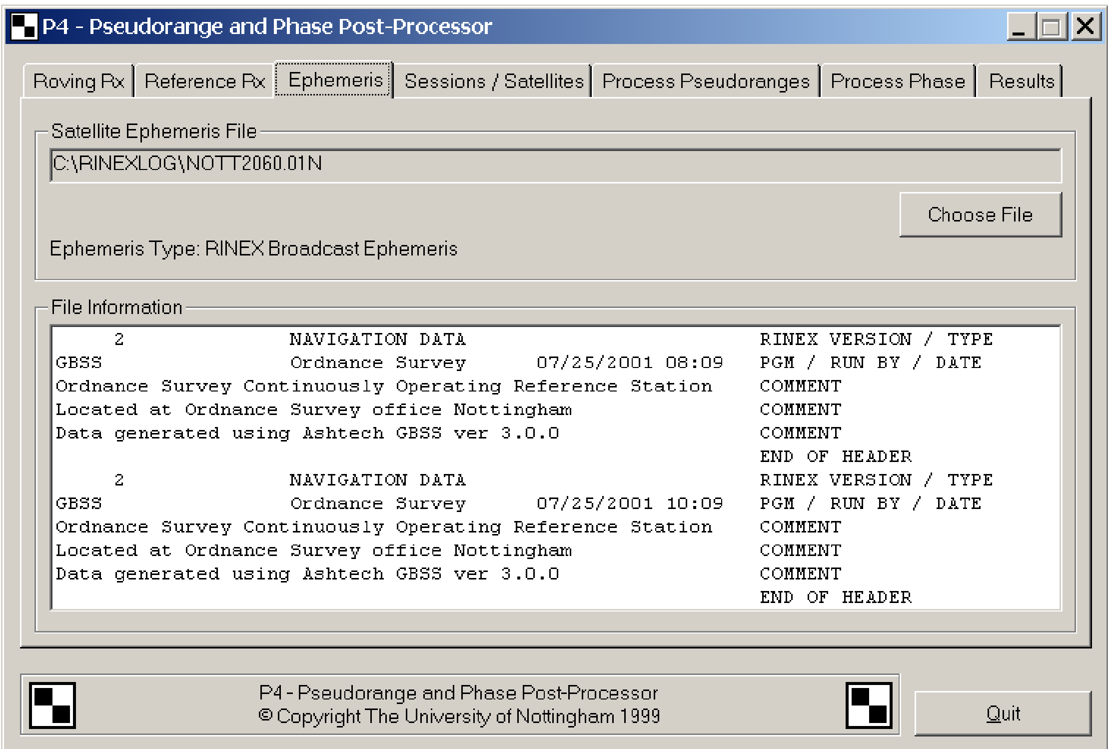


Figure 8 – 'Ephemeris' File Selection

Select the 'Satellite Ephemeris' tab, and use the 'Choose File' button to bring up a file selection dialog box. Use this to locate and open the ephemeris file. Once again, after a file has been opened, the grey box at the top of this page will be filled with the full path and filename. This filename will be recorded in the `P4.INI` file, and will be used as the default ephemeris filename the next time P4 is executed (and, once again, it will still need to be 'opened' explicitly, using the 'Choose File' button). Assuming that the supplied file is either a RINEX broadcast ephemeris or an SP3 precise ephemeris, the ephemeris type will be recorded underneath the filename, and any header lines in the file will be echoed to the 'File Information' box.

P4 will then scan the ephemeris file to determine which satellites are included, and the start and end times of the ephemeris.

As with the roving and reference receiver data files, P4 only allows you to select a single file of ephemeris data. If you are using RINEX broadcast ephemerides, and your data spans the period of more than one broadcast ephemeris file, you can use the DOS '`copy`' command to combine several RINEX ephemeris files. In this case, the order of the ephemeris files is not important, as P4 sorts the input ephemeris records as it reads them in. Note that the broadcast ephemeris file selected in the figure above has been created by combining two separate files with the DOS '`copy`' command. As a consequence, the header information from both files is visible in the 'File Information' box.

Currently, P4 will NOT allow the combination of SP3 format precise ephemeris files in this way. This is scheduled for a future release of P4.

STEP 4
DEFINE THE SESSION TIMES AND SATELLITE CONSTELLATION

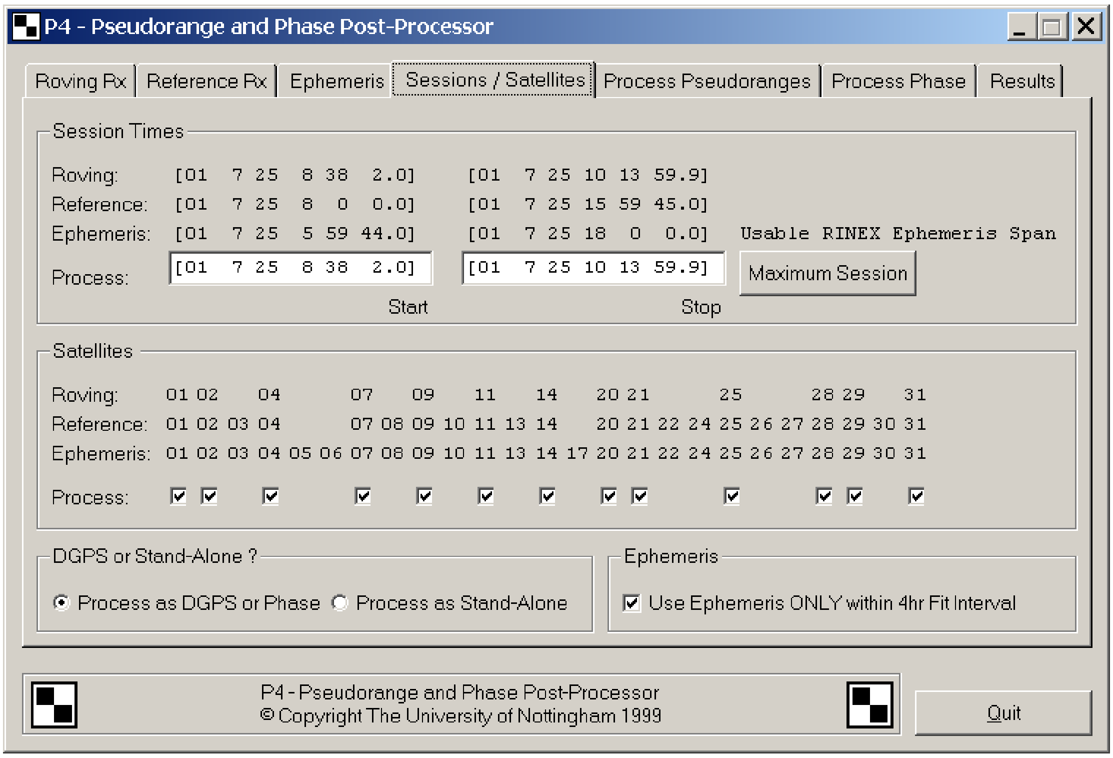


Figure 9 – Sessions / Satellites Tab

This tab allows you to select the start and end times of the session, and the satellites to be used in the processing. Using the results of the file scans that were carried out when the files were opened, P4 identifies:

- The maximum period of data which is common to the roving receiver, the satellite ephemeris and, if performing a DGPS or carrier phase solution, the reference receiver. By default, this maximum period is selected as the processing session.
- Every satellite which is common to the roving receiver, the satellite ephemeris and, if performing a DGPS or carrier phase solution, the reference receiver. By default, every common satellite is selected for processing.

SESSION TIMES

If the data files do not overlap, P4 will warn you that there is 'no common data'. Assuming there is some overlap and P4 has identified the maximum overlap period, you may edit the session start and stop times to define a shorter period. The times are in the format '`[YY MM DD hh mm ss.s]`', where

- `YY` corresponds to the last two digits of the year,

- `MM` corresponds to the Month
- `DD` corresponds to the Day (of the Month)
- `hh` corresponds to the hour of the day (24 hr format)
- `mm` corresponds to the minutes
- `ss.s` corresponds to the seconds

If you attempt to define a longer period, P4 will warn you and revert to the earliest start time and/or latest finish time. You can reset the selected period to the maximum possible period by clicking on the 'Maximum Session' button at any time.

Start and finish times for the ephemeris files are determined by P4 in the following manner.

- Broadcast ephemeris elements are usually valid for 2 hrs before and after the associated timetag. Broadcast ephemeris files usually contain several sequential sets of elements for each satellite, each with an associated 4-hour window. P4 therefore limits the period within which a broadcast ephemeris file can be used to 2 hours before the timetag of the earliest element set until 2 hours after the latest.

> *Tip:* *Outside the 4-hour window associated with an element set, the broadcast ephemeris accuracy degrades gracefully and, particularly in a differential solution where ephemeris accuracy is less important than in a stand-alone solution, the use of an element set outside the 4-hour window may be acceptable. Hence, if it is not possible to get the correct broadcast ephemeris file for your data period, P4 gives you the option to remove the 4-hour limit on a broadcast ephemeris file. By default, the* 'Use Ephemeris ONLY within 4hr Fit Interval' *check box will be checked whenever a broadcast ephemeris file is opened. However, 'unchecking' this option will force P4 to use the supplied broadcast ephemeris file even if does not overlap the RINEX data files (note that this option is unavailable when an SP3 precise ephemeris file is selected).*

- Precise Ephemeris files in the SP3 format consist of satellite positions at fixed intervals. To process data, P4 must interpolate between these positions onto the required epochs. P4 uses an interpolation scheme which requires 5 positions before the current epoch and 5 after. This means that the usable period of an SP3 file starts at the 5th epoch and finishes 5 epochs from the end. Since a typical SP3 file has an epoch interval of 15 minutes, this generally means that the first and last hours of the file are not usable by P4. However, P4 will accept any SP3 file, and will use the actual epoch interval to compute the usable period of the ephemeris.

SATELLITES

In the 'Satellites' frame, P4 will produce a check box for every satellite that is common to all the data files, and by default every check box will be checked. You have the option to 'uncheck' individual satellites in order to remove them from your solution. You should only do this if you have a particular reason to suspect that a satellite is giving poor quality measurements, as there are other means to allow low elevation satellites or low signal-to-noise measurements to be excluded (see Steps 5 and 6 below for a description of processing options).

The 'DGPS or Stand-Alone ?' frame allows you to select the type of solution to be performed. It is principally a processing option, and is therefore available on the 'Processing' tab. However, it is duplicated on this tab because the type of solution you select will affect both the session times and the common satellites.

- When you select 'Process as DGPS or Phase' (the default), P4 will expect a reference receiver file to be open, and the session times and common satellites will be determined using the roving receiver, the ephemeris and the reference receiver. In this mode, you will be warned that there is 'no common data' until all three data files (Roving, Reference and Ephemeris) are opened.
- When you select 'Process as Stand-Alone', P4 will not use the reference receiver, even if a reference file has already been opened, and the session times and common satellites will be computed only from the roving receiver and the ephemeris.

A further consequence of switching between DGPS and Stand-Alone is that the 'Reference Rx' tab will disappear when Stand-Alone processing is selected, and reappear when DGPS processing is selected. This is simply intended as a visual reminder of the type of processing you have selected.

STEP 5

SELECT THE PSEUDORANGE PROCESSING AND OUTPUT OPTIONS, AND PROCESS THE PSEUDORANGE DATA

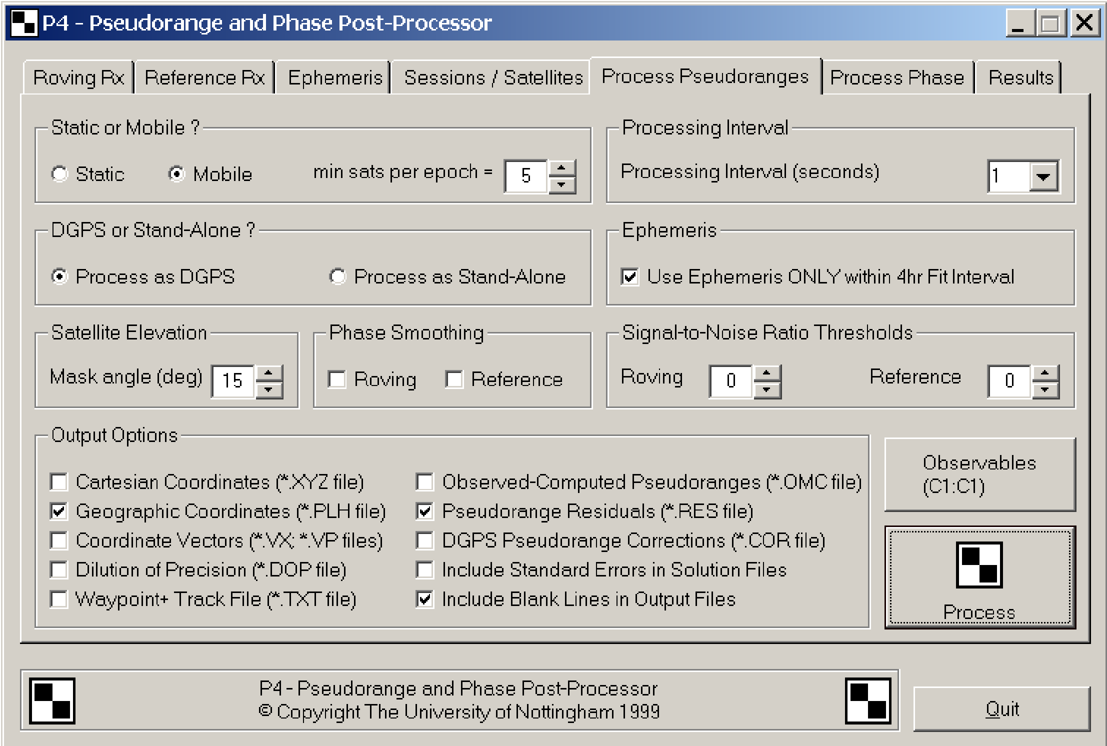


Figure 10 – Pseudorange Processing Options

On this tab you can select the pseudorange processing options to apply, and define the output files that will be produced. This tab also contains the 'Process' button, which is where you instruct P4 to begin processing. The following sections describe each of the processing options.

STATIC OR MOBILE ?

This option tells P4 whether to treat the roving receiver as a mobile receiver or as a static receiver. When it is treated as a static receiver, every epoch of data contributes to a single overall coordinate solution from the entire session. When it is treated as a mobile receiver, each epoch of data is processed independently to give the track of the mobile.

> *Tip:* *Note that a receiver that was actually static can be processed as mobile, to produce a 'scatter plot' of the individual epochs of data. However, it is meaningless to process a receiver that was actually mobile as static.*

You also have the option to specify the minimum number of satellites per epoch. If any epoch has fewer than the minimum number of satellites then it is skipped. P4 requires an absolute minimum of 4 satellites per epoch, to resolve the 3-dimensional coordinates and the receiver clock offset. However, a solution involving only 4 satellites will be particularly susceptible to errors in the observations, and you may wish to use a minimum of 5 (the default) or even higher.

PROCESSING INTERVAL

This option allows you to specify the interval between the processed epochs. For instance, a RINEX data file with observations every second could be processed to give a solution every 30 seconds.

Note that the intervening epochs would simply be ignored - they would not contribute in any way to the solutions at the 30-second intervals.

Note also that the processing interval cannot be shorter than the natural data interval of either the roving or reference receivers. Thus, if a roving data file with 1-second data is processed in DGPS mode against a reference data file with 30-second data, solution epochs will be at 30-second intervals, corresponding to the reference epochs.

Whenever a roving or reference file is opened, or the solution type is changed between DGPS and Stand-alone, the drop-down list of possible processing intervals is altered so that it starts with the shortest possible processing interval.

> *Tip: You should be aware that although GRINGO always includes the 'interval' header line in the RINEX files it produces, other software packages do not always do so. If a reference file is opened which does not have the 'interval' header line, P4 will not know the interval of the data, and will assume 1-second. However, the output can not be at a shorter interval than the actual interval of the reference data, even if a shorter interval was specified.*

DGPS OR STAND-ALONE ?

This frame allows you to select the type of solution to be performed.

- When you select 'Process as DGPS' (the default), P4 will expect a reference receiver file to be open. It will use this file to provide DGPS corrections for every processed observation in the roving data file. Note that P4 will only use an observation from the reference data file if it has the same nominal epoch as the observation from the roving file. P4 does not allow for the real-time DGPS concept of 'latency' or 'age-of-correction'.

- When you select 'Process as Stand-Alone', P4 will not use the reference receiver, even if a reference file has already been opened. Coordinate solutions will be produced solely from the roving data file.

A further consequence of switching between DGPS and Stand-Alone is that the 'Reference Rx' tab will disappear when Stand-Alone processing is selected, and reappear when DGPS processing is selected. This is simply intended as a visual reminder of the type of processing you have selected.

EPHEMERIS

As described in Step 4 above (Define the Session Times and Satellite Constellation), P4 gives you the option to remove the 4-hour limit on a broadcast ephemeris file. This could be useful if it is not possible to get the correct broadcast ephemeris file for your data period, and you wish to force P4 to use a recent broadcast ephemeris file in a DGPS solution. By default, the 'Use Ephemeris ONLY within 4hr Fit Interval' check box will be checked whenever a broadcast ephemeris file is opened. However, 'unchecking' this option will force P4 to use the supplied broadcast ephemeris file even if does not overlap the RINEX data files (note that this option is unavailable when an SP3 precise ephemeris file is selected). There are occasions when this may be an acceptable approach (eg. when using a nearby DGPS reference station and a very recent broadcast ephemeris), but it should only be used with care, as out-of-date ephemeris files will give the wrong satellite coordinates. As a rule, this option should never be used when processing the data as Stand-Alone.

SATELLITE ELEVATION

This frame allows you to select an elevation mask angle (in degrees), so that observations to satellites below this angle are not used in the solution. This is useful to exclude satellites close to the horizon, where atmospheric errors are at their greatest. However, if you only have a few satellites in your data file, you may prefer to include low elevation satellites despite their atmospheric errors, in order to improve the geometry of your solution.

PHASE SMOOTHING

You can choose to use the carrier phase data in the roving and/or reference receiver data files to smooth the pseudorange data.. Although the phase measurements cannot give an indication of the true distance between the satellite and the receiver, phase smoothing uses the principle that changes in carrier phase measurements from one epoch to the next can give a more precise indication of the changing distance than the pseudoranges do. They can therefore be used to smooth the pseudoranges. The result is a smoother post-processed track.

A few points are worth noting.

- Firstly, since the carrier phase measurements do not contain any absolute range information, the resulting track will not be any better located in space, it will simply be smoother.
- Secondly, the smoothing filter relies on good quality phase data with few cycle slips. A cycle slip breaks the link between phase rate and pseudorange rate, so the filter is restarted every time a cycle slip is detected. As a result, phase data with a lot of cycle slips will not produce a significantly smoother track.
- Finally, modern geodetic GPS receivers often produce very precise pseudorange data which does not require phase smoothing. Although it is often very useful to phase smooth Garmin pseudoranges, data from other receivers, particularly those within permanent geodetic networks, may not benefit from this technique.

SIGNAL-TO-NOISE RATIO THRESHOLDS

The RINEX format includes a field which records the quality of the observations, according to the signal-to-noise ratio reported by the receiver. RINEX defines a scale from 1 (worst) to 9 (best). The RINEX-recommended minimum is 5, which means that observations with a signal-to-noise indicator below 5 should not be used in data processing. P4 provides you with a means to select a threshold value for both the roving receiver and the reference receiver, below which observations will not be used in the processing. The default values in P4 are 0, meaning that all observations will be used.

Not all receivers provide a value for this flag. Garmin receivers do not output a value in this RINEX scale. They do, however, output a value which corresponds to the signal strength bars displayed on the Garmin screens. In the development of GRINGO, an analysis of these values, and their correspondence with the height of the signal strength bars, was carried out to determine an empirical scale for the determination of the RINEX quality indicator. The value of 5 was chosen, somewhat arbitrarily, to match signals which reach the second horizontal grid line on the GPS12XL signal strength display. However, it has not yet been shown what signal strength corresponds to a 'usable' measurement. It is therefore possible to use the Signal-to-Noise Threshold in P4 to eliminate measurements with a low signal strength, but for GRINGO RINEX files it should be used with caution, as it is possible that measurements with lower values are still usable.

OUTPUT OPTIONS

P4 can produce a variety of output files, according to your requirements. All output files will be named after the roving receiver's RINEX file, but will have different extensions. All output files will be produced in a subdirectory of the directory in which the roving receiver's RINEX file is located.

> *Tip: This means that you must have write access to the path of the roving receiver's file - so it cannot be on a CD-ROM or a restricted network drive for instance.*

The subdirectory will be named as follows:

- For a stand-alone solution, the subdirectory will be named after the first 4 characters of the roving receiver's data file. According to the RINEX file naming convention, these 4 characters represent the name of the survey marker. For instance, a roving receiver RINEX file recorded on day 123 of 1999, at a survey marker in Nottingham, may have the name `NOTT1231.99O`. If this file was located in the directory '`C:\GRINGO\LOGS\`', then P4 would locate the stand-alone solution files in '`C:\GRINGO\LOGS\NOTT\`'.
- For a DGPS solution, the subdirectory name will be constructed from the first 4 characters of the roving receiver's data file and the first 4 characters of the reference receiver's data file. For instance, if the data file used in the above example was processed in DGPS mode against the reference station in, say, Herstmonceux in the UK (eg. `HERS1230.99O`), P4 would locate the DGPS solution files in '`C:\GRINGO\LOGS\NOTTHERS\`'.

In the above examples, each output file would be named '`NOTT1231.ext`' where '`ext`' will represent the extension used for the specific type of output, as follows:

.XYZ

An output file with this extension will contain the roving receiver's coordinates expressed as WGS84 Earth-centred, Earth-fixed (ECEF) cartesian coordinates. The units are metres. This output file will also contain the roving receiver's clock offset (in milliseconds), and the number of satellites used at each epoch.

.PLH

An output file with this extension will contain the roving receiver's coordinates expressed as WGS84 Latitude, Longitude and Ellipsoidal Height. The units are decimal degrees for latitude and longitude, and metres for height. This output file will also contain the roving receiver's clock offset (in milliseconds), and the number of satellites used at each epoch.

.VX

An output file with this extension will contain the ECEF cartesian coordinate differences between the roving receiver and the reference receiver, if a DGPS solution was specified. The coordinate differences will be expressed in metres. This output file will also contain the roving receiver's clock offset (in milliseconds), and the number of satellites used at each epoch.

.VP

An output file with this extension will contain the coordinate differences in latitude, longitude and ellipsoidal height, between the roving receiver and the reference receiver, if a DGPS solution was specified. The coordinate differences will be expressed in metres in all cases. This output file will also contain the roving receiver's clock offset (in milliseconds), and the number of satellites used at each epoch.

> *Tip: The* `.VX` *and* `.VP` *output options will only be available when a DGPS solution is selected.*

.DOP

An output file with this extension will contain various 'Dilution of Precision' values. DOP values indicate the strength of the solution, as determined purely by the satellite-receiver geometry. Dimensionless parameters, they are used to scale the precision of the observed range measurements to give an indication of the precision of particular components of the solution.

For instance, if the pseudoranges had a nominal precision of 2 m, and the Horizontal DOP value was 3, the precision of the Horizontal position solution would be given by 2 m x 3 = 6 m.

P4 outputs five DOP values, namely:

- **GDOP**: Geometrical Dilution of Precision (relating to all unknowns, ie. 3D coordinates and time solution)
- **PDOP**: Position Dilution of Precision (relating to the 3D coordinates)
- **HDOP**: Horizontal Dilution of Precision (relating to the horizontal 2D coordinates)
- **VDOP**: Vertical Dilution of Precision (relating to vertical coordinates only)
- **TDOP**: Time Dilution of Precision (relating to the time solution only)

.TXT

An output file with this extension will contain the roving receiver's coordinates expressed in a format recognised by the popular Waypoint+ waypoint management program. If a mobile solution is performed, the `.TXT` file will be a Waypoint+ 'track' file, containing the coordinates derived at every epoch. If a static solution is performed, the `.TXT` file will be a Waypoint+ 'waypoint' file containing a single waypoint.

.OMC

An output file with this extension will contain the 'observed minus computed' pseudoranges at each epoch. In a DGPS solution these will include the contribution of the DGPS corrections. At each epoch, all of the observed minus computed values will be output with respect to the average of all the values at that epoch, and the average value will be converted to milliseconds and expressed as the (a priori) receiver clock offset. This process removes the major part of the observed minus computed value, so that the remainder is easier to view/plot.

.RES

An output file with this extension will contain the pseudorange residuals at each epoch, ie. the difference between the (DGPS corrected) pseudoranges and the ranges implied by the coordinate solution.

.COR

In a DGPS solution, an output file with this extension will contain the DGPS pseudorange corrections applied by P4 at each epoch.

Apart from the Waypoint+ files, each line of the above output files will be timetagged using the GPS time of week (seconds since midnight Saturday/Sunday). More recognisable date and time fields are included on the end of each line of output. Each output file will be a simple ASCII file with fields separated by commas. This type of output has been selected to be both easily readable, and simple to import into most popular spreadsheet programs for data visualisation.

For a mobile solution, each line of an output file corresponds to the solution from a single epoch of data. Coordinates (or coordinate vectors), clock offsets and residuals relate to the observations from that epoch alone. For a static solution, P4 operates sequentially, producing a solution after each successive epoch of data is added. The coordinate solution at epoch 'n' therefore corresponds to the answer that would have been produced if only the first 'n' epochs had been recorded. The final line of the coordinate (and vector) output files (`.XYZ`, `.PLH`, `.VX` and `.VP`) corresponds to the final solution from the entire session. At each epoch, the clock offset in a static solution is computed from the observations at that epoch alone, using the coordinate solution obtained from all data up to that epoch. The residuals are therefore computed with respect to the current position solution and this epoch's clock offset.

> *Tip: When a static solution is performed, the last line of the output files corresponds to the final solution. The earlier lines show how the solution has converged to the final solution.*

INCLUDE STANDARD ERRORS IN SOLUTION FILES

Using this option, the output files can be made to include standard errors of the coordinate (and vector) solutions. These are always expressed in metres, and are appended to the end of each output line.

INCLUDE BLANK LINES IN OUPUT FILES

By default, P4 will produce a line of output for every epoch that it attempts to solve. If it fails to produce a solution, perhaps because there are two few satellites, or there are no DGPS corrections, then it will produce a timetagged line of output with a brief explanation of the reason. However, principally to make the output files easier to plot in a spreadsheat package, P4 provides you with the option to toggle this feature on or off. When this option is not checked, only epochs which P4 was able to solve are included in the output.

OBSERVABLES

The GPS L1 frequency is modulated with two timing codes, namely the C/A-code (Coarse/Acquisition) code and the P-code (Precise). The pseudoranges output by the Garmin receivers correspond to measurements with the C/A-code, but some receivers are able to make measurements with the P-code. These are usually more precise than the C/A-code measurements.

The RINEX standard allows for both of these observables to be recorded (as well as many other observables). The RINEX notation for the L1 C/A-code pseudorange is C1, and for the L1 P-code pseudorange it is P1.

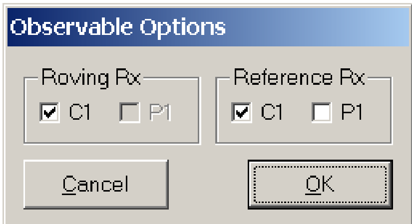


Figure 11 – Observable Options

P4 gives you the option to separately select the L1 frequency observable that you wish to process for both the Roving and Reference receivers. This may be useful in cases where your reference receiver data file only contains the P1 observable for instance. The 'Observables' button will bring up the window shown in Figure 11. Only those observables found in the header of each RINEX file will be enabled. By default, the C1 observable will be selected for both receivers, unless only the P1 observable is included in the data file. You must select at least one observable for each data file (the 'Reference Rx' frame will be disabled if you select stand-alone processing), and P4 will warn you if you inadvertently deselect both options for one of the open data files.

> *Tip: The caption on the* 'observables' *button displays the currently selected observables. If you are happy to process with these default observables, you do not need to click on this button.*

PROCESS

When you are happy with the processing and output file options, click on the 'Process' button to begin processing. Progress will be indicated in the frame at the bottom of the page.

> *Tip: You can force P4 to jump to the* 'Process Pseudoranges' *tab and begin processing at any time, simply by pressing the* 'F5' *key on your keyboard.*

Before starting to process, P4 will perform a number of basic checks on your data files and selected options.

- It checks that you have assigned a data file for the roving receiver, and, if you have selected DGPS processing, that you have assigned a (different) file for the reference receiver. If you have not assigned a reference file, P4 asks if you wish to process the data as stand-alone.
- It checks that you have assigned an ephemeris file. Unless you have opted to use a broadcast ephemeris outside its 4 hour fit interval, P4 will check that the ephemeris overlaps the RINEX data files.
- It checks that you have at least 4 satellites selected
- It checks whether you have selected any output files. If not, you are asked whether you wish to proceed. Processing without any output options is not as pointless as it appears, because you will still be able to plot the coordinate solutions in the final step.

When the processing is complete, if the 'Static' option was selected, P4 offers you the opportunity to update the approximate coordinates of the Roving receiver. If you choose 'yes', the Approximate Coordinates displayed on the 'Roving Rx' tab will be updated with the solution from this run. This option is included as an aid to the carrier phase processing in the next step (P4 employs a cycle slip detection process that benefits from having Roving receiver coordinates that are consistent with those of the Reference receiver).

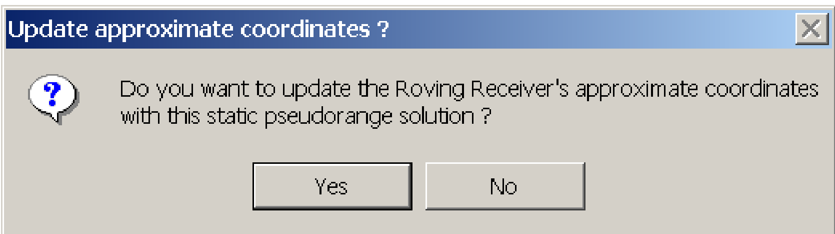


Figure 12 – Update approximate coordinates ?

STEP 6

SELECT THE CARRIER PHASE PROCESSING AND OUTPUT OPTIONS, AND PROCESS THE CARRIER PHASE DATA

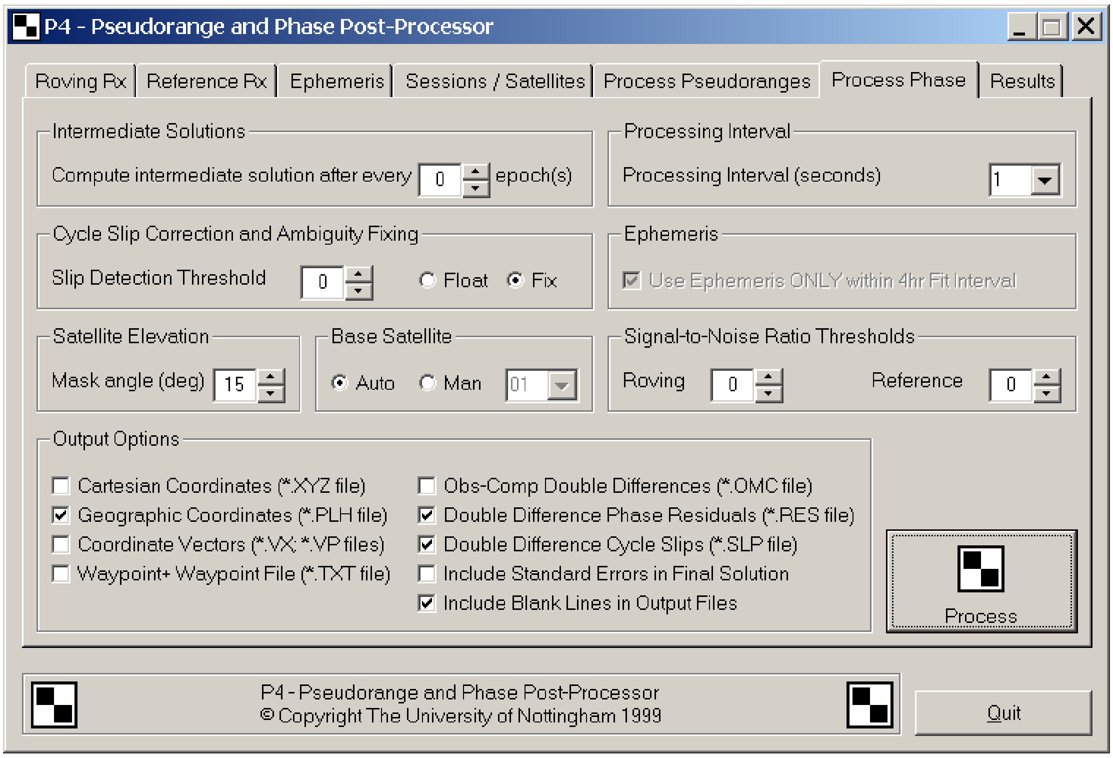


Figure 13 – Carrier Phase Processing Options

On this tab you can select the carrier phase processing options to apply, and define the output files that will be produced. This tab also contains the 'Process' button, which is where you instruct P4 to begin processing. The following sections describe each of the processing options.

> *Tip: P4 uses a conventional 'double difference' approach to carrier phase processing. P4 will ONLY process carrier phase data from a single static baseline. If the roving receiver is mobile, the only processing option in P4 is to use the pseudoranges. If you have more than one baseline to process, they must be processed separately.*

INTERMEDIATE SOLUTIONS

This option specifies whether, and how often, P4 should produce a solution from the accumulating observations. By default, P4 will only produce a single coordinate solution from the entire data set. However, the equations are built up from the observations epoch by epoch as the processing proceeds, and can usually be solved at any point in the process to produce an 'intermediate solution'. The 'Intermediate Solutions' option allows you to specify how many epochs should be accumulated between these intermediate solutions. The default of zero tells P4 not to produce any intermediate solutions, so the only output is from the entire data set.

Note that if this option is used in conjunction with a 'Processing Interval' other than 1, the interval between intermediate solutions will be the PRODUCT of the processing interval and the intermediate solutions option. For instance, if the processing interval is set to 15 seconds, and you request intermediate solutions every 4 epochs, the interval between intermediate solutions will be 4 x 15 seconds, giving one intermediate solution every minute.

> *Tip: It should be remembered that P4's carrier phase processing can ONLY be applied to a static baseline, so although the* 'Intermediate Solutions' *option may produce multiple rows in the output files, these solutions should NOT be interpreted as the 'track' of a mobile receiver. They simply show the way that the static solution converges to its final values.*

PROCESSING INTERVAL

This option allows you to specify the interval between the processed epochs. For instance, a RINEX data file with observations every second could be processed to give a solution every 30 seconds.

- Note that the intervening epochs would simply be ignored - they would not contribute in any way to the solutions at the 30-second intervals.
- Note also that the processing interval cannot be shorter than the natural data interval of either the roving or reference receivers. Thus, if a roving data file with 1-second data is processed against a reference data file with 30-second data, solution epochs will be at 30-second intervals, corresponding to the reference epochs.

Whenever a roving or reference file is opened, the drop-down list of possible processing intervals is altered so that it starts with the shortest possible processing interval.

> *Tip: You should be aware that although GRINGO always includes the 'interval' header line in the RINEX files it produces, other software packages do not always do so. If a reference file is opened which does not have the 'interval' header line, P4 will not know the interval of the data, and will assume 1-second. However, the output can not be at a shorter interval than the actual interval of the reference data, even if a shorter interval was specified.*

CYCLE SLIP CORRECTION AND AMBIGUITY FIXING

Carrier phase data initially tells us nothing about the distance between the receiver and the satellite. A carrier phase observation, as the name suggests, is simply a measure of the phase of the carrier wave onto which the timing and navigation signals are modulated. When a receiver first locks on to a satellite, it cannot determine how many whole wavelengths there are between the receiver and the satellite, but the phase measurement indicates the fraction of the last wavelength. Since the L1 wavelength is approximately 19 cm, a phase measurement of even a few degrees leads to a very precise measurement. While the receiver maintains a lock on the satellite, it can track the number of whole cycles that are accumulated, and add a measure of the carrier phase, so that successive phase measurements give a very precise measure of the *change* in the range, but they are still ambiguous about the true range.

When processing carrier phase data, one of the tasks is to resolve this 'carrier phase ambiguity', ie. to determine the number of whole wavelengths that existed in the measurement at the moment the receiver first locked on to the satellite. In fact, in double difference processing, the pure carrier phase ambiguity is not determined, but instead the task is to determine a combination of 4 ambiguities, involving two satellites and two receivers (the roving and reference receivers), known as the 'double difference ambiguities'. The double difference phase solution is configured in such a way that these initial double difference ambiguities are expressed as 'unknown' parameters in the equations, and the solution attempts to use the observational data to solve for these ambiguities.

It can be shown that these double difference ambiguities should actually be integers, as they are simply combinations of the original pure phase ambiguities, which are themselves integers. However, the equations which lead to the solution of the ambiguities do not know that they should be integers, so they are solved as 'real' values. In general though, the coordinate solution will be more accurate if these 'real' values can be assigned their correct integer values. However, this is not always a straightforward task, and the resolution of carrier phase ambiguities, particularly when one of the receivers is moving, has been a 'hot' topic for research over many years.

P4 uses an elementary algorithm to resolve (or 'fix') the double difference carrier phase ambiguities. The algorithm can be invoked in the solution by selecting the 'Fix' option, and P4 will attempt to resolve the real-valued ambiguities into integers. The alternative is to let the solution 'Float', in which case the ambiguities are still solved for, but they are allowed to retain the 'real' values that the solution naturally leads to.

> *Note: A complication occurs when processing Garmin data, as the carrier phase data can actually have half-cycle ambiguities, as a consequence of the receiver's phase tracking strategy. Instead of resolving these ambiguities to integer values, P4 therefore attempts to resolve them to half-integer values.*

In the above discussion, it has been assumed that the receiver is able to maintain a lock on the satellites for the entire observing session, from the moment it first locks on. In practice, many things can cause the receiver to lose lock, such as obstructions in the line of sight, caused by passing people, vehicles etc, or the satellite passing behind buildings, trees etc. When this happens, the receiver is unable to track the whole number of accumulating cycles, and when it recovers lock on the satellite, it must reset the initial number of cycles. There will then be what is termed a 'cycle slip' in the phase data.

In processing, cycle slips introduce extra problems, as the initial ambiguities can no longer apply to the entire data set. P4 handles this situation by introducing extra unknown parameters into the solution whenever a cycle slip is detected. These slips should theoretically be integers, but again, as a consequence of the Garmin phase tracking strategy, half-integer cycle slips can occur, so P4 allows for half-integer slips. With sufficient data, the resolution of cycle slips is usually straightforward. Like the ambiguities above, the best solution usually comes from fixing these slips to their correct (half-)integer values. P4 will use the 'Fix'/'Float' option (described above) to determine whether to fix the detected slips, or leave them as their natural 'real' values.

The main problem for P4 is detecting a slip, in order to introduce an unknown and solve for the value of the slip. P4 uses a number of strategies to ensure that the majority of cycle slips are identified. P4 has an option to select a threshold for the detection of cycle slips, ie. any apparent slip above the threshold value should be identified. The default of zero forces P4 to identify and solve for any cycle slips. If your data set has a lot of cycle slips, you may wish to try a higher threshold initially, so that only the gross slips are corrected. The discussion of a typical processing session (Session 2 – A Static Receiver Processed as a Carrier Phase Baseline) at the end of this document may provide some additional hints for dealing with cycle slips.

EPHEMERIS

As described in Step 4 above (Define the Session Times and Satellite Constellation), P4 gives you the option to remove the 4-hour limit on a broadcast ephemeris file. This could be useful if it is not possible to get the correct broadcast ephemeris file for your data period, and you wish to force P4 to use a recent broadcast ephemeris file. By default, the 'Use Ephemeris ONLY within 4hr Fit

Interval' check box will be checked whenever a broadcast ephemeris file is opened. However, 'unchecking' this option will force P4 to use the supplied broadcast ephemeris file even if does not overlap the RINEX data files (note that this option is unavailable when an SP3 precise ephemeris file is selected). There are occasions when this may be an acceptable approach (eg. when using a nearby reference station and a very recent broadcast ephemeris), but it should only be used with care, as out-of-date ephemeris files will give the wrong satellite coordinates.

SATELLITE ELEVATION

This frame allows you to select an elevation mask angle (in degrees), so that observations to satellites below this angle are not used in the solution. This is useful to exclude satellites close to the horizon, where atmospheric errors are at their greatest. However, if you only have a few satellites in your data file, you may prefer to include low elevation satellites despite their atmospheric errors, in order to improve the geometry of your solution.

BASE SATELLITE

The 'base' satellite is a concept associated with the double difference processing employed by P4. At an epoch with 'n' satellites common to the roving and reference receiver, a total of 'n-1' *independent* double difference observations can be formed. It is usual to select these n-1 combinations in such a way that they all share a common satellite, known as the 'base' satellite. If the default 'Auto' option is selected, P4 will use the highest elevation satellite at each epoch as the base satellite. However, the 'Man' option allows you to manually select another satellite from those in the data set to be used as the base satellite throughout the session.

> *Tip: If you use the manual option to select a base satellite, you should be aware that any epoch that does not include the selected satellite will not be processed.*

SIGNAL-TO-NOISE RATIO THRESHOLDS

The RINEX format includes a field which records the quality of the observations, according to the signal-to-noise ratio reported by the receiver. RINEX defines a scale from 1 (worst) to 9 (best). The RINEX-recommended minimum is 5, which means that observations with a signal-to-noise indicator below 5 should not be used in data processing. P4 provides you with a means to select a threshold value for both the roving receiver and the reference receiver, below which observations will not be used in the processing. The default values in P4 are 0, meaning that all observations will be used.

Not all receivers provide a value for this flag. Garmin receivers do not output a value in this RINEX scale. They do, however, output a value which corresponds to the signal strength bars displayed on the Garmin screens. In the development of GRINGO, an analysis of these values, and their correspondence with the height of the signal strength bars, was carried out to determine an empirical scale for the determination of the RINEX quality indicator. The value of 5 was chosen, somewhat arbitrarily, to match signals which reach the second horizontal grid line on the GPS12XL signal strength display. However, it has not yet been shown what signal strength corresponds to a 'usable' measurement. It is therefore possible to use the Signal-to-Noise Threshold in P4 to eliminate measurements with a low signal strength, but for GRINGO RINEX files it should be used with caution, as it is possible that measurements with lower values are still usable.

OUTPUT OPTIONS

P4 can produce a variety of output files, according to your requirements. All output files will be named after the roving receiver's RINEX file, but will have different extensions. All output files will be produced in a subdirectory of the directory in which the roving receiver's RINEX file is located.

> *Tip: This means that you must have write access to the path of the roving receiver's file - so it cannot be on a CD-ROM or a restricted network drive for instance.*

For a carrier phase solution, the subdirectory name will be constructed from the first 4 characters of the roving receiver's data file and the first 4 characters of the reference receiver's data file. For instance, a roving receiver RINEX file recorded on day 123 of 1999, at a survey marker in Nottingham, may have the name `NOTT1231.99O`. If this file was located in the directory '`C:\GRINGO\LOGS\`', and was processed against the reference station in, say, Herstmonceux in the UK (eg. `HERS1230.99O`), P4 would locate the carrier phase solution files in '`C:\GRINGO\LOGS\NOTTHERS\`'.

In the above examples, each output file would be named '`NOTT1231.ext`' where '`ext`' will represent the extension used for the specific type of output, as follows:

.XYZ

An output file with this extension will contain the roving receiver's coordinates expressed as WGS84 Earth-centred, Earth-fixed (ECEF) cartesian coordinates. The units are metres. This output file will also contain the roving receiver's clock offset (in milliseconds), and the number of satellites used at each epoch.

.PLH

An output file with this extension will contain the roving receiver's coordinates expressed as WGS84 Latitude, Longitude and Ellipsoidal Height. The units are decimal degrees for latitude and longitude, and metres for height. This output file will also contain the roving receiver's clock offset (in milliseconds), and the number of satellites used at each epoch.

.VX

An output file with this extension will contain the ECEF cartesian coordinate differences between the roving receiver and the reference receiver. The coordinate differences will be expressed in metres. This output file will also contain the roving receiver's clock offset (in milliseconds), and the number of satellites used at each epoch.

.VP

An output file with this extension will contain the coordinate differences in latitude, longitude and ellipsoidal height, between the roving receiver and the reference receiver. The coordinate differences will be expressed in metres in all cases. This output file will also contain the roving receiver's clock offset (in milliseconds), and the number of satellites used at each epoch.

.TXT

An output file with this extension will contain the roving receiver's coordinates expressed in a format recognised by the popular Waypoint+ waypoint management program. Since a P4 carrier phase solution is always a static solution, the `.TXT` file will be a Waypoint+ 'waypoint' file containing a single waypoint.

.OMC

An output file with this extension will contain the 'observed minus computed' double difference carrier phase measurements at each epoch.

.RES

An output file with this extension will contain the double difference carrier phase residuals at each epoch, ie. the difference between the double differenced carrier phase observations and the double differences implied by the coordinate solution.

.SLP

An output file with this extension will include details of the double difference ambiguities and cycle slips relating to the processed data. This file can be both an output from and an input to P4, and can be used to manually resolve slips and ambiguities in cases where the automatic algorithms in P4 have not succeeded.

More details of the use of this file are given in the later description of a typical processing session (Session 2 – A Static Receiver Processed as a Carrier Phase Baseline).

INCLUDE STANDARD ERRORS IN SOLUTION FILES

Using this option, the output files can be made to include standard errors of the coordinate (and vector) solutions. These are always expressed in metres, and are appended to the end of each output line.

INCLUDE BLANK LINES IN OUPUT FILES

By default, P4 will produce a line of output for every epoch that it attempts to solve. If it fails to produce a solution, perhaps because there are two few satellites, or there are no DGPS corrections, then it will produce a timetagged line of output with a brief explanation of the reason. However, principally to make the output files easier to plot in a spreadsheat package, P4 provides you with the option to toggle this feature on or off. When this option is not checked, only epochs which P4 was able to solve are included in the output.

PROCESS

When you are happy with the processing and output file options, click on the 'Process' button to begin processing.

> *Tip: You can force P4 to jump to the* 'Process Phase' *tab and begin processing at any time, simply by pressing the* '`F6`' *key on your keyboard.*

Before starting to process, P4 will perform a number of basic checks on your data files and selected options.

- It checks that you have assigned a data file for the roving receiver, and that you have assigned a (different) file for the reference receiver. For carrier phase processing, you MUST have a reference receiver, so if a reference file is not yet opened, P4 automatically selects the 'Reference Rx' tab to allow you to open a reference file.
- It checks that you have assigned an ephemeris file. Unless you have opted to use a broadcast ephemeris outside its 4 hour fit interval, P4 will check that the ephemeris overlaps the RINEX data files.
- It checks whether you have selected any output files. If not, you are asked whether you wish to proceed. Processing without any output options is not as pointless as it appears, because you will still be able to plot the coordinate solutions in the final step.

If you have selected the necessary input files and valid processing options, P4 begins to process the carrier phase data.

If this is the first time you have processed this data, processing will begin immediately. Progress will be indicated in the frame at the bottom of the page. P4 goes though 3 separate stages.

- Firstly, P4 forms the observation equations, based on the double difference observations that it is able to form from the available data and the selected options. During this stage, P4 attempts to find cycle slips in the phase data, and introduces extra unknown parameters to solve for them.
- Secondly, P4 forms and solves the positioning equations from these observation equations. If P4 has identified a large number of cycle slips in the data, and has therefore introduced a lot of extra unknown parameters, you may notice that the progress bar for this second stage slows down. This is due to the increasing size of the equation matrices that are involved when extra unknowns are encountered.
- Thirdly, P4 computes the residuals from the double difference observations and has one last look for remaining cycle slips. If there are jumps in the residuals that P4 identifies as remaining cycle slips, P4 will warn you with the following message. You may wish to view the residuals (see Step 7 View the results), to confirm that the detected jumps actually correspond to remaining cycle slips.

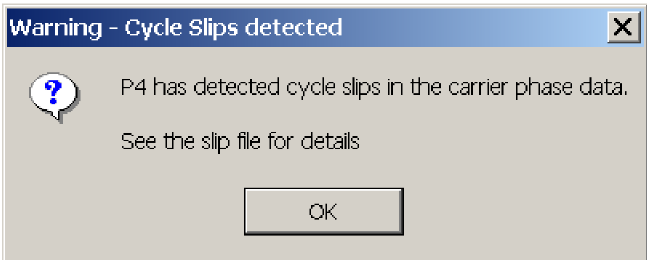


Figure 14 – Cycle Slips detected

Tip:	*Any solution in which cycle slips are not accounted for should be treated with extreme caution. ANY cycle slip will lead to the wrong answer, and a solution with a lot of unresolved cycle slips may be many metres in error.*

Having once processed this combination of data, you may have cause to re-process it, either with different processing options, or after manually correcting any remaining cycle slips.

When you next click on the Process button, P4 will find a slip file with the appropriate name (<roving_data_file_root>.SLP) in the results folder. In this case, P4 will alert you with the following screen, and give you several options for using the slip file. The use of these options is covered in more detail in the sample processing session, but the options may be summarised as follows:

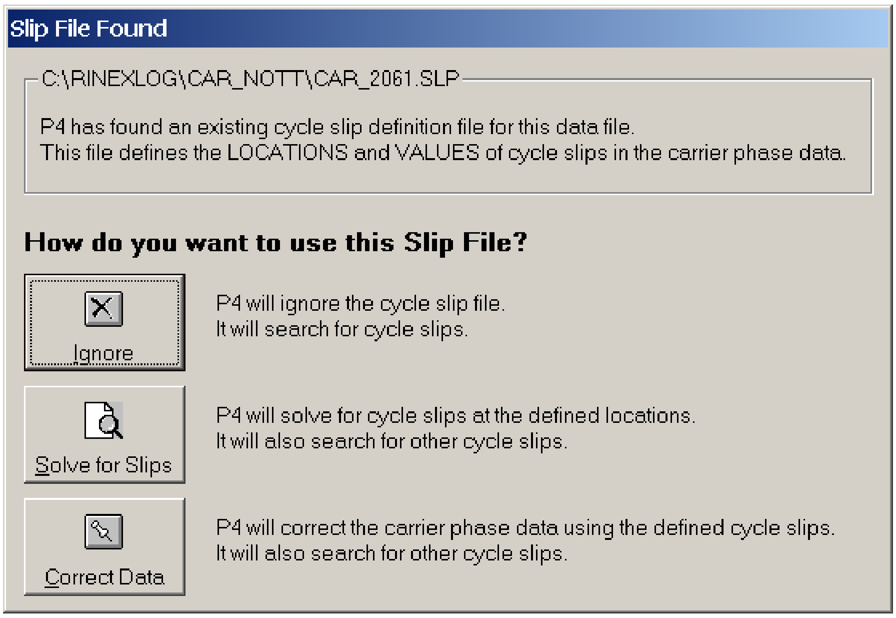


Figure 15 – Slip File Options

- **Ignore**. Use this option if you have not edited the slip file at all. Any information that was determined during the last processing run will be redetermined in the next run. This is particularly important if you have changed any settings that will change the amount of data that is used or the way it is used, such as the session times, the elevation mask, the signal-to-noise thresholds, the base satellite option etc. If the processed data is not exactly the same as before, the slip file may contain ambiguities and slips that are not necessarily relevant to this processing run.
- **Solve for Slips**. Use this option if you have previously processed the data and received the cycle slips warning. In this case, you may have edited the slip file to insert a timetag for a manually identified slip. P4 will then use the timetags in the slip file as markers for epochs at which additional cycle slips should be solved for. Hence, you do not need to know the amount of the slip at this epoch, you simply need to know that a slip occurred.
- **Correct Data**. Use this option if you have previously processed the data, and you are happy that no further slips are present in the data and that the slip file contains correctly fixed ambiguities and slips (ie. they have the correct (half-)integer values. In this case, P4 will correct the data using the slips detailed in the slip file, thereby reducing the number of unknowns in the solution, and resulting in a quicker solution. This option may be useful if you wish to try fixing slips that P4 was unable to determine a value for. It can also be useful if you have previously archived this session's slip file for future use.

STEP 7
VIEW THE RESULTS

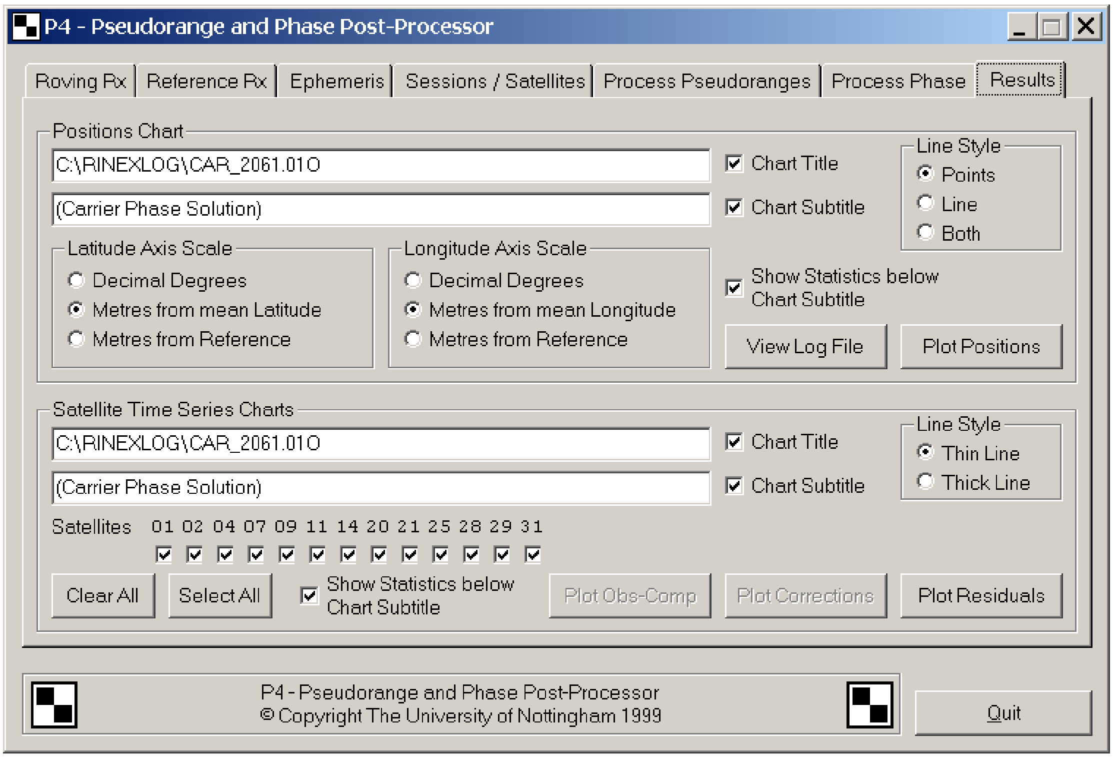


Figure 16 – Plotting Options

Once you have processed your data, you can produce a number of charts from the output.

There are two types of chart.

- You can plot the 2-dimensional position solutions, or
- You can plot a time series of residuals, DGPS corrections or 'observed minus computed' measurements.

POSITIONS CHART

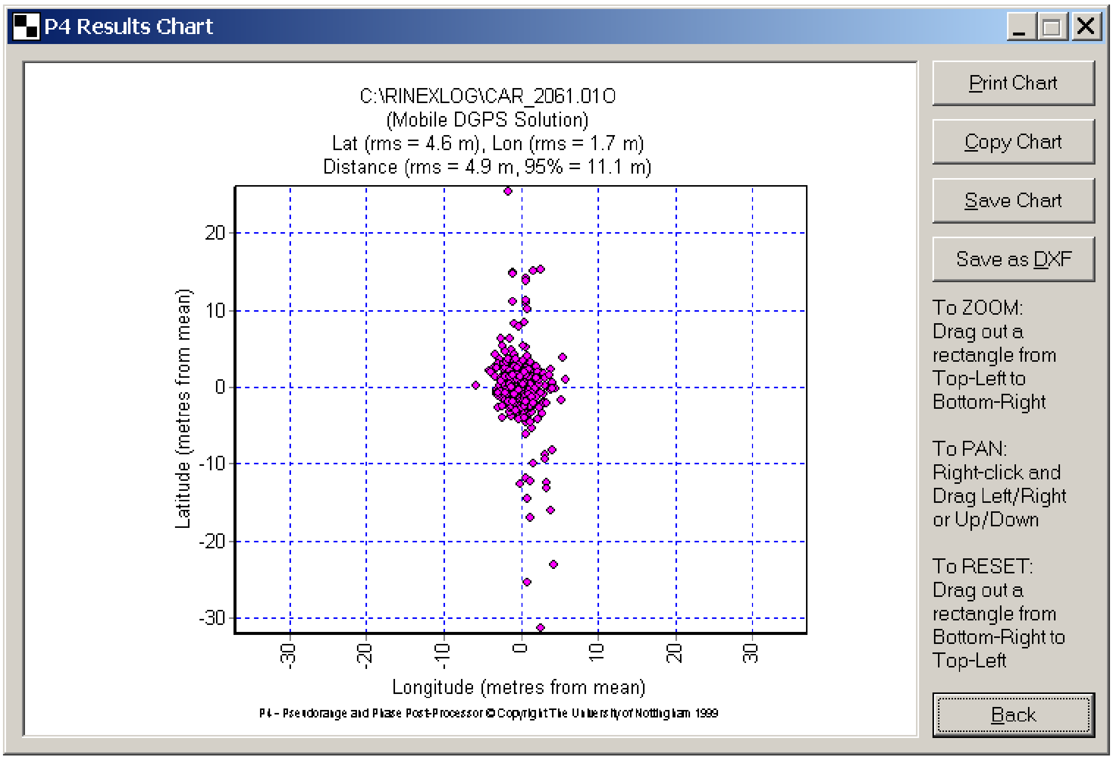


Figure 17 – A Sample Positions Chart

The positions chart consists of a plot of latitude against longitude. You have a number of options for axis labelling, but regardless of the selected format, the chart is constructed in such a way that the scale along both axes is the same, ie. one metre on the latitude scale will be the same size as one metre on the longitude scale (try doing that in most spreadsheet packages!). If you have selected one of the 'Metres from ... ' axis labelling options on each axis, you will notice a square grid, as a consequence of the common scale.

The axis labelling options are straightforward.

- 'Decimal Degrees' requires no explanation.
- 'Metres from Mean Latitude (or Longitude)' produces an axis where zero is the mean of all the points plotted, and the axis gridlines are marked in metres from that point. This is useful to assess the spread of solutions.
- 'Metres from Reference', which is only available after a DGPS or carrier phase solution, produces an axis where zero represents the latitude (or longitude) of the reference receiver, and the axis gridlines are marked in metres from that point. This is useful to assess the distance of your solution from the reference receiver.

P4 will produce a default title and subtitle for the chart, which you can edit or replace in the boxes provided. You can even opt not to include a chart title or subtitle, using the check boxes provided.

Using the 'Line Style' option, you can choose whether to plot the positions as discrete points, as a continuous line, or as both (points joined by a line).

P4 will also produce some basic statistics (mean, rms and 95% values), which will be plotted underneath the chart subtitle. You can opt to leave these off the chart if you wish.

You can produce a Positions Chart whenever P4 has produced a coordinate solution of any kind. P4 uses an internal temporary file to store the position results, so you do not need to specify any of the coordinate or vector output files on the 'Process' tab.

When a static pseudorange solution (either DGPS or stand-alone) is computed, the Positions Chart will still produce one 'dot' for each epoch of data in the solution. Although it is the solution from the entire data set that will be of interest (and this is output in the .LOG file), the positions plot shows how the solution has converged to its final value, as follows:

The **first** dot shows the solution from the **first** epoch of data;

The **second** dot shows the solution from the **first two** epochs of data;

The **nth** dot shows the solution from the **first n** epochs of data;

The **last** dot shows the solution from **all** epochs of data.

Such a plot will usually show a 'cluster' of dots, with a 'tail'. The 'tail' will correspond to the first few epochs, when each new epoch may have a significant effect on the cumulative solution. The 'cluster' will correspond to the later epochs, when the solution has virtually converged and each new epoch has only a small effect on the cumulative solution. This type of plot may be easier to visualise if the option to display 'points' and 'lines' is selected, so that the dots are joined sequentially by a line.

When a carrier phase solution is computed, the Positions Chart may show a series of dots from the cumulative solution, or it may simply show a single dot, representing the final solution. The series of dots will correspond to the 'Intermediate Solutions' setting on the 'Process Phase' tab. Again, this type of plot is useful to show how the solution has converged to the final value. If no intermediate solutions were computed (ie. the 'Intermediate Solutions' setting was zero), then only a single dot will appear on the plot. This would simply show the final coordinates or the final distance from the reference receiver, according to the axis scale settings.

SATELLITE TIME SERIES CHARTS

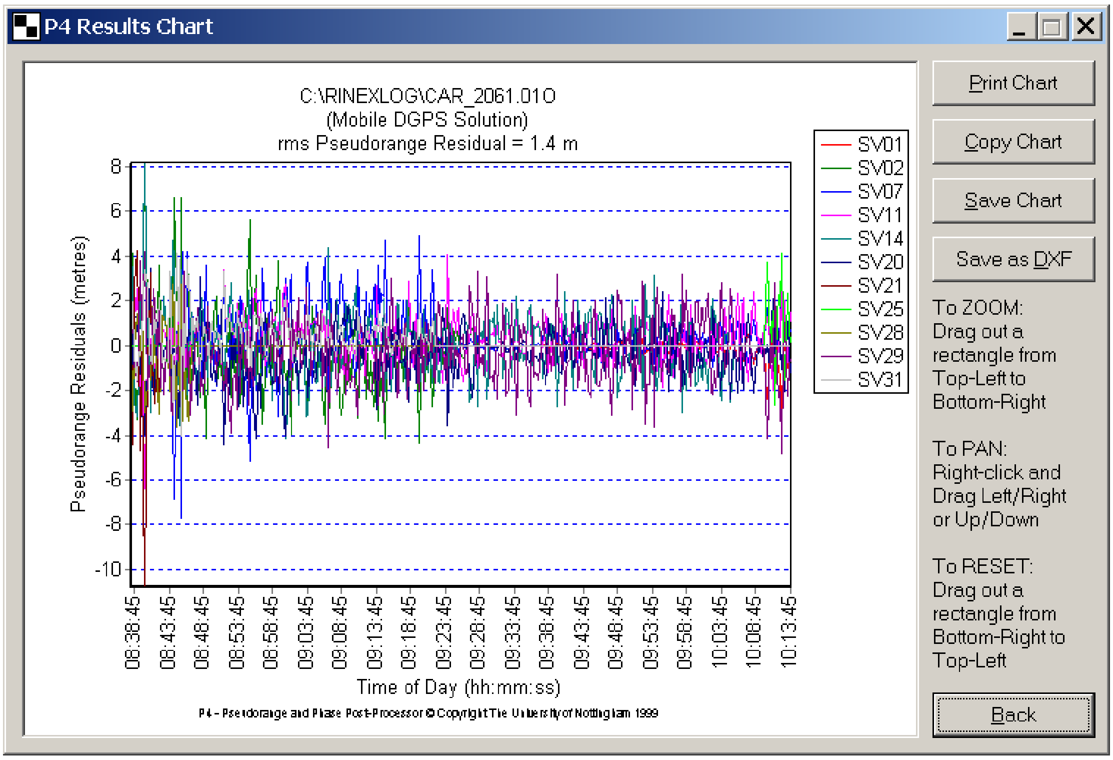


Figure 18 – A Sample Time Series Chart of Pseudorange Residuals

If you selected the .RES, .COR or .OMC output option on the 'Process' tab, then you will be able to plot the corresponding output file once processing is complete. P4 will produce a chart of residuals, DGPS corrections or 'observed minus computed' measurements against time of day (hh:mm:ss).

You can select which satellites from the solution you wish to plot, using the check boxes generated by P4 (use the 'Clear All' and 'Select All' buttons as required).

As with the Positions Chart above, you can edit and include/exclude the chart title and subtitle.

You can plot the time series with a Thick Line (generally better for viewing on screen) or a Thin Line (generally better for printing, or including in documents).

P4 will calculate the rms of the plotted data, and will include this below the chart subtitle. You can opt to exclude this from the plot if you wish.

When you click on the appropriate Plot button, P4 will bring up a new window with the plotted chart. For a positions chart, you may see the chart 'jump' momentarily, as P4 adjusts the axes to ensure a common scale along both axes.

Once the chart has been plotted, you have several options.

- The 'Print Chart' button can be used to send the chart to the default printer.

- The 'Copy Chart' button can be used to copy the chart to the clipboard in Windows Metafile Format (WMF). You can then paste the chart into a document or presentation. If your destination package gives you the option (eg. 'Paste Special' in MS Powerpoint), select Windows Metafile as the paste format.
- The 'Save Chart' button allows you to save the chart as a Windows Metafile for later use.
- The 'Save as DXF' button allows you to export the plotted data to a DXF file, which is recognised by many CAD and drawing packages. This may be useful if you wish to overlay the processed track onto a map, for instance.

LOG FILE AND MESSAGE FILE

In addition to the output files selected on the 'Processing' tab, P4 will create a log file and a message file each time the 'Process' button is pressed.

The log file keeps a record of the options selected and the data files used. It will also include a directory listing of the output files, including file sizes and dates.

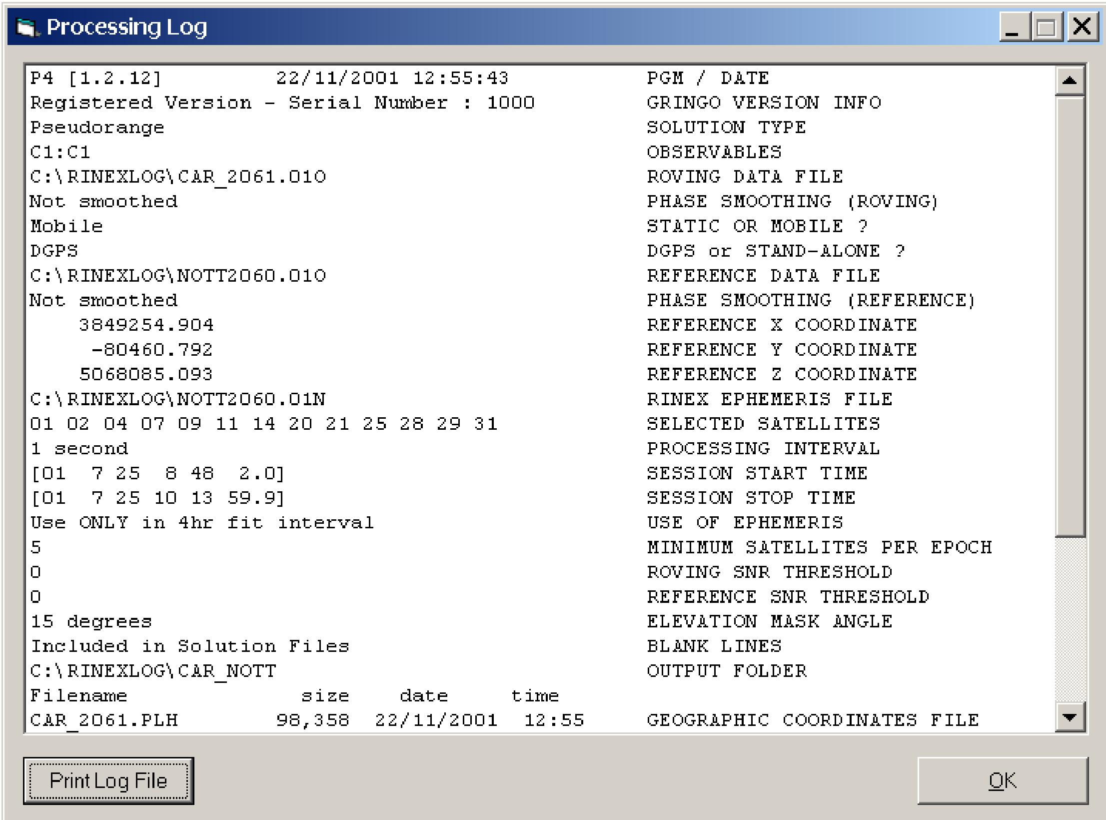


Figure 19 – Viewing a Sample Log File

The message file is used by P4 to record any problems with the processed data files, such as observations with low signal to noise ratios, missing DGPS corrections, or epochs with too few useable observations. Use this file to help you identify the cause of problem epochs in the data.

These two files will have the same basic name as the other output files (ie. the root of the roving data file name), and will be located in the same output directory. The log file will have a '`.LOG`' extension and the message file will have a '`.MSG`' extension.

SAMPLE PROCESSING SESSIONS

The following sample sessions should illustrate how to use the various processing options, and what to expect of the output.

SESSION 1 – A MOVING RECEIVER PROCESSED AS DGPS

A typical use of P4 might be to process the pseudorange data from a mobile receiver, using a nearby reference receiver to generate the DGPS corrections. This type of solution should produce a more accurate track of the receiver's motion than the basic stand-alone receiver can. It may be of use in a GIS application, for instance, for marking footpaths or other features on a map.

The following steps illustrate how to process this type of data file.

Step 1. Choose a RINEX file for the 'Roving' receiver. This step is detailed on page 5. Simply use the 'Choose File' button to start a file selection dialog, and navigate to the RINEX file recorded by your mobile receiver. If the roving receiver was at a constant height above the ground, you may wish to input the Antenna Height at this stage, so that the resulting track refers to ground level.

Step 2. Choose a RINEX file for the 'Reference' receiver. This step is detailed on page 7. Simply use the 'Choose File' button to start a file selection dialog, and navigate to the RINEX file recorded by the reference receiver. Be sure to check that the Reference Coordinates are correct, and that the reference receiver's Antenna Height (if applicable) is also correct.

Step 3. Choose a satellite Ephemeris file. This step is detailed on page 10. Simply use the 'Choose File' button to start a file selection dialog, and navigate to the ephemeris file you wish to use with these data files.

Step 4. Define the session times and satellite constellation (see page 12). At this stage, you will probably not have any reason to remove satellites from the solution, so unless you wish to limit the processing session times, you simply need to look at the 'Sessions / Satellites' tab to confirm that the session start and end times have been automatically determined. If these fields indicate 'no common data', it will be because the roving receiver and reference receiver data files correspond to different times, or because the ephemeris file does not overlap the session.

Step 5. Select the Pseudorange processing and output options, and process the pseudorange data (see page 15). The default options on this page should be sufficient for a first run through the data.

- By default, P4 will perform a mobile DGPS solution, using the shortest possible processing interval.
- If a broadcast ephemeris is used, it will be restricted to the 4hr window.

- A default mask angle of 15 degrees will be applied.
- If present, the C/A-code pseudoranges will be used (C1:C1), and phase smoothing will not be applied to either receiver.
- No data will be excluded on the basis of signal-to-noise ratio.
- The default outputs of `.PLH` and `.RES` are usually sufficient.

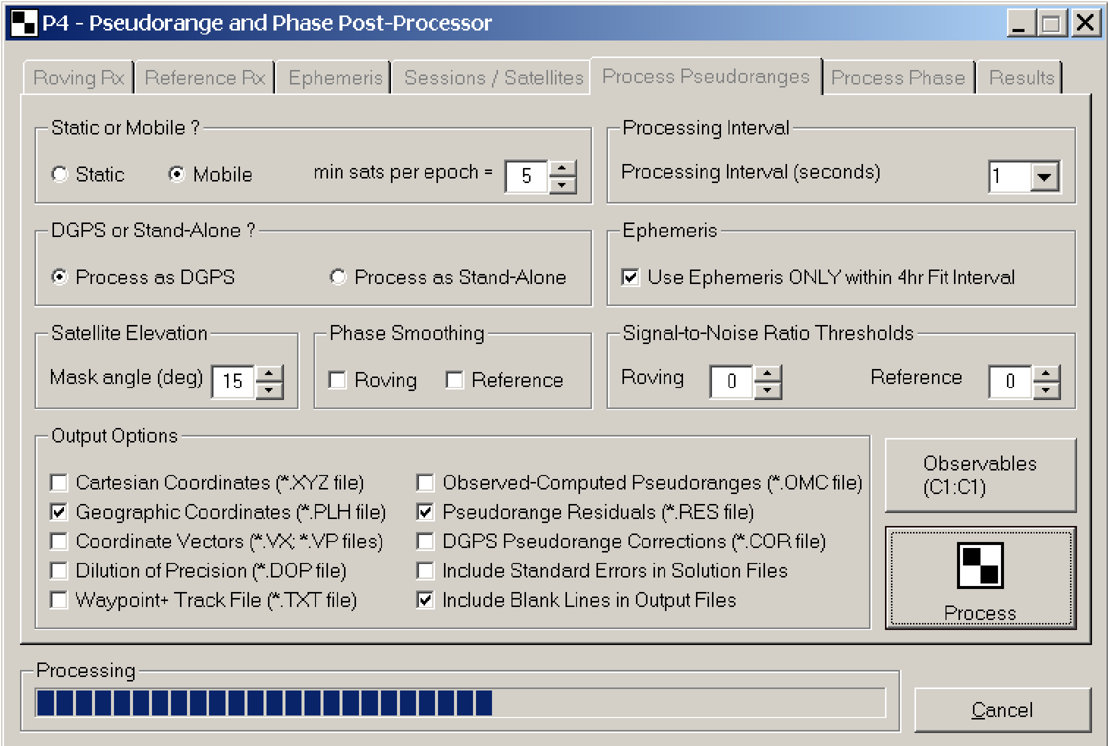


Figure 20 – Processing Pseudorange data with default options

Step 6 (see page 24). For a mobile DGPS solution, you do not need to visit the 'Process Phase' page.

Step 7. View the results (see page 34). A plot of the track of the roving receiver can simply be produced by clicking on the 'Plot Positions' button on the 'Results' tab. In the following example, the line style option was changed to 'Both' (so that the route through the data points can be seen more easily), and 'Show Statistics below Chart Subtitle' option was deselected, as the statistics are not useful for a mobile receiver.

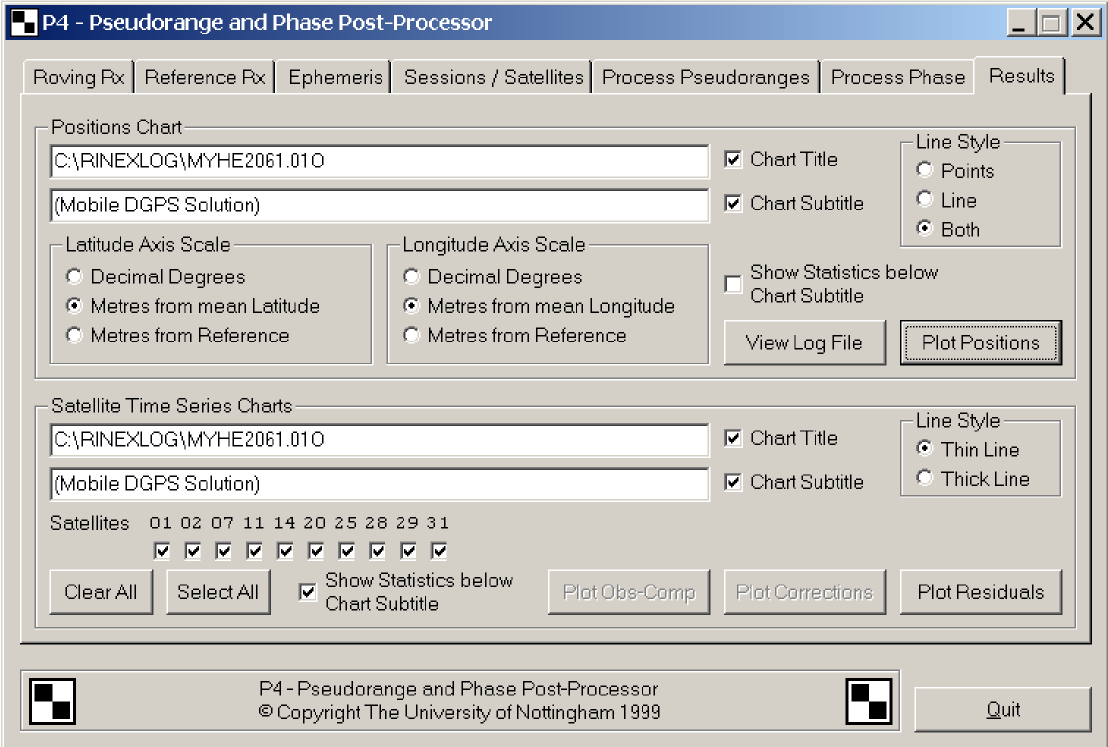


Figure 21 – Basic plotting options for a mobile solution

When the 'Plot Positions' button is clicked, P4 brings up the following window. It contains the requested chart, which shows the track of the mobile receiver.

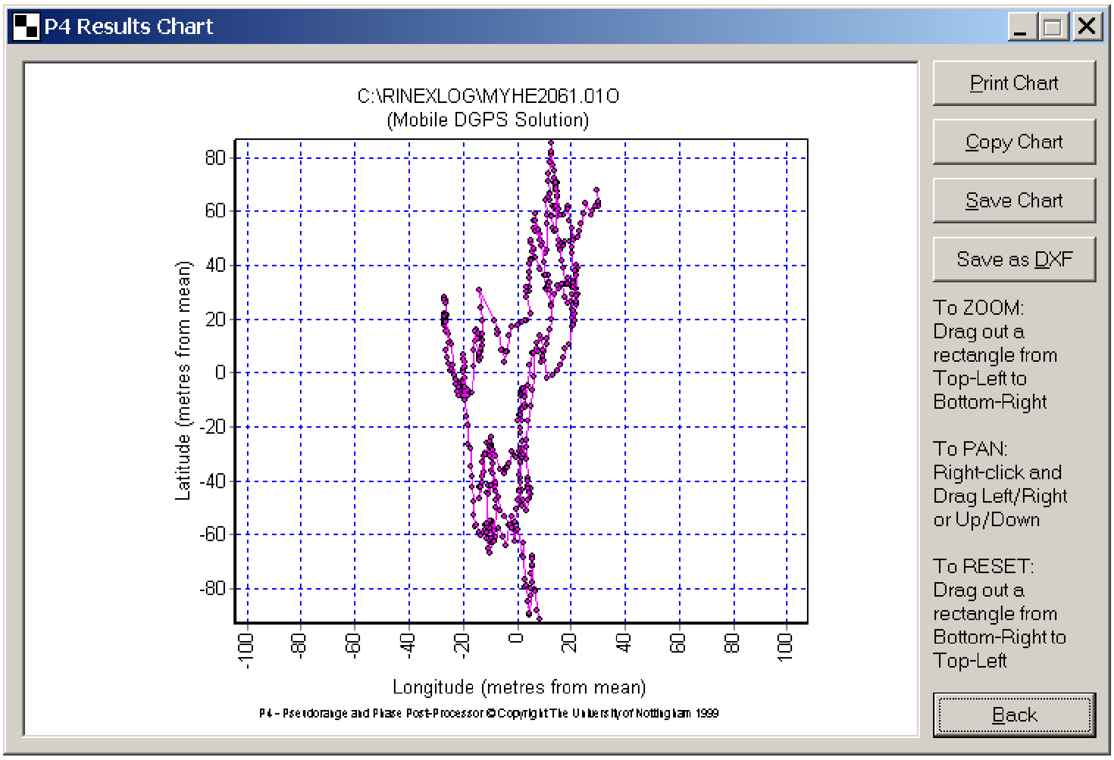


Figure 22 – P4 results chart

The chart can be printed, copied or saved (as a windows metafile), using the buttons on the side panel. The chart data can also be saved in DXF format for use in other CAD or drawing packages. The chart can also be zoomed and panned, as described in the side panel. As an example, the above chart was first zoomed, and then the 'Copy Chart' button was used to place the chart in the clipboard, from where it was pasted into this document to produce the following figure.

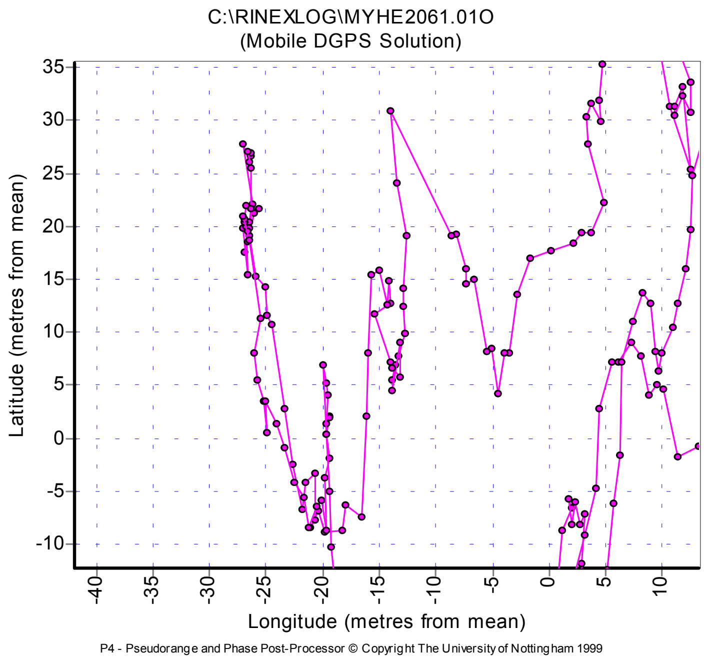


Figure 23 – The zoomed positions chart, 'pasted' into this document

As the default option of outputting the residuals (`.RES`) was retained, it is also now possible to plot those residuals. The following chart was simply created by

- clicking on the 'Plot Residuals' button, then
- clicking on the 'Copy Chart' button, and finally
- pasting the chart into this document.

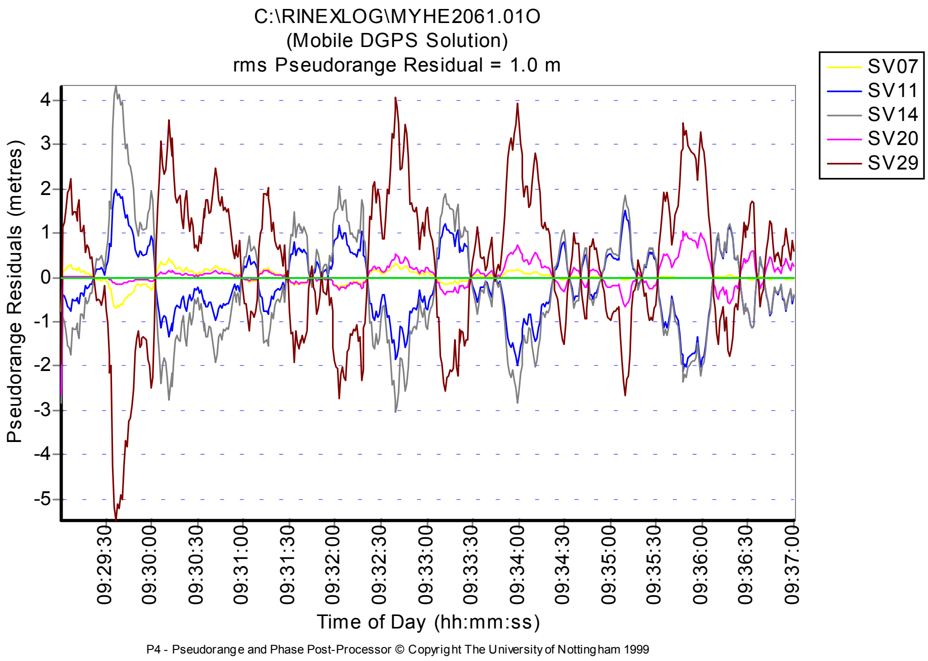


Figure 24 – P4 Residuals chart

The processed track in Figure 22 does not show the expected smooth track that the receiver followed. Since the roving and reference receivers are both Garmin receivers, it may be useful to apply the 'phase smoothing' option to both of them.

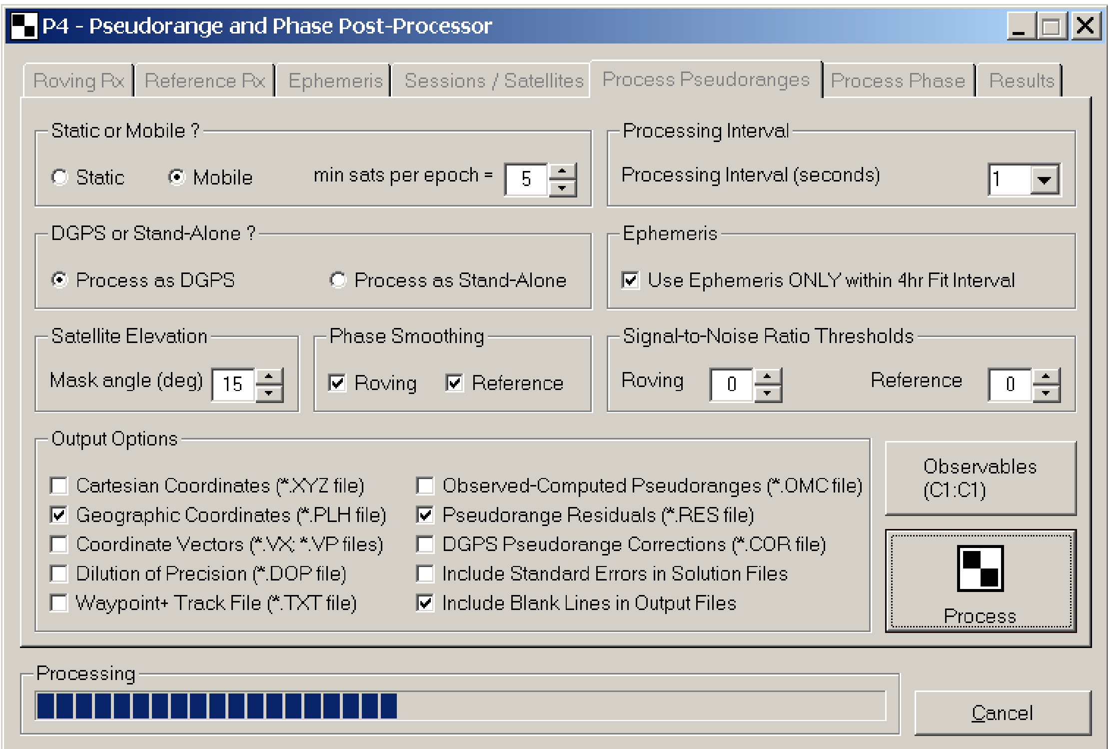


Figure 25 – Reprocessing with Phase Smoothing

Figure 26 shows the results of the phase smoothed processing. The track is clearly smoother, although it should be remembered that the phase data contains no position information, so the track is no better located on average.

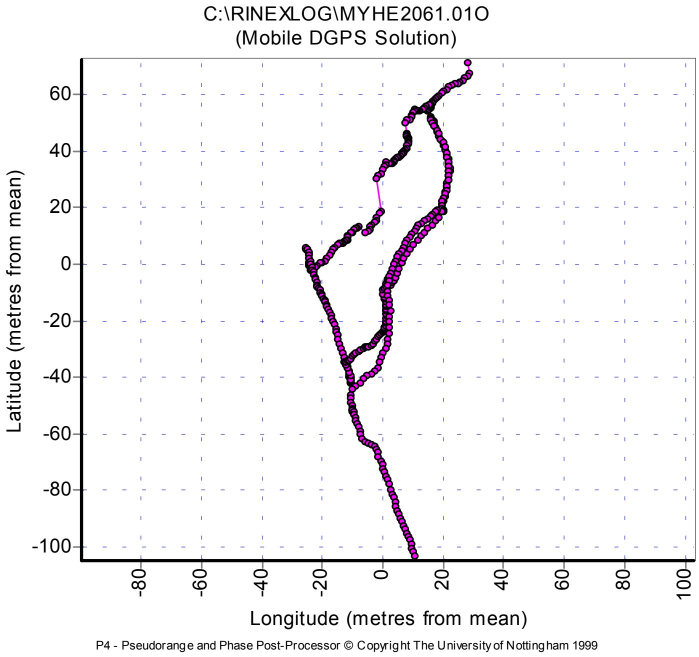


Figure 26 – The phase smoothed track

As a further illustration of the effect of phase smoothing, the residuals chart shows how the 'noise' in the residuals has been reduced, compared to Figure 24.

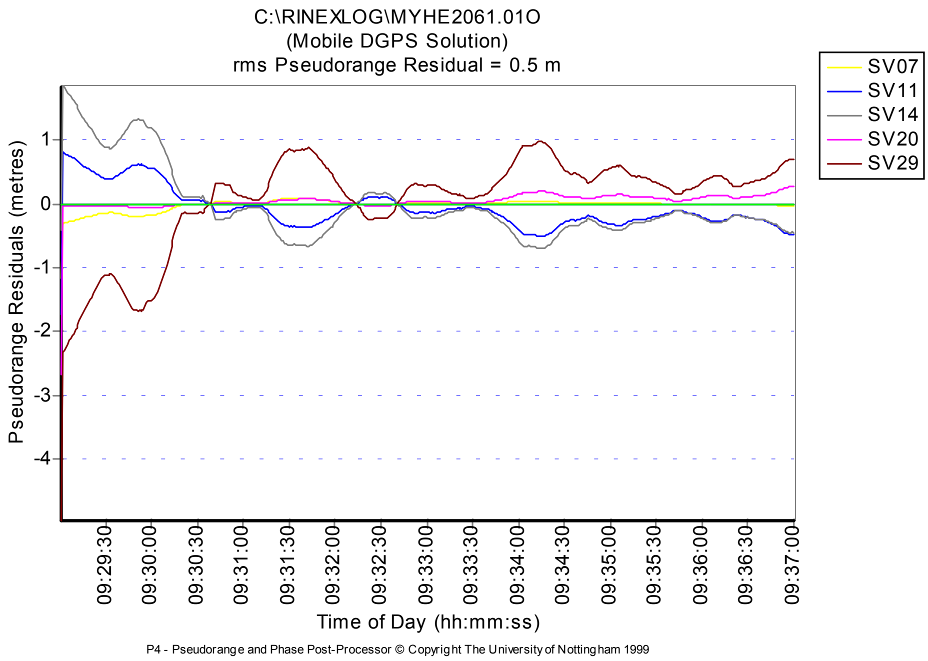


Figure 27 – Pseudorange residuals from the phase smoothed solution

SESSION 2 – A STATIC RECEIVER PROCESSED AS A CARRIER PHASE BASELINE

Another typical use of P4 might be to process the carrier phase data from a static receiver and a reference receiver, to determine very accurate coordinates for the static receiver.

The following steps illustrate how to process this type of data file.

Step 1. Choose a RINEX file for the 'Roving' receiver. This step is detailed on page 5. Simply use the 'Choose File' button to start a file selection dialog, and navigate to the RINEX file recorded by your mobile receiver. If the roving receiver's antenna was at a known height above the survey marker, enter that height now, so that the resulting coordinates will refer to the survey marker and not the antenna.

Step 2. Choose a RINEX file for the 'Reference' receiver. This step is detailed on page 7. Simply use the 'Choose File' button to start a file selection dialog, and navigate to the RINEX file recorded by the reference receiver. Be sure to check that the Reference Coordinates are correct, and that the reference receiver's Antenna Height (if applicable) is also correct.

Step 3. Choose a satellite Ephemeris file. This step is detailed on page 10. Simply use the 'Choose File' button to start a file selection dialog, and navigate to the ephemeris file you wish to use with these data files.

Step 4. Define the session times and satellite constellation (see page 12). At this stage, you will probably not have any reason to remove satellites from the solution, so unless you wish to limit the processing session times, you simply need to look at the 'Sessions / Satellites' tab to confirm that the session start and end times have been automatically determined. If these fields indicate 'no common data', it will be because the roving receiver and reference receiver data files correspond to different times, or because the ephemeris file does not overlap the session.

Step 5. Select the Pseudorange processing and output options, and process the pseudorange data (see page 15). To assist P4 in detecting and fixing cycle slips and resolving the carrier phase ambiguities, it is useful to ensure that the approximate coordinates of the roving receiver are as accurate as possible before processing the carrier phase data. In fact, it is sufficient that the roving receiver's approximate coordinates are *consistent* with those of the reference receiver. For this reason, it is useful to use the pseudorange data to update the roving receiver's coordinates. If the roving receiver's approximate coordinates are not consistent with the reference receiver's coordinates, you may see the following message when attempting a carrier phase solution. This is because the phase measurements do not agree with the values P4 has predicted, based on the inconsistent coordinates.

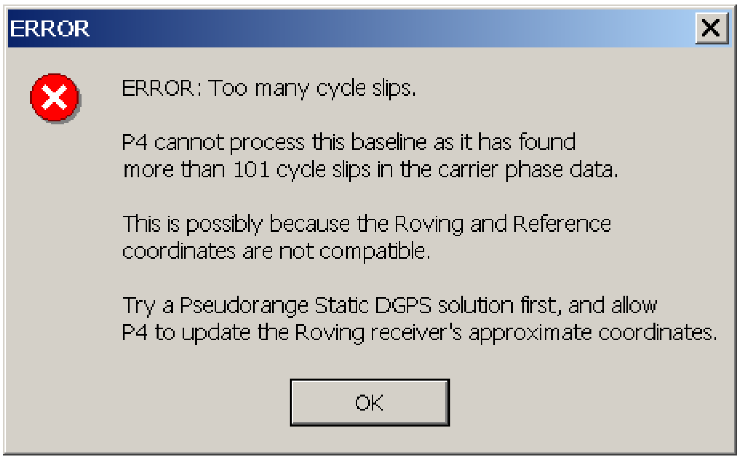


Figure 28 – Too many cycle slips

The only non-default option required on the 'Process Pseudoranges' page is to change the solution type to 'Static'. All other defaults should be sufficient.

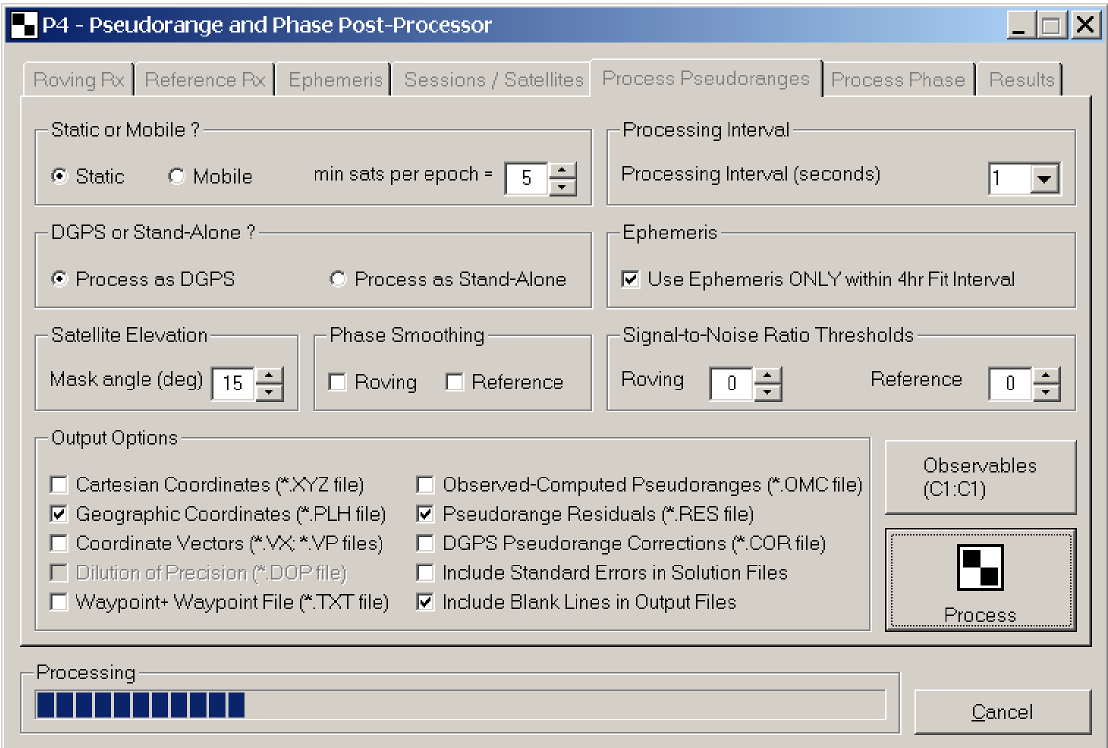


Figure 29 – Processing Pseudorange data for Static solution

When the static DGPS solution is complete, P4 will ask if you wish to update the approximate coordinates. You should answer 'yes', but take care to check that the positions chart and residuals chart are free of obvious problems, to ensure that the updated coordinates can be relied upon.

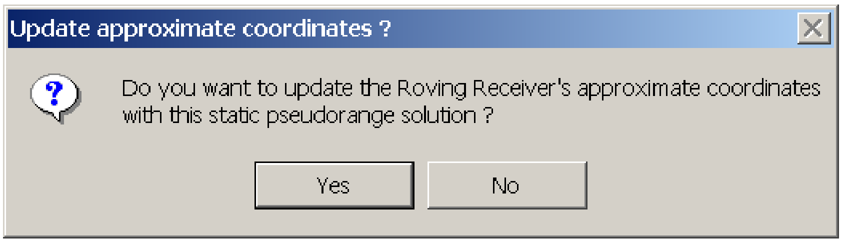


Figure 30 – Update approximate coordinates ?

Step 6 (see page 24). Once the static DGPS solution has been performed, select the 'Process Phase' tab. The default options should be sufficient for a frist run through the data.

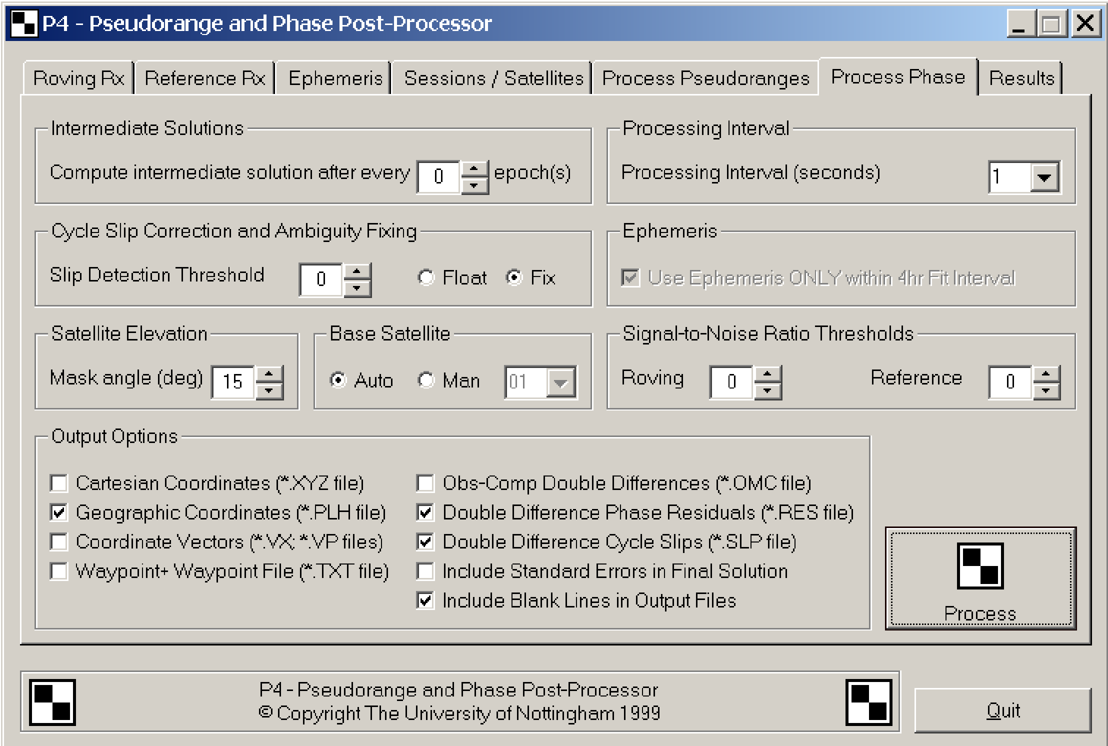


Figure 31 – Processing Carrier Phase data with default options

Depending on P4's success at detecting and resolving cycle slips, P4 will either complete the processing with no warnings, or present the cycle slip warning screen as follows:

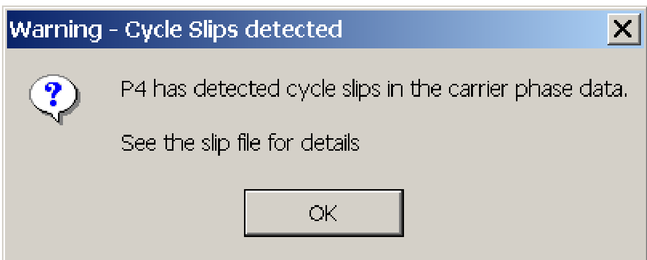


Figure 32 – Cycle slip warning

Step 7. View the results (see page 34). For a carrier phase solution, the most important chart to view is the residuals chart. A look at this chart will enable you to confirm that there were no cycle slips in the data (and therefore have some confidence in the solution) or locate and identify the remaining slips.

A plot of the double difference carrier phase residuals can simply be produced by clicking on the 'Plot Residuals' button on the 'Results' tab (assuming that the default residuals output option was not changed).

In this worked example, P4 produced the cycle slips warning, and the following chart shows where the slips occurred. Look for jumps in the residuals plots of multiples of whole cycles (or half cycles for Garmin data). In the following figure, the 'zoom' option is being used to draw the red box around the section of data where the slip(s) appear(s) to be.

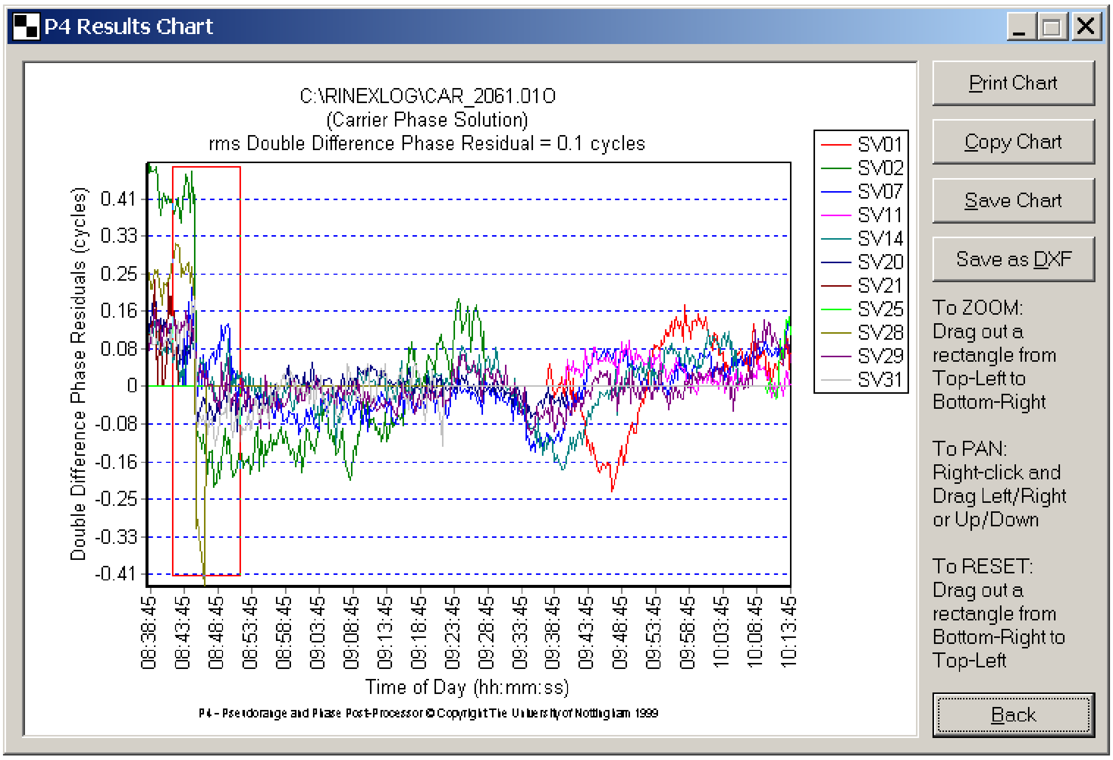


Figure 33 – Residuals chart, showing cycle slips

The result of the zoom is shown in the next figure. It is clear that the residuals traces for two satellites (SV02 and SV28) show jumps of approximately half a cycle, both at the same epoch, followed by another slip on SV28 a few epochs later.

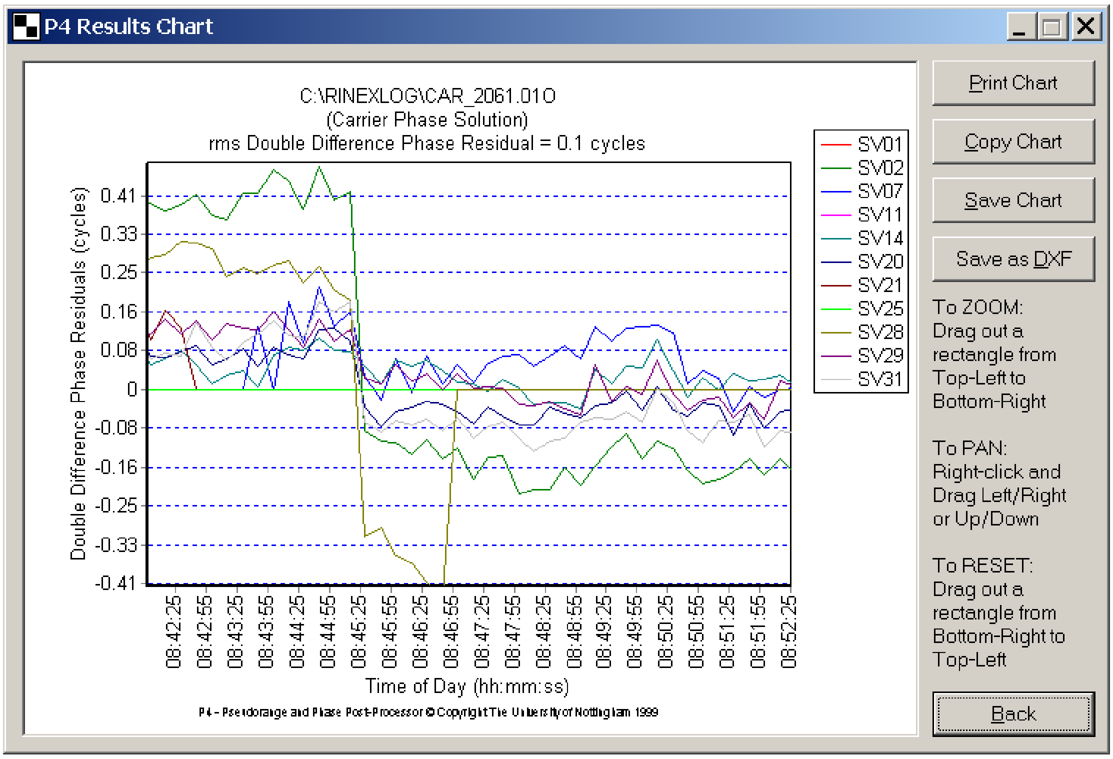


Figure 34 – Residuals chart, zoomed in on cycle slips

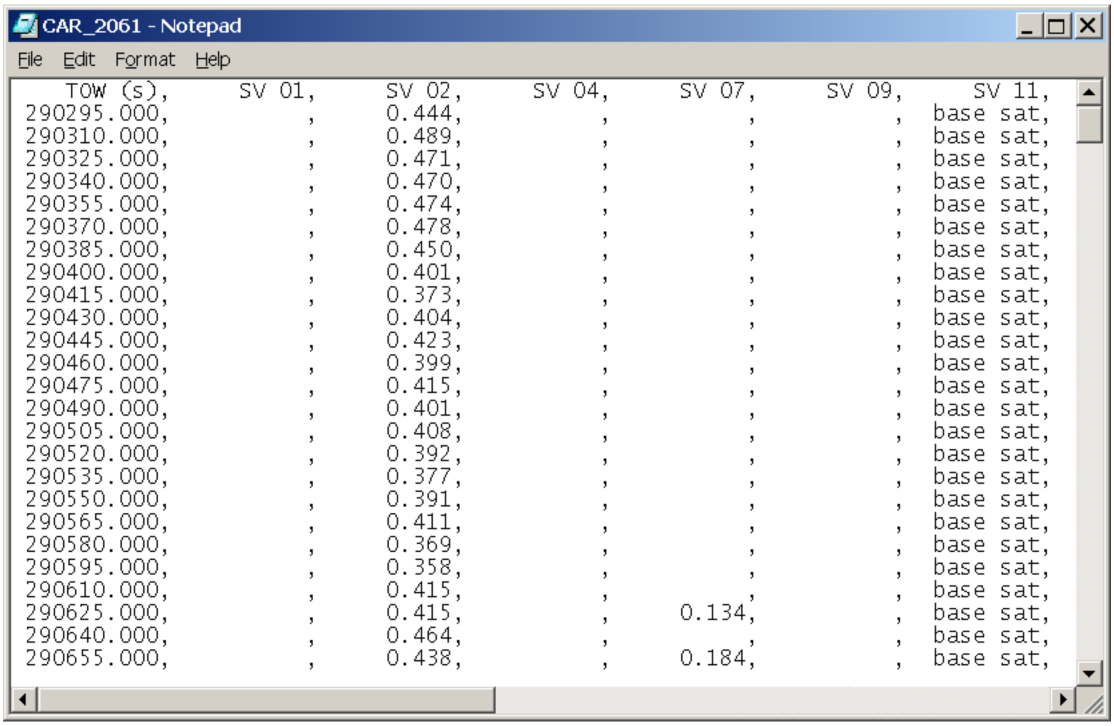
At this point, there are several options for dealing with these remaining slips.

- Firstly, since the slips occur relatively early in the session, it would be acceptable to adjust the session start time to exclude these epochs. A start time of 08:47:00 should just miss these epochs.
- Secondly, since there are 11 satellites in the solution, and the slips appear to affect only satellites 2 and 28, it may be tempting to go back to the 'Sessions / Satellites' tab and deselect these two satellites. However, a large part of the data set may become unusable as a result, as not all 11 satellites are present throughout, and the removal of 2 may leave too few satellites much of the time.
- Finally, the best option is to attempt to complete the job that P4 started, and manually fix the remaining slips with the help of the `.RES` and `.SLP` files. Be warned though, that this approach is not for the faint-hearted, and is usually impractical if there are a large number of slips. The approach is detailed here though as it may be the only practicable method in some cases.

To manually fix these slips, we first need to know exactly when they occurred. The zoomed residuals plot has sufficient resolution to pinpoint the slips to within 30 seconds. Make a note of the approximate times and the satellites involved, ie:

08:45:30, SV02 and SV28   08:47:00, SV28

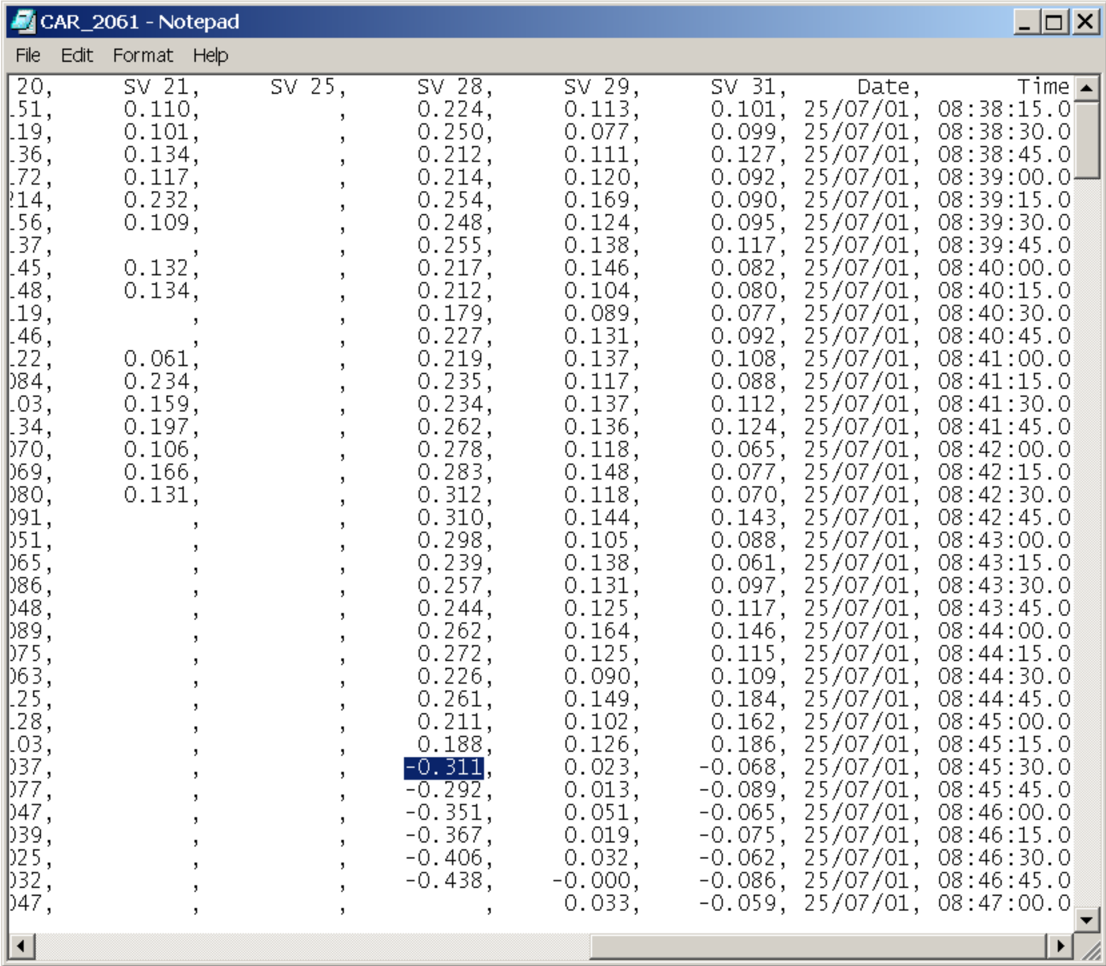
Now we need to find the exact timetags, in 'GPS seconds of week' format. For this we need to inspect the `.RES` file. Use a file editor, such as Notepad, to open the `.RES` file (make sure that Word Wrap is OFF, or the contents of this file will be very confusing).



TOW (s),	SV 01,	SV 02,	SV 04,	SV 07,	SV 09,	SV 11,
290295.000,	,	0.444,	,	,	,	base sat,
290310.000,	,	0.489,	,	,	,	base sat,
290325.000,	,	0.471,	,	,	,	base sat,
290340.000,	,	0.470,	,	,	,	base sat,
290355.000,	,	0.474,	,	,	,	base sat,
290370.000,	,	0.478,	,	,	,	base sat,
290385.000,	,	0.450,	,	,	,	base sat,
290400.000,	,	0.401,	,	,	,	base sat,
290415.000,	,	0.373,	,	,	,	base sat,
290430.000,	,	0.404,	,	,	,	base sat,
290445.000,	,	0.423,	,	,	,	base sat,
290460.000,	,	0.399,	,	,	,	base sat,
290475.000,	,	0.415,	,	,	,	base sat,
290490.000,	,	0.401,	,	,	,	base sat,
290505.000,	,	0.408,	,	,	,	base sat,
290520.000,	,	0.392,	,	,	,	base sat,
290535.000,	,	0.377,	,	,	,	base sat,
290550.000,	,	0.391,	,	,	,	base sat,
290565.000,	,	0.411,	,	,	,	base sat,
290580.000,	,	0.369,	,	,	,	base sat,
290595.000,	,	0.358,	,	,	,	base sat,
290610.000,	,	0.415,	,	,	,	base sat,
290625.000,	,	0.415,	,	0.134,	,	base sat,
290640.000,	,	0.464,	,	,	,	base sat,
290655.000,	,	0.438,	,	0.184,	,	base sat,

Figure 35 – P4 residuals file

The first column of this file contains the timetags that we need (TOW = Time Of Week). The other columns correspond to the residuals for each satellite. The last few columns contain the date and time in a more conventional format. We need to move down the file until we come to the times noted above (08:45:30 and 08:47:00), and then locate the columns corresponding to satellites 2 and 28. In the following figure, the residual corresponding to satellite 28 at 08:45:30 is highlighted. The residual at this epoch is approximately half a cycle (0.499) different from the previous epoch, so this is clearly a slip. We can also see that at 08:47:00, the residuals from satellite 28 finish, so the jump that was visible on the residuals plot is simply caused by the plotting software jumping back to zero, and is not actually a slip.



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File Edit Format Help

20,	SV 21,	SV 25,	SV 28,	SV 29,	SV 31,	Date,	Time
51,	0.110,	,	0.224,	0.113,	0.101,	25/07/01,	08:38:15.0
19,	0.101,	,	0.250,	0.077,	0.099,	25/07/01,	08:38:30.0
36,	0.134,	,	0.212,	0.111,	0.127,	25/07/01,	08:38:45.0
72,	0.117,	,	0.214,	0.120,	0.092,	25/07/01,	08:39:00.0
14,	0.232,	,	0.254,	0.169,	0.090,	25/07/01,	08:39:15.0
56,	0.109,	,	0.248,	0.124,	0.095,	25/07/01,	08:39:30.0
37,	,	,	0.255,	0.138,	0.117,	25/07/01,	08:39:45.0
45,	0.132,	,	0.217,	0.146,	0.082,	25/07/01,	08:40:00.0
48,	0.134,	,	0.212,	0.104,	0.080,	25/07/01,	08:40:15.0
19,	,	,	0.179,	0.089,	0.077,	25/07/01,	08:40:30.0
46,	,	,	0.227,	0.131,	0.092,	25/07/01,	08:40:45.0
22,	0.061,	,	0.219,	0.137,	0.108,	25/07/01,	08:41:00.0
84,	0.234,	,	0.235,	0.117,	0.088,	25/07/01,	08:41:15.0
03,	0.159,	,	0.234,	0.137,	0.112,	25/07/01,	08:41:30.0
34,	0.197,	,	0.262,	0.136,	0.124,	25/07/01,	08:41:45.0
70,	0.106,	,	0.278,	0.118,	0.065,	25/07/01,	08:42:00.0
69,	0.166,	,	0.283,	0.148,	0.077,	25/07/01,	08:42:15.0
80,	0.131,	,	0.312,	0.118,	0.070,	25/07/01,	08:42:30.0
91,	,	,	0.310,	0.144,	0.143,	25/07/01,	08:42:45.0
51,	,	,	0.298,	0.105,	0.088,	25/07/01,	08:43:00.0
65,	,	,	0.239,	0.138,	0.061,	25/07/01,	08:43:15.0
86,	,	,	0.257,	0.131,	0.097,	25/07/01,	08:43:30.0
48,	,	,	0.244,	0.125,	0.117,	25/07/01,	08:43:45.0
89,	,	,	0.262,	0.164,	0.146,	25/07/01,	08:44:00.0
75,	,	,	0.272,	0.125,	0.115,	25/07/01,	08:44:15.0
63,	,	,	0.226,	0.090,	0.109,	25/07/01,	08:44:30.0
25,	,	,	0.261,	0.149,	0.184,	25/07/01,	08:44:45.0
28,	,	,	0.211,	0.102,	0.162,	25/07/01,	08:45:00.0
03,	,	,	0.188,	0.126,	0.186,	25/07/01,	08:45:15.0
37,	,	,	-0.311,	0.023,	-0.068,	25/07/01,	08:45:30.0
77,	,	,	-0.292,	0.013,	-0.089,	25/07/01,	08:45:45.0
47,	,	,	-0.351,	0.051,	-0.065,	25/07/01,	08:46:00.0
39,	,	,	-0.367,	0.019,	-0.075,	25/07/01,	08:46:15.0
25,	,	,	-0.406,	0.032,	-0.062,	25/07/01,	08:46:30.0
32,	,	,	-0.438,	-0.000,	-0.086,	25/07/01,	08:46:45.0
47,	,	,	,	0.033,	-0.059,	25/07/01,	08:47:00.0

Figure 36 – Half-integer cycle slip on SV28

If we look on the same row (08:45:30) of this file under the column for satellite 2, we can see another half cycle slip (0.506), and we can see that the TOW at this epoch is 290730.000 (Figure 37).

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TOW (s),	SV 01,	SV 02,	SV 04,	SV 07,	SV 09,	SV 11,
290295.000,	,	0.444,	,	,	,	base sat,
290310.000,	,	0.489,	,	,	,	base sat,
290325.000,	,	0.471,	,	,	,	base sat,
290340.000,	,	0.470,	,	,	,	base sat,
290355.000,	,	0.474,	,	,	,	base sat,
290370.000,	,	0.478,	,	,	,	base sat,
290385.000,	,	0.450,	,	,	,	base sat,
290400.000,	,	0.401,	,	,	,	base sat,
290415.000,	,	0.373,	,	,	,	base sat,
290430.000,	,	0.404,	,	,	,	base sat,
290445.000,	,	0.423,	,	,	,	base sat,
290460.000,	,	0.399,	,	,	,	base sat,
290475.000,	,	0.415,	,	,	,	base sat,
290490.000,	,	0.401,	,	,	,	base sat,
290505.000,	,	0.408,	,	,	,	base sat,
290520.000,	,	0.392,	,	,	,	base sat,
290535.000,	,	0.377,	,	,	,	base sat,
290550.000,	,	0.391,	,	,	,	base sat,
290565.000,	,	0.411,	,	,	,	base sat,
290580.000,	,	0.369,	,	,	,	base sat,
290595.000,	,	0.358,	,	,	,	base sat,
290610.000,	,	0.415,	,	,	,	base sat,
290625.000,	,	0.415,	,	0.134,	,	base sat,
290640.000,	,	0.464,	,	,	,	base sat,
290655.000,	,	0.438,	,	0.184,	,	base sat,
290670.000,	,	0.380,	,	0.097,	,	base sat,
290685.000,	,	0.471,	,	0.217,	,	base sat,
290700.000,	,	0.398,	,	0.132,	,	base sat,
290715.000,	,	0.418,	,	0.164,	,	base sat,
290730.000,	,	-0.088,	,	0.026,	,	base sat,
290745.000,	,	-0.108,	,	-0.022,	,	base sat,
290760.000,	,	-0.112,	,	0.063,	,	base sat,
290775.000,	,	-0.137,	,	-0.006,	,	base sat,
290790.000,	,	-0.105,	,	0.070,	,	base sat,
290805.000,	,	-0.147,	,	0.013,	,	base sat,
290820.000,	,	-0.124,	,	0.052,	,	base sat,

Figure 37 – Half-integer cycle slip on SV02 at TOW 290730.000

With this information, we can now edit the slip file (.SLP), so that P4 can subsequently attempt to correct for these slips.

We have two choices.

Firstly, we can introduce a line in the slip file that simply contains the TOW and the ID of the satellite concerned for each slip. When we process the data again, we would then tell p4 to 'Solve for Slips', and it would use the timetags in the slip file to introduce an unknown for each slip, and hopefully resolve them correctly.

Secondly, we can introduce a line in the slip file that contains not just the TOW and the ID of satellite concerned, but also the amount of the slip. When we process the data again, we would then tell P4 to 'Correct Data', and it would use the timetag and the size of each slip to remove the slips while the data is being processed.

The following figures illustrate both options.

Firstly, the slip file resulting from the first processing run is shown.

CAR_2061.SLP - Notepad

File Edit Format Help

```
                   TOW,      SV,        cycle slip
Ambiguity    290295.000    29         6807746.50
Ambiguity    290295.000    31         5963401.50
Ambiguity    290295.000    20         7480651.00
Ambiguity    290295.000    14         3188103.00
Ambiguity    290295.000     2        10779774.84
Ambiguity    290295.000    28        -7652829.00
Ambiguity    290295.000    21         8823244.50
Solved       290400.000    21             160.50
Solved       290415.000    21              95.00
Solved       290460.000    21             300.66
Solved       290490.000    21             102.08
Solved       290505.000    21             135.43
Ambiguity    290625.000     7         8122556.73
Solved       290655.000     7              -1.00
Solved       290670.000     7               1.00
Solved       290685.000     7              -3.00
Solved       290730.000    29               0.90
Solved       290730.000    31               0.30
Solved       290730.000    20               0.37
Solved       290730.000     7             -59.66
Ambiguity    293865.000     1         6067386.37
Ambiguity    295815.000    25         1992756.15
```

Figure 38 – raw slip file

- We can see that the file contains a combination of double difference ambiguities and 'solved' cycle slips.
- We can also see that many of the values have been determined to integer or half-integer values, but several have real values.
- We can also see that at TOW 290730.000 (where we have observed cycle slips in the residuals), there are already a number of cycle slips. In fact, since the slips on satellites 29, 31 and 20, as well as 2 and 28, are all equal, it is likely that there was slip on the base satellite, instead of all of the others. Nevertheless, since P4 does not have a mechanism to correct slips on the base satellite, we must correct the effect by correcting all of the affected satellites.

Solve for Slips option

To force P4 to solve for slips on satellites 2 and 28, we can edit the slip file until it appears as in the following figure. Note that the value of the slip need not be entered. Note that all other slips should be removed from the slip file.

CAR_2061.SLP - Notepad

File Edit Format Help

```
                   TOW,      SV,        cycle slip
Manual       290730.000     2
Manual       290730.000    28
```

Figure 39 – Slip file for solving identified slips

When P4 is re-run with this slip file, and the 'Solve for Slips' option is selected when the slip file is found, P4 solves for the slips on satellites 2 and 28 at 08:45:30, along with all of the other slips that it finds. The resulting residuals plot is shown in the following figure:

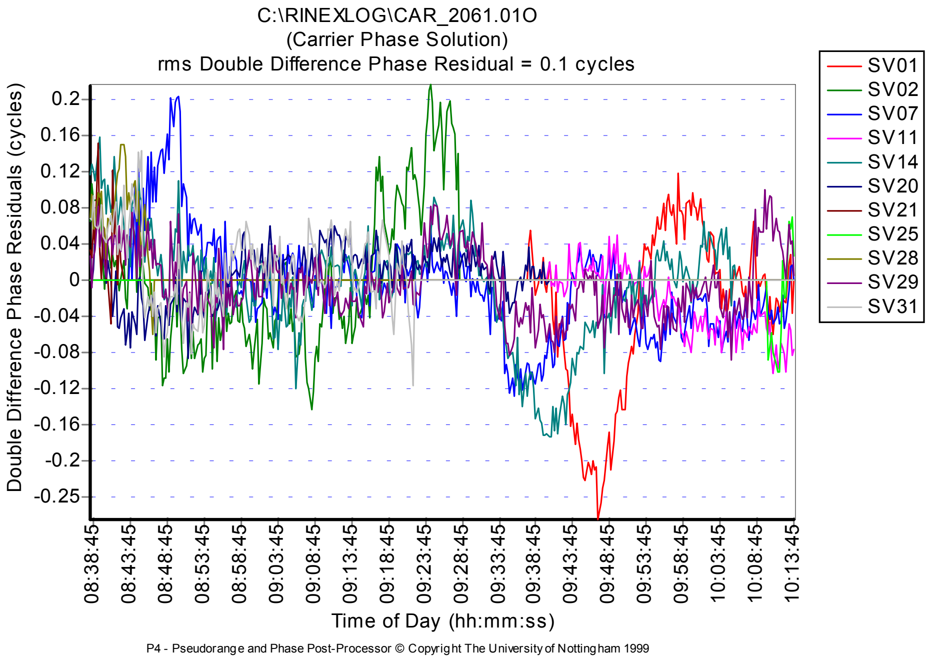
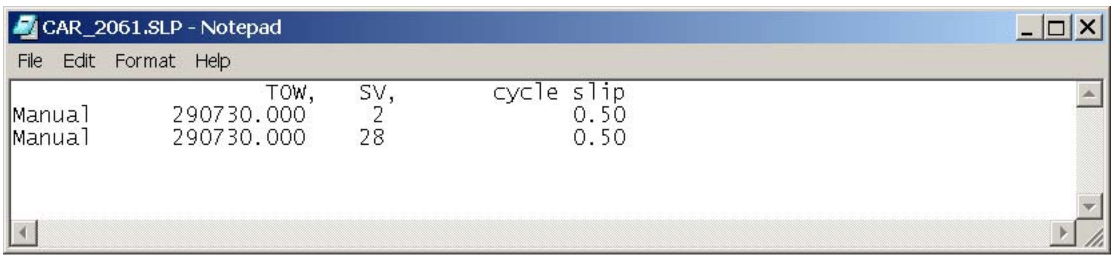


Figure 40 – Residuals after fixing slips

Correct Data options

To force P4 to use slip values that we choose, we can edit the slip file until it is as shown in the following figure. Note that the slip values are both positive, while the jumps visible in Figure 34 are both in a downwards (negative) direction. The convention in P4 is that the slip file contains the corrections required to remove the jumps in the residuals plots. A downward residual jump requires an upward (positive) slip to be entered in the slip file.


CAR_2061.SLP - Notepad

File Edit Format Help

```
                TOW,      SV,        cycle slip
Manual       290730.000    2              0.50
Manual       290730.000   28              0.50
```

Figure 41 – Slip file for correcting identified slips

When P4 is re-run with this slip file, and the 'Correct Data' option is selected when the slip file is found, P4 corrects for the slips on satellites 2 and 28 at 08:45:30, and attempts to solve for all of the other slips that it finds. The resulting residuals plot is identical to Figure 40.

In summary

When processing carrier phase data, P4 may report that it has found an existing slip file, and ask you what you would like to do with the file.

- On the first run through the data set, or when you have changed the processing options, use the 'Ignore' option, and P4 will create a new slip file for the current processing run.
- If you have identified slips manually, by referring to the residuals plot and the residuals file, use the 'Solve for Slips' option to force P4 to solve for slips at the indicated epochs.
- If you have determined the correct values for the slips, again by referring to the residuals plot and the residuals file, use the 'Correct Data' option to force P4 to use the values you have entered.