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ESA GNSS Education

GNSS-Lab tool

Software User Manual

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Document Change Log

Iss./Rev	Date	Section / Page	Change Description
1.0	08/09/2009	All	First version of the document
1.1	29/10/2009	All	Included RIDS comments from ESA and new screenshots from gLAB v1.2.
1.2	22/01/2010	All	General revision with new gLAB v1.3.1
1.3	08/07/2010	Section 4 - 6	Revision and update with new gLAB v1.4
1.4	31/07/2010	Section 4.1 Section 6.4	Description of Auxiliary files. Inclusion of preferences and about snapshot Removed limitation of combination measurements and to save current configuration to a file.
1.5	31/08/2010	Section 2.1.1 Section 4.2.5 Section 4.2.3	Maximum number of filter iterations added. Satellite elevation and azimuth addition in the Model message. Update according to the new DCB management

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1.6	22/09/2010	All	Update according to the final DCB management and new gLAB v 1.4.4
1.7	1/07/2011	All	Revision and update with new gLAB v2.0.0 SATSEL message included in the output. Troposheric model spitted into nominal and mapping.

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1 INTRODUCTION

The GNSS-Lab Tool suite (gLAB) is an interactive educational multipurpose package to process and analyse GNSS data. The first release of this software package allows processing only GPS data, but it is prepared to incorporate future module updates, such as an expansion to Galileo and GLONASS systems, EGNOS and differential processing.

This software package is targeting the following groups of users:

- Education professionals aiming to teach GNSS from both a theoretical and practical points of view.
- Standalone students and professionals with basic knowledge on GNSS as a self-learning tool.
- Professionals with more in deep knowledge on GNSS who want an easy and user-friendly tool with precise positioning capability.

From an operative point view, this tool is conceived as a software package to support a practical GNSS course, where the fundamentals introduced in the theory are experimented through guided exercises. In this way, the tool is conceived for being used:

- as part of a GNSS course with practical exercises integrated following a manual, or
- experimenting around with contextual help with hyperlinks for more information, or
- to process RINEX data and obtain both GPS standalone or Precise Point Positioning (PPP) solutions.

The gLAB tool is distributed within a learning material package containing the following components:

- **Software:** A binary which will be able to read GPS RINEX data, process it and show the results in the form of data files and graphics. The processing options will be fully parametrizable through a GUI that will ease to understand the tool and its different options. The software is able to work both in Windows and Linux Operating Systems.
- **Tutorial:** A book containing the GNSS fundamentals and several practical exercises covering from the basics of data processing, such as reading standard RINEX format to more complex processes, as positioning a rover and analysing the results.
- **Data:** The data sets files used in the exercises.

1.1 DOCUMENT SCOPE AND PURPOSES

This document contains the information related to the use of the gLAB software package component of the gLAB suite, and its purpose is to provide an overall overview to the end user of the software. In particular, how to install it and use it, with all the different options that the software has.

1.2 DOCUMENT OVERVIEW AND STRUCTURE

This document is split in sections, which describe:

- A generic description on the different software modules included in the package (Section 2).
- A detailed description of the installation procedure (Section 3).
- How to use the Graphic User Interface (GUI) component (Section 4).
- How to use the Data Processing Core (DPC) component (Section 5).
- How to use the Data Analysis Tool (DAT) component (Section 6).

1.3 APPLICABLE AND REFERENCE DOCUMENTS

1.3.1 Applicable documents

The following documents refer to the applicable documents for the project.

AD-01 RINEX-2.10 format: http://igscb.jpl.nasa.gov/igscb/data/format/rinex211.txt

AD-02 RINEX-3.00 format: ftp://epncb.oma.be/pub/data/format/rinex300.pdf

AD-03 IONEX format: http://igscb.jpl.nasa.gov/igscb/data/format/ionex1.pdf

AD-04 SP3 format: http://igscb.jpl.nasa.gov/igscb/data/format/sp3.txt

AD-05 RINEX clock format: http://igscb.jpl.nasa.gov/igscb/data/format/rinex_clock.txt

AD-06 ANTEX format: ftp://igscb.jpl.nasa.gov/igscb/station/general/antex13.txt

AD-07 RTCA-MOPS, December 2006.

1.3.2 Reference Documents

RD-1 Python Programming Language, http://www.python.org

RD-2 Guide to Applying the ESA Software Engineering Standards to small Software Projects Doc.-No. ESA BSSC (96)2 Issue 1, 199.

RD-3 Gnuplot: http://www.gnuplot.info

RD-4 Architecture Design Document for gLAB, gAGE/UPC 2009.

RD-5 ANTEX file: http://igscb.jpl.nasa.gov/igscb/station/general/igs05.atx

RD-6 SP3 files: http://igscb.jpl.nasa.gov/igscb/product

RD-7 GIPSY OASIS-II, Mathematical description, 1986

RD-8 A. E. Niell, Global mapping functions for the atmosphere delay at radio wavelengths, Journal of Geophysical Research, Vol. 101, No. B2, p. 3227-3246, 1996.

RD-9 RTCA, 2001. Minimum Operational Performance Standards For Global Positioning Sysmte/Wide Area Augmentation System Airborne Equipment. RTCA/DO-229C. Prepared by SC-159. November 28, 2001. Supersedes DO-229B. Available at http://www.rtca.org/doclist.asp . pp. 338-340 of 586 in PDF.

RD-10 D. McCarthy and G. Petit, IERS Conventions, International Earth Rotation and Reference Systems Service (IERS), 2003

RD-11 S. Malsys, M. Larezos, S. Gottschalk, S. Mobbs, B. Winn, W. Feess, M. Menn, E. Swift, E. Merrigan and W. Mathon, The GPS accuracy improvement initiative, ION GNSS 1997, Kansas City, USA, pp. 375-384, 1997.

RD-12 GPSConstellationStatus.txt file, available at: http://gge.unb.ca/Resources/GPSConstellationStatus.txt

RD-13 ICD-GPS-200, Navstar GPS Space Segment / Navigation User Interfaces, 1993.

RD-14 Global Positioning System Standard Positioning Service Signal Specification. U.S. Department of Defense, DOD 4650.5/SPSSP V3, 3rd Edition, August 1, 1998.

1.3.3 Acronyms and Terms

AD	Applicable Document
DAT	Data Analysis Tool
DPC	Data Processing Core
ESA	European Space Agency
gAGE	Research Group of Astronomy and Geomatics
gLAB	GNSS-Lab tool
GNSS	Global Navigation Satellite System
GUI	Graphic User interface
IGS	International GNSS Service
OS	Operative System
PPP	Precise point Positioning
RD	Reference Document
SIS	Signal In Space
SOW	Statement Of Work
S/W	Software
TBC	To Be Confirmed
TBD	To Be Determined
TBW	To Be Written
TGD	Total Group Delay
UD	User Domain

UPC	Technical University of Catalonia

2 gLAB SOFTWARE TOOL

The gLAB software tool is able to run under Linux and Windows operating systems (OS). It is programmed in ANSI C and Python languages and contains three main software modules:

- Data Processing Core (DPC) [gLAB.exe in Windows, gLAB_linux for Linux]
- Graphic User Interface (GUI) and [gLAB_GUI.exe in Windows, gLAB_GUI.py in Linux]
- Data Analysis Tool (DAT) [graph.exe in Windows, graph.py in Linux].

The DPC implements all the data processing algorithms and can be executed either, in command line or with the GUI. The GUI consists in different graphic panels for a user friendly managing of the SW and the tool configuration. They provide all the options to configure the model and navigation. The Data Analysis Tool provides a user friendly environment for the data analysis and results visualizing.

The tool contains a precise modelling of the GNSS observables (code and phase) at the centimetre level, allowing both standalone GPS positioning and PPP. The software is ready to incorporate future updates to Galileo or GLONASS systems.

2.1.1 Software package features

- Graphic User Interface (GUI) to ease the utilisation of the tool with most of the capabilities of the DPC. The GUI allows a high customisation interface to process a wide range of options.
- Tooltips in the GUI, which allow understanding and using the different options.
- Capable to read:
    - Station measurements from Observation RINEX standard 2.11.
    - Station measurements from Observation RINEX standard 3.00.
    - Broadcast message from Navigation RINEX standard.
    - Satellite clocks from Clocks RINEX standard.
    - Satellite orbits and clocks from SP3 standard.
    - Ionospheric maps from IONEX standard.
    - Constellation status (with information between Satellite Vehicle Number (SVN) and PRN) of the satellite.
    - Antenna Phase Center information from ANTEX standard.
    - Differential Code Biases from precise .DCB files.
    - Receiver type information from GPS Receiver File Types,

- The DPC is able to work both with command-line parameters and a configuration file.
- Automatically detects if the format is RINEX 2.11 or 3.00.
- Fully capable to read Galileo (and other constellations) from RINEX.
- Able to process both pseudorange and carrier phase.
- Detection of cycle-slips in carrier phase measurements for GPS with three different methods:
    - Geometric-free carrier phase combination.
    - Melbourne-Wübbena combination.
    - Code-Phase difference (for single-frequency receivers),
- Time handling routines (The native time format of the software is Modified Julian Day and seconds of day).
- Prealignment of carrier phase to pseudorange measurements. This is done to avoid large differences between both kinds of measurements, and allow a more direct comparison. The alignment is done keeping the integer part of the carrier phase.
- Pseudorange jump checking. Some receivers have an inconsistent set of pseudorange and carrier phase measurements when they adjust their own clock (doing one or more leap miliseconds). Their pseudorange measurements are consistent with this change in clock, but carrier phases do not show it. This creates an inconsistency and a general cycle-slip for all satellites if not handled properly. gLAB detects and corrects this problem.
- Decimation capabilities. gLAB can decimate the input RINEX to increase computation speed if a high sampling rate is not needed. The decimation comes after the cycle-slip detection to take full profit of the input data rate.
- Able to individually select/deselect each satellite for processing.
- Able to set an elevation mask to ignore low satellites for processing.
- Able to specifically mark which frequencies are available (to simulate single-frequency receivers from dual-frequency RINEX data).
- Pseudorange smoothing option.
- Orbit interpolation of SP3 data.
- Broadcast message support (orbit estimation, clock correction, TGD correction).
- Orbit/Clock comparison mode (it can compare the orbit and clocks from 2 different sources, i.e. broadcast, SP3 and clocks files).
- Sun approximate positioning (for satellite orientation).
- Models implemented (all of them can be enabled or disabled):
    - Satellite clock error correction.
    - Transmission time computation.

  - Earth rotation in flight time of the signal.
  - Satellite phase center correction.
  - Receiver phase center correction.
  - Receiver Antenna Reference Point (ARP) correction.
  - Relativistic correction.
  - Klobuchar ionospheric correction.
  - Tropospheric correction [one simple model and the more refined Niell mapping model]
  - P1 – P2 Differential Code Bias (DCB) correction.
  - P1 – C1 Differential Code Bias (DCB) correction.
  - Wind up effect.
  - Solid tides correction.
  - Gravitational delay correction [an effect of general relativity due to the gravity field gradient between receiver and transmitter].
- Able to choose different measurements (1 or more) for the filter estimation (both carrier phase and pseudorange). It could even work with a set of different pseudorange measurements from different signals. This can be useful in the future Galileo scenario, where some processing with different measurements can be desired.
- Able to assign different weights for different measurements.
- Able to assign elevation dependant weights.
- Able to translate from cartesian (native of the software) to geodetic coordinates.
- Orientation estimation of both the satellites and the receiver (and thence the azimuth/elevation of the receiver-satellite pair).
- Standalone processing using broadcast and C/A code (fully configurable to be able to used also carrier phase if required).
- Precise Point Positioning (PPP) with precise orbit and clocks, precise models and Pc/Lc measurements (ionospheric-free combinations). It is also fully configurable.
- Able to create different plots to visualise the data processed.
- Detection and warning of convergence problems.

2.1.2 Identified limitations

The current version gLAB only implements full processing capabilities for GPS data. Nevertheless, the reading of RINEX-3.00 Galileo and GLONASS data functionality is also included, allowing performing some exercises on data analysis with real or simulated Galileo and GLONASS measurements.

2.1.3 Minimum hardware requirements

gLAB requires the following computer minimum hardware requirements in order to be properly executed:

- 256 MB of memory.
- CPU with at least 1GHz.
- 200MB of hard disk free space.
- Screen resolution of at least 1024x768 is recommended. In order to cope with potential users using small screens, scrollbars can be displayed in the preferences button.

2.1.4 Minimum software requirements

The program runs under Windows XP and Linux Operating systems.

2.1.4.1 Windows

No specific software is required to execute the program in Windows XP.

For Windows Vista users, it is necessary to generate new binaries for gLAB (as explained is section 3.1.1). In this sense, the following programs are required:

- MinGW v5.1.4 (http://sourceforge.net/projects/mingw/files/)
- Python(x,y) v2.1.14 (http://www.pythonxy.com). During its installation please select as “type of install”: *Full*.

2.1.4.2 Linux

For Linux users, the following programs are required (later versions may also work):

- make 3.81
- gcc 4.1.3
- Python v2.5.4
- wxPython v2.8.9.2
- Python matplotlib v0.98.5.4

- Python Tkinter v5.4.0

3 INSTALLATION PROCEDURE

The gLAB software package can be downloaded from the following URL:

http://www.gage.es/gLAB/

In this web page it is possible to download the last version of gLAB both in Windows and Linux.

3.1 WINDOWS XP AND VISTA

The installation of the Windows version is initiated by executing the installation program. During the installation process you have several configurable options, such as the installation directory (by default, C:\Program Files\gLAB), and the possibility to create shortcuts.

The installation will create a gLAB group in the start menu with the following elements:

- *gLAB on the Web*, will forward to the webpage of gLAB.
- *Uninstall gLAB*, to completely remove gLAB from the computer.
- *gLAB_GUI*, the Graphic User Interface of gLAB.
- *Command line in directory*, which will open a new command line window in the directory gLAB was installed.

Executing the gLAB_GUI option will run the GUI program.

3.1.1 Manual binary generation

All the binaries of the Windows XP version of gLAB have been precompiled, so no need to compile them again would be required. In the case that the source code is modified, or in the case that some of the binaries are not properly working a manual binary generation would be needed. Windows Vista has some problems with the precompiled version of XP, so this procedure should be applied to Windows Vista users.

For the manual binary generation the following programs need to be installed (other versions may also work):

- MinGW v5.1.4 (http://sourceforge.net/projects/mingw/files/)
- Python(x,y) v2.1.14 (http://www.pythonxy.com). During its installation please select as “type of install”: *Full*.

Once these programs have been installed, the script “createEXE.bat” can be executed. This script can be found in the installation directory of gLAB, and will compile everything and create the proper binaries.

3.2 LINUX

gLAB has been successfully tested under Ubuntu, but should work in other Linux distributions.

The Linux version of gLAB has to be decompressed to a directory, using the following command:

tar –xvzf glab_vx.x.tgz

This will create a directory called 'gLAB' with all the program structure. Next, it is necessary to compile the DPC, for this:

cd gLAB

make –f makefile_linux

This will create the binary for the DPC of gLAB (gLAB_linux).

In order to be able to launch the python programs (GUI and DAT), it is necessary to have the following packets installed in the system (other versions may also work):

- Python v2.5.4
- wxPython v2.8.9.2
- Python matplotlib v0.98.5.4
- Python Tkinter v5.4.0

In ubuntu, this can easily be done by using the following command:

apt-get install python python-wxtools python-matplotlib python-tk

3.3 DIRECTORY STRUCTURE

gLAB

gLAB/src

gLAB/test

gLAB/win

The *gLAB* directory contains all the binaries, python programs and other files.

The *gLAB/src* directory contains the C source code of the DPC.

The *gLAB/win* (only available in the windows distribution) directory contains all the required data for the GUI and DAT binaries. This directory can be fully generated by the "Manual binary generation" procedure set above.

The *gLAB/test* directory contains a set of test files to be used with the gLAB program.

4 *gLAB* GRAPHIC USER INTERFACE (GUI)

4.1 THE BASICS

The GUI is an interface between the other two components, the DPC and the DAT. It will allow the user changing different parameters, and execute the other two programs with the proper arguments. The initial screen of the GUI can be seen in Figure 4-1.

Figure 4-1: Initial screen of the gLAB Graphic User Interface

Two main tabs can be found:

- **Positioning**: This tabs interfaces with the DPC tool, and allows selecting all the different processing options.
- **Analysis**: This tabs interfaces with the DAT tool, and allows selecting all the different plotting options.

The following sections will provide in-deep information on the different options of the GUI. Most of the information here can also be found with the inline tooltips. On the top of the screen two different buttons can be found:

- **Preferences**: Allows to select/deselect explanatory tooltips (selected by default), to select/deselect scrollbars, and to check for new updates of the tool.

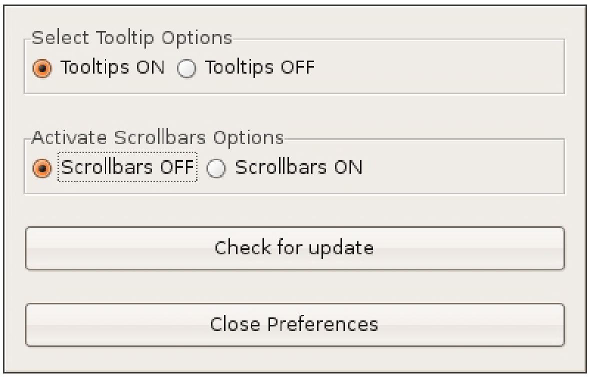

Figure 4-2: Preferences Frame

- **About**: General information on the tool.

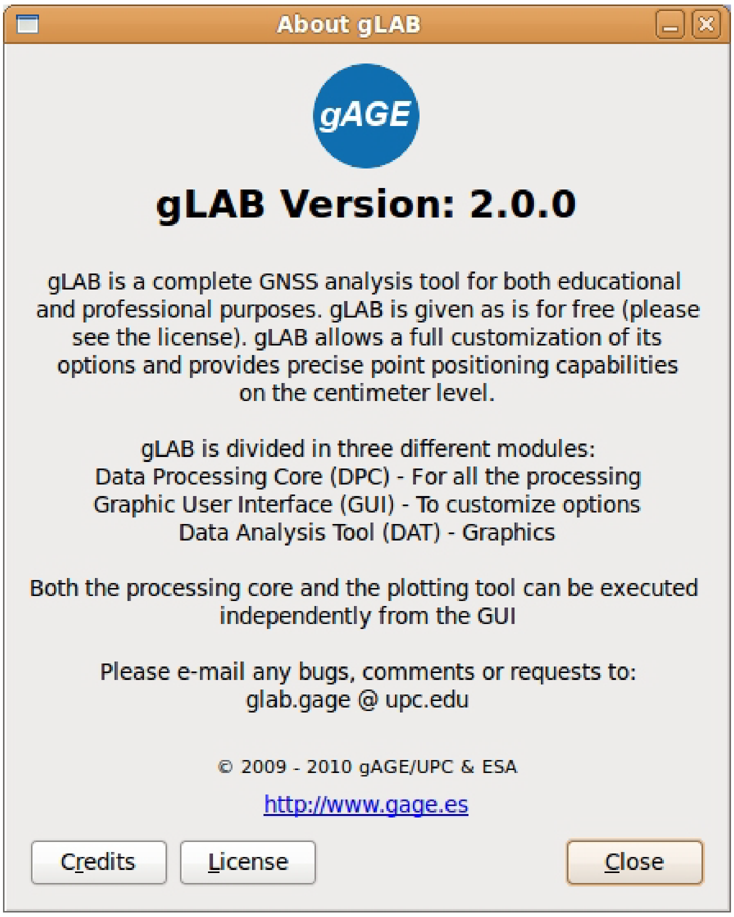

Figure 4-3: About Frame

4.2 CALCULUS (DPC INTERFACE)

The calculus tab is split into 5 different sections, which correspond to 5 different modules inside the DPC (see the Architecture Design Document for gLAB RD-4). The different modules of the DPC are:

- *DATAHANDLING module*: It is the storage of the data. This module does not appear in the GUI interface, because it has no configuration options. It defines all the structures and enumerators of the program and has functions to access the data.
- *INPUT module*: It can be understand as a "driver" between the input data and the rest of the program. This module implements all the input reading capabilities and stores it in structures defined in the DATAHANDLING module.
- *PREPROCESS module*: This module process the data before the MODEL. It checks for cycle-slips, pseudorange-carrier phase inconsistencies and decimates the data (if requiered).

- *MODEL module*: This module has all the functions to fully model the receiver measurements. As said, it implements several kind of models, which can be activated or desactivated.
- *FILTER module*: This module implements an Extended Kalman Filter (EKF) fully configurable, and obtains the estimations of the required parameters.
- *OUTPUT module*: This module outputs the data obtained from the FILTER.

4.2.1 Input

This section provides all the configuration options to select the input files for gLAB.

Figure 4-4: Screenshot of the INPUT section.

- Default Templates: Configure all the options of the program for a specific processing:
  - o SPS Template: Selects all the options to perform a Standard Positioning Service (SPS) processing.
  - o PPP Template: Selects all the options to perform a Precise Point Positioning (PPP) processing for the computation of precise coordinates.
- Input files: Section to include all the files required for the proper functioning of the program.
  - o RINEX Observation File: Source GNSS measurements data file in RINEX format (version 2.11 or 3.00).

- ANTEX File: Antenna phase center information for both GNSS satellites and receiver antennas[1].
- Orbit and Clock Source: Origin of the orbit and clock products. The option selected here must be consistent with the *Navigation Mode* in the Filter section: Broadcast => Standalone, Precise (1 file) or Precise (2 files) => PPP
  - Broadcast: RINEX navigation file with the broadcasted message [Standalone option must be marked in the Filter section].
  - Precise (1 file): SP3 format file with the position/clock errors of GNSS satellites for a set of specific timestamps [PPP option must be marked in the Filter section][2].
  - Precise (2 files): The source of orbits will be an SP3 format file, and the clocks will be a RINEX clock format. While orbit data can be interpolated without much data degradation, clocks cannot be. The RINEX clock format allows providing clocks at a high rate, while reading the orbits at a lower rate from the SP3 file [PPP option must be marked in the Filter section].
    - Orbits SP3 File: Source of orbit data.
    - Clocks Rinex File: Source of clock data.
- Ionosphere Source: Origin of the ionosphere data when correcting it (see the

[1] The last ANTEX files can be found in: [RD-5]. The gLAB suite includes two different ANTEX files: igs05.atx and igs_pre1400.atx. The first file is directly downloaded from [RD-5], and should be used for data sets after GPS week 1400 (5th of November of 2006). The second one should be used before this date. This is because there was a change in the way that Satellite Phase Centers were obtained. Thence using Precise files for navigation with the incorrect set of ANTEX file will be translated in higher than expected errors.

[2] SP3 files can be found at the IGS site: [RD-6].

Modeling section (4.2.3) for more information).

    - Broadcast (same as navigation): For Klobuchar ionospheric model, use the same broadcasted file as for the orbits and clocks for the Klobuchar parameters.
    - Broadcast (specify): For Klobuchar ionospheric model, specify a different broadcasted file to use for the Klobuchar parameters. This option is also useful when using SP3 and correcting ionosphere.

- A priori Receiver Position: Initial receiver position. This is used to linearize the filter and to obtain the values for the models. The OUTPUT message type gives the position obtained by the filter differenced with this apriori position. So if this position is accurate enough, the difference can be used as a direct measure of the error.
  - Specify: Specify the receiver position in XYZ components (in meters).
  - Use RINEX Position: Use the *APROX POSITION XYZ* field of the RINEX of measurements.
  - Calculate: Do not provide apriori position, gLAB will calculate it, and adjust it as necessary (useful for moving receivers, or when the approximate receiver position is unknown).
  - Use SINEX File: Match the observation RINEX header record MARKER NAME with the marker position present in the SINEX file.
- Auxiliary files: User can provide different auxiliary files: to get information about the receiver and to correct the Differential Code Biases (DCB) which are the delays due to electronic, antennas and cables of receiver and transmitter devices which directly affect the measurements with a bias. This effect can be corrected using the information extracted from: The RINEX Navigation file or Precise .DCB files.
  - P1 – P2 DCB Source files:
    - Broadcast (same as navigation): Use the same RINEX navigation file for the DCB computations than the orbit and clock product source.
    - Broadcast (specify): Specify a different RINEX broadcasted file to obtain the codes (P1 – P2) digital bias.
    - Precise .DCB file: Specify a .DCB file for the (P1 – P2) biases for all satellites.
  - P1 – C1 DCB Source files:
    - Receiver Type file: Specify a file with the receiver type information: Receivers, Antennas, Radomes, and Antenna+Radome manufacturer's name, model and code.
    - Precise .DCB files Specify a .DCB file for the (P1 – C1) biases for all satellites.
- Save Config button: Stores all the GUI configuration into a .cfg file, which can afterwards be read by the processing core by means of the '-inpu:cfg' parameter.

In Linux:

./gLAB_linux –input:cfg gLAB.cfg

In Windows:

gLAB.exe –input:cfg gLAB.cfg

- Show Config button: Opens a text editor to show the stored GUI configuration file.
- RUN button: Execute the DPC program with all the configured parameters of the *Calculus* tab. This button can be used in all Input, Preprocess, Modeling, Filter and Output sections.
- Show Output button: Opens a text editor of the output of the last execution of gLAB.

4.2.2 Preprocess

This section provides all the configuration options to preprocess the input data. In particular, it allows changing the decimation rate, the elevation mask, the cycle-slip detection, and selecting individual satellites for the processing. Figure 4-5 shows a screenshot of the PREPROCESS section.

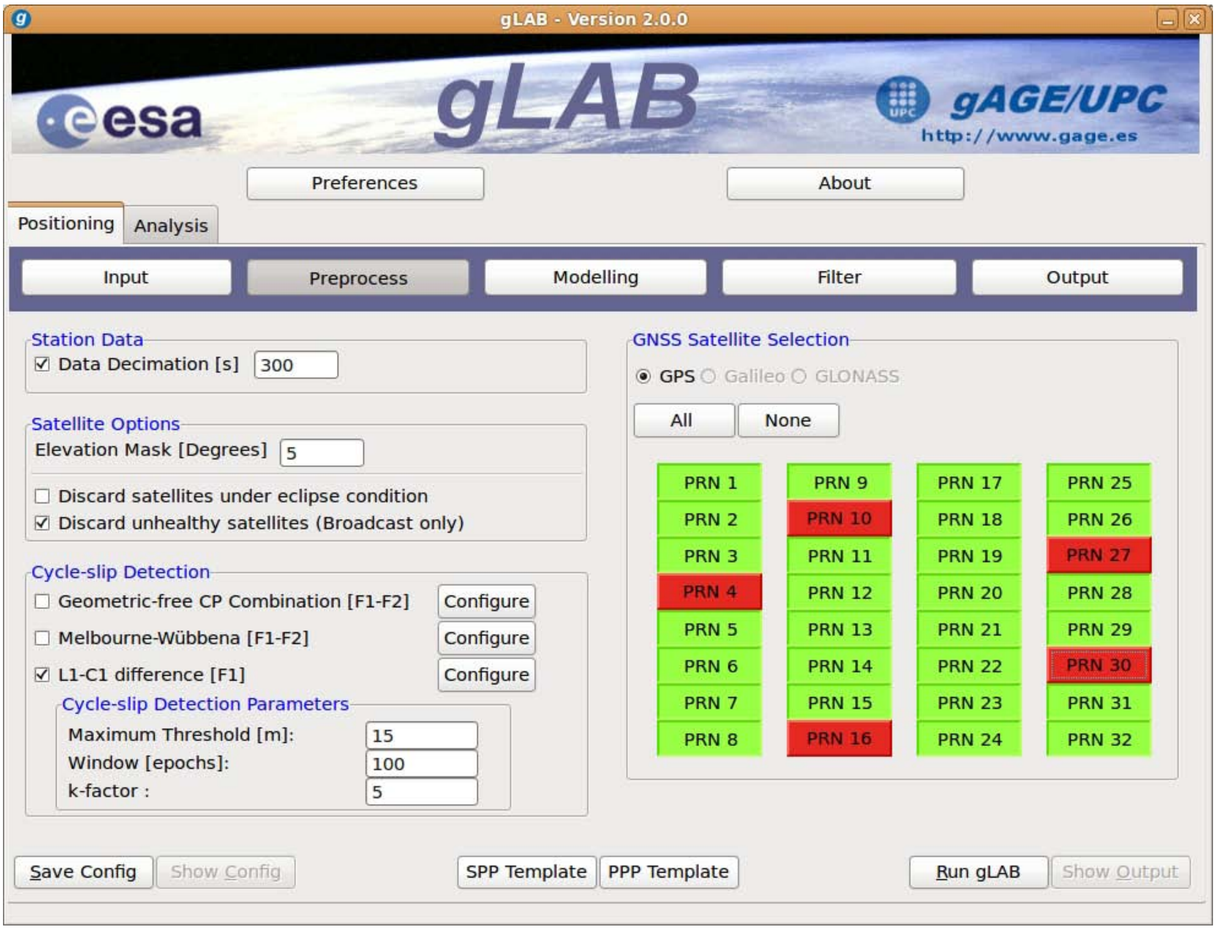

Figure 4-5: Preprocess section screenshot.

- Station Data.
  - o Data Decimation [s]: This option will decimate the input data at the specified rate [in seconds]. If this option is unchecked, every time an epoch is found in the input RINEX observation file, all the processing takes place. If this option is checked, the data is decimated and not even modeled. Even in decimated data, all the epochs are used for cycle slip detection, and arc length computations, but the process is stopped just before the modeling. This option is meant to be used to reduce computation time.
- Satellite options.
  - o Elevation Mask [Degrees]: The elevation mask parameter is used to discard all the satellites below the specified elevation. Low elevation satellites should

be discarded for geodetic processing as they may contain increased errors due to low signal-to-noise ratio and multipath.

- Discard satellites under eclipse condition: This option allows to activate the discard of satellites if they are under eclipse conditions:
  - They do not have direct visibility of the Sun or
  - They have been in the former condition at some time of the last 30 minutes.
- Discard unhealthy satellites (Broadcast only): This parameter allows discarding satellites based upon the healthy flag of the broadcasted navigation message.

- Cycle-slip Detection: This section provides all the configuration options for cycle-slip detection. This is only used for carrier phase measurements, and in the present version of the software for GPS only. Each cycle-slip detection method can be enabled/disabled individually.
  - Geometric-free CP Combination [F1-F2]: This cycle-slip detector for dual-frequency receivers uses only carrier phase measurements. It creates a geometric-free combination (which shall be affected by ionosphere) and will follow its shape with a second order interpolator. If the expected value is higher than the measured one by more than a specific threshold, a cycle-slip is declared. The threshold is obtained as:

    $$Th = \mathbf{max} - (\mathbf{max}\text{-}\mathbf{min})*\exp(-step/\mathbf{T_0})$$

    Being **max, min** and $\mathbf{T_0}$ configurable parameters (*Minimum Threshold*, *Maximum Threshold* and *Time Constant*), and step the time step between epochs.
  - Melbourne-Wübbena Combination [F1-F2]: This cycle-slip detector for dual-frequency receivers uses the Melbourne-Wübbena combination (geometric-free ionospheric-free). This combination uses pseudorange measurements, and thence, is affected by code receiver noise and multipath effects. This combination is basically a constant with noise and jumps due to the cycle-slips. A mobile mean and standard deviation of the last epochs is computed. The mean is compared against the measured value, and if it is higher than a specified threshold, a cycle-slip is declared. The threshold depends on the standard deviation of the last epochs, and is computed as:

    $$Th = \text{minimum}(\mathbf{max},\text{maximum}(\mathbf{k}\cdot stdDev,\mathbf{min}))$$

    being **max**, **min** and **k** configurable parameters (see below) and *stdDev* the computed standard deviation. minimum() and maximum() are functions returning the minimum and maximum between two values.
  - L1-C1 Difference [F1]: This cycle-slip detector for single-frequency receivers uses the difference between L1 and C1 (L1P and C1C). This difference contains basically noise coming from C1, sudden jumps coming from cycle-slips, and a ionospheric divergence with time, due to the different effects that the ionosphere causes in carrier phase and pseudorange measurements.

This detector computes the mean and standard deviation of L1-C1 along the epochs, proving a window to limit the divergence. The expected mean value is compared against the obtained one, and if it is higher than a specific threshold, a cycle-slip is declared. The threshold is obtained as:

Th = minimum(**k**·*stdDev*,**max**)

being **k**, **max** and the window size configurable parameters, *stdDev* the computed standard deviation, and minimum() the function returning the minimum between two values.

- GNSS Satellite Selection: The buttons allow to individually select/deselect each satellite for processing. A deselected satellite shall not be taken into account when processing. Green color marks selected satellites and red deselected satellites.

4.2.3 Modeling

This section provides the configuration options to set/unset each individual model that is used by gLAB. Figure 4-6 shows a screenshot of the MODEL section.

Figure 4-6: Modeling section screenshot

- Modeling Options: The following options allow to enable/disable the different models included in the processing.
    - o Satellite clock offset correction: The satellite clock errors correspond to the clock synchronism errors of the satellite clocks in relation to the GNSS system time scale. These errors depend heavily on the type of oscillator of the satellite and are quite unpredictable. They can only be obtained by some kind of estimation. The typical source for estimations of these errors are the own navigation message, or some kind of external estimation, such as SP3 files. The effect of these clock errors can reach up hundreds of kilometers.
    - o Consider satellite movement during signal flight time: Due to the distance between satellites and receivers (between 20000 and 26000 Km for GPS), the signal travel time is not despicable (about 70 ms for GPS). Thence the receiver is obtaining the measurement after it has been emitted by the

satellite. This fact should be taken into consideration, as the position of the satellite must be computed in the transmission time, not in the reception time. This effect can impact on the measurements up to hundreds of meters.

- Consider Earth rotation during signal flight time: Besides the satellite movement during signal flight time, the Earth also moves [rotates]. If this effect is not taken into consideration, an error of about 30 m in the east direction would be seen.

- Satellite mass center to antenna phase center correction: Each data source of satellite orbits (in general the navigation message or an SP3 file) provides these orbits in its specific reference. In particular, the SP3 files provide the positions of the satellite referred to its mass center (which is different than the antenna phase centers). In order to properly correct the GNSS measurements with the satellite position, a correction between these two centers must be done. Usually these corrections can be obtained from an ANTEX file. This error can be up to 1-2 m. The positions computed from the navigation message do not require any additional corrections, as they are referred to the antenna phase center.

- Receiver antenna phase center correction: Normally the positions of the stations are given in relation to the base of the station. The difference between this point and the antenna phase center should be taken into account. This effect depends on the frequency, and can reach up to some decimetres.

- Receiver antenna reference point correction: Additionally to the Antenna Phase Center, the position of a station can be given in relation to a specific point (such as a geodetically positioned point in the ground). This correction allows to give a specific correction to the position in North/East/Up components.

- Relativistic clock correction: The rate of advance of two identical clocks, one placed in the satellite and the other on the terrestrial surface, will differ due to the difference of the gravitational potential (general relativity) and to the relative speed between them (special relativity). The special relativity difference can be broken into (Hofmann-Wellenhof): 1) A constant component that only depends on the nominal value of the semi-major axis of the satellite orbit, which is adjusted modifying the clock oscillating frequency of the satellite. 2) A periodical component due to the orbit eccentricity (that must be adjusted by the user receiver) equal to:

  $$rel = 2*(\mathbf{r}\cdot\mathbf{v})/c$$

  This effect can reach up to 13 m.

- Ionospheric correction: The ionosphere is the zone of the terrestrial atmosphere that extends itself from about 60 km until more than 2000 km high. Due to the interaction with free electrons, electromagnetic signals that go through it suffer a delay/advancement in relation to the propagation in a vacuum. This effect is a dispersive effect (frequency dependent), and can be removed in multi-frequency receivers (with a specific combination of measurements). The ionosphere is hard to model, and the Klobuchar model (the one defined in the GPS/SPS-SS [RD-14] and available in the navigation message) can only reduce its impact between a 50% and a 60%. The ionosphere effect can reach up to 50 m in turbulent ionospheric environments.

- Tropospheric correction: At the frequency which the GPS signal is emitted, the troposphere behaves like a non dispersive media, being its effect independent of the frequency. The tropospheric delay can be modelled in an approximate way (approximately about 90%-95%) using the following expression:

$$T = d_{dry} \cdot m_{dry}(elev) + d_{wet} \cdot m_{wet}(elev)$$

where d_{dry} corresponds to the vertical delay due to the dry component of the troposphere and d_{wet} corresponds to the vertical delay associated with the wet component (due to the water vapor of the atmosphere). These two different nominals can ve computed as

  - Using a simple nominal described in GIPSY-OASIS [RD-7]:

    $d_{dry} = 2.3 \exp(-0.116 \cdot 10^{-3} \cdot \mathrm{H})$

    $d_{wet} = 0.1$

    where H is the height over the ellipsoid.

  - Computing a nominal from the receiver's height and estimates of five meteorological parameters: pressure, temperature, water vapour pressure, temperature lapse rate and water vapour lapse rate. It is adopted by SBAS systems (AD-07).

Finally mdry(elev) and mwet(elev) are the slant factors in order to project the vertical delay in the direction of the satellite observation for the dry and wet components. Two models can be chosen to compute these m(elev):

  - A simple mapping model (used in SBAS [RD-9]). This mapping only depends on satellite elevation and it is common for wet and dry components.
  - The more refined Niell mapping model [RD-8]. This mapping considers different obliquity factors for the wet and dry components.

The main part of the troposphere which has not been properly modelled (about 10%) corresponds mainly to the wet component. The total effect of troposphere can range up to 10 m.

- P1 – P2 correction: Differential Code Biases (DCB) are the delays due to electronic, antennas and cables of receiver and transmitter devices which directly affect the measurements with a bias. This effect depends on the frequency and can be corrected using the information extracted from:

  - The RINEX Navigation file, where the (P2-P1) bias are given as the Total Group Delay (TGD).

        - Precise .DCB files, where the International GNSS Service (IGS) gives an accurate estimation of the (P1-P2) bias. This file contains a monthly estimation of this bias for all Satellites
    - P1 – C1 DCB correction: Differential Code Biases (DCB) are the delays due to electronic, antennas and cables of receiver and transmitter devices which directly affect the measurements with a bias. Because the code generation depends on the Receiver Type, this receiver-related information has to be given together with the corrections. gLAB works in two different modes:
        - Flexible: gLAB will use whichever C1 or P1 measurement is available in the receiver, without correcting DCB. If both code measures are available, P1 will be used as default. Used when receiver provides C1 but P1 is missing (or viceversa).
        - Strict: gLAB Data Processing Core (DPC) stops if both files are not provided:
            - Receiver Type File: To identify how codes are generated in the receiver, and how to remove these C1-P1 biases.
            - P1-C1 DCB File : Containing the P1-C1 DCB corrections.
    - Wind up correction (Carrier phase only): The wind up only appears in carrier phase measurements and is due to the rotation of the Line-of-sight vector in relation to the antenna. The wind-up has an accumulative effect, and for fixed antennas can reach up to half the wave length of the measurement.
    - Solid tides correction: The attraction of Sun and Moon and the inelasticity of the Earth's mantle cause variations to the positions of ground receivers. This effect can reach up to some decimetres (the model used is described in [RD-10], and is implemented up to degree 3).
    - Relativistic path range correction: As introduced in the *Relativistic clock correction* section, the difference of the gravitational potential (general relativity) affects the measurement. This is a small effect that has elevation dependence, and has a total effect of about 4 cm.
- Precise Products Data Interpolation: This is the degree of the interpolation polynomial for the precise orbit and clocks (this option has no effect when using broadcasted products).
    - Orbit Interpolation Degree: By default, the interpolation is done with a polynomial of degree 9, but this value can be adjusted with this parameter. Excessively low values would strongly affect the precision of the position obtained.
    - Clock Interpolation Degree: By default, no interpolation is done ("degree" 0), but you can chose to activate the interpolation by providing a number different than 0. Due to the unpredictability of clocks, and its non-smoothed nature, the interpolation of low sampling rate clocks (i.e., t>30 secs) would strongly affect the precision of the clocks obtained. Only clocks with sampling rate higher than 1/30s should be interpolated with a polynomial of degree 1.

- Receiver Antenna Phase Center:
    - Specify: Specify in North/East/Up components the receiver antenna phase center. Different values can be specified for different frequencies.
        - F1/F2: Frequency selector.
        - North/East/Up [m]: Each of the components expressed in meters.
    - Read from ANTEX: Read the Phase Center data of the receiver from the ANTEX file specified in the Input section. It tries to obtain the name of the antenna using the RINEX header record *ANT # / TYPE*, and seeks for that name in the ANTEX file.
- Receiver Antenna Reference Point:
    - Specify: Specify in North/East/Up components the receiver Antenna Reference Point.
    - Read from RINEX: Read the receiver Antenna Reference Point from the RINEX file. It seeks for the *ANTENNA: DELTA H/E/N* RINEX header record.

4.2.4 Filter

This section provides all the configuration options to specify the behaviour of the Kalman Filter. In particular, the selection of measurement and the parameters to be estimated can be chosen in this section. Figure 4-7 shows a screenshot of the FILTER section.

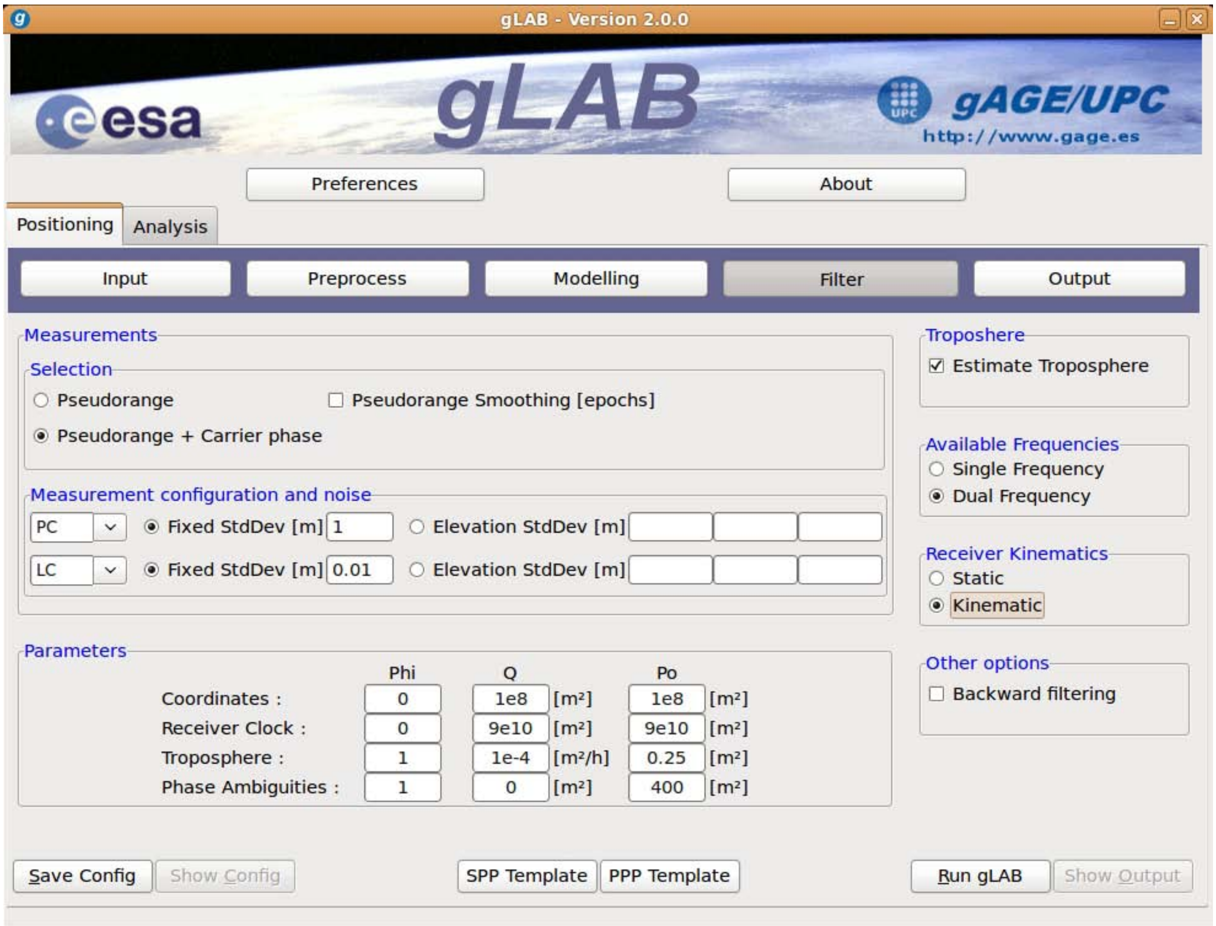

Figure 4-7: Filter section screenshot

- Troposphere: Activates the estimation of the troposphere. This estimation tries to remove the part of the wet troposphere delay not removed by the nominal modeling (see

Modeling section). The estimation depends on the model chosen to compute the m_{wet}(*elev*) function (Niell mapping should be used for more realistic results).

IMPORTANT: Reliable troposphere estimation can only be obtained following options:

Navigation Mode: PPP Template

Measurements: Pseudorange + Carrier phase

Available frequencies: Dual Frequency

Outside this specific case, the troposhere estimation should be disabled.

- Available Frequencies: Select which frequencies are available.
    - Single Frequency: Use this option to force the receiver to be understood as a single-frequency one. Discarding all the measurements in the F2. For conditions with the rest of the values of this window, see *SPP/PPP Navigation Mode Templates*.
    - Dual Frequency: Use this option to have the measurements for both frequencies (F1 and F2) available. For conditions with the rest of the values of this window, see *SPP/PPP Navigation Mode Templates* tooltips.
- Receiver Kinematics: Select which is the supposed movement of the receiver.
    - Static: Select this option to do a processing supposing that the receiver is static. This modifies the filter parameters **Phi** (propagation) and **Q** (process noise) for the positions to: **Phi** = 1 and **Q** = 0.
    - Kinematic: Select this option to do a processing supposing that the receiver is in movement. This modifies the filter parameters **Phi** (propagation) and **Q** (process noise) for the positions to: **Phi** = 0 and **Q** = inf.
- Other options: Backward filtering. This kind of processing reverses the input observation RINEX file when it reaches the end of the file, and processes it backwards. This is also called smoothing and it allows to have good estimation of the parameters (such as the troposphere, and the position in a kinematic receiver) in the beginning of the file, what would be the convergence period.
- Measurement configuration and noise: Section to specify the input measurements used in the filter, and its corresponding standard deviation noise (to be used for the filter weights).
    - Selection:
        - Pseudorange: Use only pseudorange measurements for the processing. The ambiguity estimation in the filter will be disconnected with this option set. For conditions with the rest of the values of this window, see *SPP/PPP Navigation Mode Templates*.
        - Pseudorange + Carrier phase: Use both pseudorange and carrier phase measurements for the processing. For conditions with the rest of the values of this window, see *SPP/PPP Navigation Mode Templates*.

- Pseudorange smoothing [epochs]: Use the Hatch filter to smooth the pseudorange measurements with carrier phase one. This option will reduce the noise of the measurements included in the filter. This should only be activated when processing with pseudorange only (no carrier phase), as the carrier phase is better included in the filter in that other way better than using smoothing. The use of smoothing allows to enhance the pseudorange without the cost of the increased filter complexity for carrier phase amibiguities estimations. The Hatch filter is defined as:

  $$P_{i,smoothed} = mean(P\text{-}L)_i + L_i$$

  Being the mean() a function that computes the mean of pseudorange and carrier phase measurements. This mean at epoch *i* is obtained:

  $$mean(P\text{-}L)_i = ((n-1)*mean(P\text{-}L)_{i-1} + (P\text{-}L)_i)/n$$

  being *n* the arc length at epoch *i* limited to a maximum value. This limitation is to reduce the effect of the ionospheric divergence between pseudorange and carrier phase measurements. If both measurements do not have ionospheric divergence (i.e. Pc and Lc), the parameter can be as high as desired.

- Configuration.
  - [Grayed option]: Selected measurements for the filter.
  - Fixed stdDev [m]: This sets the standard deviation of the corresponding measurement to be used as weight in the filter. The weight is computed as:

    $$W = 1/(stdDev)^2$$

  - Elevation stdDev: This sets the standard deviation of the corresponding measurement to be used as weight in the filter as a function of the elevation. The standard deviation is computed as:

    $$stdDev = \mathbf{a} + \mathbf{b} \cdot e\hat{}(elev/\mathbf{c})$$

    Being **a**, **b** and **c** the three parameters, and *elev* the elevation in degrees of the satellite. The filter weight is finally computed as:

    $$W = 1/(stdDev)^2$$

- Parameters:
  - Phi: **Phi** sets the propagation of parameters between epochs (transition state matrix). '1' means that the value estimated in the epoch *i+1* is used as apriori value in the epoch *i*, '0', means that the apriori value is always '0'.
  - Q: The process noise parameter (**Q**) sets the stability of a parameter along time. The process noise is included after the estimation when propagating the parameters to the next epoch, and is an increase in the covariance of the parameter. A process noise of '0' means that the parameter is a constant.
  - P_0: The Kalman filter requieres initial values for all its parameters:

Position: The *Apriori receiver position* in the Input section is used.

Clock: A '0' value is assigned due to its high variability.

Troposphere: Due to the fact that about 90% of the troposphere is corrected by a proper modeling, and only about a 10% has to be estimated (and is usually around 10 cm), a '0' value is used for apriori.

Carrier phase ambiguities: As carrier phase is prealigned with code, the ambiguities are not far from '0', thence this value is used as apriori.

The parameter $\mathbf{P_0}$ sets the initial uncertainty of these apriori values.

- Position: This comprises the 3 parameters with the 3D position [XYZ] of the receiver. Typical values:

  Apriori value: Apriori receiver position, configured in Input section.

  Phi: '1' [Static positioning], '0' [Kinematic positioning].

  Process noise: '0' [Static positioning], 'inf' [Kinematic positioning].

  Initial covariance: 'inf' (A smaller value for the initial covariance will increase the convergence time, but would require a good initial position).

- Receiver Clock: This parameter is the receiver clock synchronism error referring to GPS time scale. Typical values:

  Apriori value: '0'.

  Phi: '0'.

  Process noise: 'inf'.

  Initial covariance: 'inf'.

- Troposphere: This parameter estimates part of the troposphere not taken into account in the nominal model (see Modeling section). This 10% is mostly associated with the wet component of the troposphere, which is due to the water vapor of the atmosphere. The mapping $m_{wet}(elev)$ function described in the Modeling section is used in the troposhere estimation. Typical values:

  Apriori value: '0'.

  Phi: '1'.

  Process noise: '1e-4' in units of [m²/h]. Contrary to the rest of parameters, troposphere process noise is given as increase of **Q** per time unit.

  Initial covariance: '0.025' (equivalent to 0.5 meters of uncertainty).

- Phase ambiguities: Carrier phase ambiguities are the parameters which estimates the ambiguities of the carrier phase measurements (or combinations) used in the filter. Each epoch, there is one parameter for each satellite. Additionally, when a cycle-slip is detected, the carrier phase ambiguity is reset (by providing a new initial value and covariance).Typical values:

Phi: '1'

Process noise: '0'.

Initial covariance: '400' (equivalent to 20 meters in relation to the pseudorange measurement used to prealign the carrier phase).

4.2.5 Output

This section provides all the configuration options to select which messages are output. Figure 4-8 shows a screenshot of the OUTPUT section.

Figure 4-8: Output section screenshot

- Output Destination: Sets the output file where all messages will be written.
- Messages: Individually select which messages are printed.
  - o Print INFO Messages: INFO messages are shown at several points in the program and provide information on the program configuration and problems it may encounter.
  - o Print CS (Cycle-Slip) Messages: CS messages are shown when a cycle-slip is found by any detector. The first 5 fields are fixed, afterwards, there are three possible blocks depending on the cycle-slip detector activated.

    Field 1: 'CS'

    Field 2: Year

Field 3: Doy

Field 4: Seconds of day

Field 5: PRN satellite identifier

Block 1: Geometric-free carrier phase cycle-slip detector (Li)

Field 1: 'Li:x', being x, 0 or 1 (0-> Li did not detect the cycle-slip, 1-> Li did)

Field 2: Li value (estimated-observed)

Field 3: Li Threshold

Block 2: Melbourne-Wübbena cycle-slip detector (Bw)

Field 1: 'Bw:x', being x, 0 or 1 (0-> Bw did not detect the cycle-slip, 1-> Bw did)

Field 2: Bw value (estimated-observed)

Field 3: Bw Threshold

Block 3: L1-C1 average cycle-slip detector (L1C1)

Field 1: 'L1C1:x', being x, 0 or 1 (0-> L1C1 did not detect the cycle-slip, 1-> L1C1 did)

Field 2: L1C1 value (estimated-observed)

Field 3: L1C1 Threshold

Sample: CS 2006 200 25350.00 1 Li:0 (6.266301 [0.052100]) Bw:1 (3.747907 [0.900000])

- Print INPUT Messages: Input data message. It is shown after an epoch is read (and decimated). It contains the measurements for each satellite for this epoch[3].

Field 1: 'INPUT'

Field 2: Year

Field 3: Doy

Field 4: Seconds of day

Field 5: GNSS System (GPS, GAL, GLO or GEO)

Field 6: PRN satellite identifier

Field 7: Arc length (number of undecimated epochs after the last cycle-slip)

[3] These measurements are the ones that are shown in the INPUT message. Nevertheless all the measurements included in the RINEX are read and stored by gLAB for its later use, in case of need, even if they are not printed in the INPUT message.

For GPS:

Field 8: C1 [C1C]

Field 9: P1 [C1P]

Field 10: P2 [C2P]

Field 11: L1 [L1P] (prealigned, in meters)

Field 12: L2 [L2P] (prealigned, in meters)

For Galileo (GAL):

Field 8: C1A

Field 9: C1B

Field 10: C1C

Field 11: C7Q

Field 12: C8Q

Field 13: L1A (prealigned, in meters)

Field 14: L1B (prealigned, in meters)

Field 15: L1C (prealigned, in meters)

Field 16: L7Q (prealigned, in meters)

Field 17: L8Q (prealigned, in meters)

For GLONASS (GLO):

Field 8: C1 [C1C]

Field 9: C2 [C2C]

Field 10: L1 [L1P] (prealigned, in meters)

Field 11: L2 [L2P] (prealigned, in meters)

For GEO:

Field 8: C1 [C1C]

Sample: INPUT 2006 200 0.00 GPS 19 1 23119003.9020 23119002.6110 23119004.0750 23119002.7507 23119004.0925

- Print MEAS Messages: It provides the MEASurement values. It is shown after an epoch is read (and decimated). It contains the measurements for each satellite for this epoch.

Field 1: MEAS

Field 2: Year

Field 3: Doy

Field 4: Seconds of day

Field 5: GNSS System (GPS, GAL, GLO or GEO)

Field 6: PRN satellite identifier

Field 7: Elevation of the satellite [degrees]

Field 8: Azimuth of the satellite [degrees]

Field 9: Number of Measurement(s)

Field 10: Measurement identifier (as string)

Field 11: Measurement(s) value [m]

Sample: MEAS 2010 081 300.00 GPS 30 30.00 240.00 6 C1C:L1C:C1P:L1P:C2P:L2P 20228715.3270 0.0000 0.0000 20228715.2722 20228714.8230 20228714.7005

- o Print MODEL Messages: Model break down message. It is shown when a model can be fully computed for each measurement.

Field 1: 'MODEL'

Field 2: Year

Field 3: Doy

Field 4: Seconds of day

Field 5: GNSS System (GPS, GAL, GLO or GEO)

Field 6: PRN satellite identifier

Field 7: Measurement identifier (as string)

Field 8: Signal flight time [sec]

Field 9: Measured value [m]

Field 10: Full model value [m]

Field 11: Satellite X position [m]

Field 12: Satellite Y position [m]

Field 13: Satellite Z position [m]

Field 14: Satellite X velocity [m]

Field 15: Satellite Y velocity [m]

Field 16: Satellite Z velocity [m]

Field 17: Satellite-receiver geometric distance [m]

Field 18: Satellite clock correction [m]

Field 19: Satellite phase center projection [m]

Field 20: Receiver phase center projection [m]

Field 21: Receiver Antenna Reference Point (ARP) projection [m]

Field 22: Relativistic clock correction [m]

Field 23: Wind-up correction [m] (for carrier phase measurements)

Field 24: Troposphere nominal correction [m]

Field 25: Ionosphere correction [m]

Field 26: Relativistic path range correction [m]

Field 27: Total Group Delay (TGD) correction [m]

Field 28: Solid tides correction [m]

Field 29: Elevation of the satellite [degrees]

Field 30: Azimuth of the satellite [degrees]

Sample: MODEL 2006 200 0.00 GPS 19 L1P 0.07712 23119002.7507 23119008.7502 8811456.7780 -21033910.1687 13675922.8867 1828.7339 2353.7679 2467.3576 23119457.7539 -456.317873 0.000000 -0.049360 0.000000 2.323328 0.106706 4.854110 -0.000000 0.015435 0.000000 0.063943 9.16487738221 -79.27496674531

The satellite coordinates (fields 11-16) are given in the reception epoch if the model of the signal transmission time is enabled (if it is disabled, they are given in the transmission time). The coordinates are relative of the antenna phase center or satellite mass center, depending on the option chosen in the Input section:

- Broadcast: Antenna Phase Center.
- Precise: Satellite Mass Center.

Field 9 is the direct measurement (as in the RINEX file), but scaled to meters for carrier phase measurements. Field 10 is the model computed for this measurement. Field 10 is the direct sum of fields 17 to 28.

- Print EPOCHSAT Messages: Message with the satellites used to compute the solution. It is shown when the filter is run, and is given for each measurement

  Field 1: 'EPOCHSAT'

  Field 2: Year

  Field 3: Doy

  Field 4: Seconds of day

  Field 5: Measurement identifier (as string)

  Field 6: Number of satellites in view

  Field 7-: Each following column is the identifier of a satellite

Sample: EPOCHSAT 2006 200 300.00 PC 7 15 3 19 16 18 21 22

- Print SATSEL Messages: Message with debug information of the reason why a satellite has been discarded (or selected) for processing.

  Sample: SATSEL 7 discarded: Elevation too low (3.04)

- Print PREFIT Messages: Prefilter values message. It provides the measurement-model values. It is shown in each filter execution.

  Field 1: 'PREFIT' (if the satellite is used in the computation) or 'PREFIT*' (if it is not)

  Field 2: Year

  Field 3: Doy

  Field 4: Seconds of day

  Field 5: GNSS System (GPS, GAL, GLO or GEO)

  Field 6: PRN satellite identifier

  Field 7: Measurement identifier (as string)

  Field 8: Measurement-model value (prefit) [m]

  Field 9: Measurement value [m]

  Field 10: Model value [m]

  Field 11: Elevation of the satellite [degrees]

  Field 12: Azimuth of the satellite [degrees]

  Sample: PREFIT 2006 200 300.00 GPS 19 LC -7.3029 22982271.7155 22982279.0184 28.28 -77.91

  In general Field 8 = Field 9 - Field 10, but this is no longer true when using smoothing, as the Field 9 is the raw measurement without smoothing, but the Field 8 computation takes smoothing into account.

- Print POSTFIT Messages: Postfilter values message. It provides the corrected prefits with the filter estimation. It is shown in each filter execution.

  Field 1: 'POSTFIT'

  Field 2: Year

  Field 3: Doy

  Field 4: Seconds of day

  Field 5: GNSS System (GPS, GAL, GLO or GEO)

  Field 6: PRN satellite identifier

  Field 7: Measurement identifier (as string)

  Field 8: Measurement-corrected model value (postfit) [m]

  Field 9: Measurement value [m]

Field 10: Corrected model value with the filter estimations[m]

Field 11: Elevation of the satellite [degrees]

Field 12: Azimuth of the satellite [degrees]

Field 13: Only given for carrier phase measurements. It is the estimated carrier phase ambiguity. [m]

Sample: POSTFIT 2006 200 300.00 GPS 19 PC -0.0160 22982271.6557 22982270.5509 28.28 -77.91

As with PREFIT messages, Field 8 is not necessary Field 9 - Field 10 when using smoothing.

- Print FILTER Messages: Filter solution message. This message provides direct information on the filter estimates. It is shown in each filter execution.

Field 1: 'FILTER'

Field 2: Year

Field 3: Doy

Field 4: Seconds of day

Field 5-: Filter estimates. The order is: 3D estimated position, clock, troposphere and ambiguities. The number of fields is variable in this message. With a full filter (troposphere and ambiguities estimation), the fileds are as follows:

Field 5: Receiver X position [m]

Field 6: Receiver Y position [m]

Field 7: Receiver Z position [m]

Field 8: Receiver clock [m]

Field 9: Troposphere [m]

Field 10: Carrier phase ambiguities [m]

Sample: FILTER 2006 200 300.00 4849202.0700 -360328.8991 4114913.3520 -8.4316 -0.0010 -0.0001 0.9389 -0.8663 1.1051 0.2317 0.0707 0.0001 0.5066 0.2393

- Print OUTPUT Messages: Receiver solution message. This message provides the estimated receiver position. It is shown in each filter execution.

Field 1: 'OUTPUT'

Field 2: Year

Field 3: Doy

Field 4: Seconds of day

Field 5: Square root of the sum of the covariance matrix. This is a measure of the convergence of the filter

Field 6: Receiver X position [m]

Field 7: Receiver Y position [m]

Field 8: Receiver Z position [m]

Field 9: Receiver X position - Nominal apriori X position [m]

Field 10: Receiver Y position - Nominal apriori Y position [m]

Field 11: Receiver Z position - Nominal apriori Z position [m]

Field 12: Receiver X formal error [m]

Field 13: Receiver Y formal error [m]

Field 14: Receiver Z formal error [m]

Field 15: Receiver latitude [degrees]

Field 16: Receiver longitude [degrees]

Field 17: Receiver height [m]

Field 18: Receiver North difference in relation to nominal apriori position [m]

Field 19: Receiver East difference in relation to nominal apriori position [m]

Field 20: Receiver Up difference in relation to nominal apriori position [m]

Field 21: Receiver formal error in North direction [m]

Field 22: Receiver formal error in East direction [m]

Field 23: Receiver formal error in Up direction [m]

Field 24: Horizontal Dilution of Precision (HDOP)

Field 25: Vertical Dilution of Precision (VDOP)

Field 26: Zenith Tropospheric Delay (including nominal value) [m]

Field 27: Zenith Tropospheric Delay (excluding nominal value) [m]

Field 28: Zenith Tropospheric Delay formal error [m]

Sample: OUTPUT 2006 200 300.00 2.6219 4849202.0700 -360328.8991 4114913.3520 -0.3037 0.0397 0.1401 1.9353 0.6998 1.6246 40.429164806 -4.249658495 829.311998170 0.3057 0.0171 -0.1403 1.1365 0.6772 2.2637 0.9572 1.8306 2.1982 0.0097 0.4995

Providing a nominal a priori position is option for the processing, but if it is given, fields 9, 10, 11, 18, 19 and 20 will be given to this a priori position. See the option *A priori Receiver Position* in the INPUT section.

4.3 ANALYSIS (DAT INTERFACE)

The analysis tab allows configuring all the visualization options for the DAT. Figure 4-9 shows a screenshot of the Analysis tab.

Figure 4-9: Analysis tab screenshot

- Templates: The templates are a set of preconfigured plotting options for the *Graphic Details* section. Clicking on any button will load the options in that section, allowing modifying or plotting them directly.
    - NEU position error: The NEU position error template sets the options to print the three components (North, East and Up) of the error of the receiver positioning obtained by the filter. This error is computed by the difference between the direct filter estimation and the Apriori Receiver Position in the Input section of Calculus. Thence to obtain a reliable error estimation, this apriori position should be precise.

      If you do not have any precise position of the receiver, you can obtain it by doing a PPP processing (*SP3*/*Static*/*Dual frequency*/*Pseudorange*+*Carrier phase*). The XYZ position (fields 6 to 8 of OUTPUT message) of the last epoch should have an accuracy in the order of the centimeter, and can be used as a good reference position.

- North-East dispersion: The North-East dispersion template sets the options to print the North vs East position error components. This provides an insight of the horizontal dispersion and bias of the errors.
- Model components: The Model components template sets the options to print a component of the model as a function of time. By default, it selects the Relativity effect, but it can easily be chosen which model to print, by selecting it in the Y Column option.
- Ionospheric combinations: The Ionospheric combinations template sets the options to print the two ionospheric (geometric-free) combinations: P_I (P2-P1) [pseudorange] and L_I (L1-L2) [carrier phase].
- Zenith Tropospheric Delay: The Zenith Tropospheric Delay template sets the options to print the tropospheric estimations as a function of time. It includes the nominal part corrected in the modelling and the estimated part computed in the filter.
- Postfit residuals: The Postfit residuals template sets the options to print the filter residuals (postfits) as a function of the satellite elevation. It prints both pseudorange and carrier phase postfits. This plot allows observing the dependence of residuals from elevation. In general, carrier phase residuals will be quite independent from elevation, and pseudorange residuals can have a large dependence on elevation.
- Satellite skyplot: The Satellite skyplot template sets the options to print the elevation/azimuth of the satellites in a skyplot, being the center of the plot the zenith of the satellite, and the extremes, the lower elevations. This is a special plot which makes use of sin and cos in the X column and Y column to obtain a polar plot.
- Carrier phase ambiguities: The Carrier phase ambiguities template sets the options to print the estimation of carrier phase measurements in the filter. This is only possible in a processing with the *Pseudorange + carrier phase* measurements (in the Filter section).

- Global Graphic Parameters: Specify the different options of the graphic.
  - Title: Sets the title of the graphic.
  - X-label: Sets the X label of the graphic.
  - Y-label: Sets the Y label of the graphic.
  - Clear: Clear all the options in the *Graphic Details* section.
  - Automatic Plot Limits: The limits of the graphic axis can be automatically or user set:
    - Xmin & Xmax
    - Ymin & Ymax

  - Individual Plot(s) Configuration: Options for the different plots that can contain a graphic (up to four plots).
    - Plot 1/2/3/4: Selector for each plot. The options below this one are plot-dependent.
    - Source File: Selects the source input file for the plot.
    - Lines/Dot list: Allows changing the style of the plot, using Lines or Dots among many plot marker styles.
    - Color Selection: Allows changing the color of the plot.
    - Condition: The condition is a way to insert one or more conditions in order to select which lines of the source file will be used in the plotting. This has a space to write the required conditions and two comboboxes, which automatically sets the condition text. The text is the only that matters and the combo boxes only configure the text.

      To specify a column, it should be done as '$x' being x the number of the column. For example if you would like to specify the condition that the sixth column must be greater or equal than 10, you should do it as: ($6>=10)

      You can specify a set of conditions by using AND [&] and OR [|] operators, such as: ($6>=10) &($6<=20)|($8==2)

      You can specify that a column matches a specific string by surrounding the string by \", such as: ($1==\"OUTPUT\")

      You can specify mathematical operations and constants, as: math.pi, math.e, math.sin() and math.cos(), as example: ($1==\"POSTFIT\")&(math.cos($11+5)>0.707)

      You can specify a specific character inside a column, by using $x[y], being x the column and y the character position beginning by 0, such as: ($1==\"POSTFIT\")&($7[0]==\"P\") [First character of seventh column is 'P']

      You can also operate between columns, such as: (($9-$11)<2)
    - X Column: This allows specifying the column for the x values for the selected plot. The combo box will be updated by the First condition, but the text part is the one that matters. As in the conditions, you can specify several things. In general if it is required to plot a column it can be done by putting its column position, such as: 4. It can also be used the $4 to plot the forth column. As before, operations between scalars and columns can be done (and even use functions), such as: ($9*2-$11*3-1.5).
    - Y Column: This allows specifying the column for the y values for the selected plot. The format is the same as in *X Column*.
    - Label: Sets the label for the selected plot.

- Plot button: This button executes the plotting tool of gLAB with the specified options.

4.4 GUI LIMITATIONS

For an increased easiness in use, the GUI does not include all the different options that the DPC is able to cope. In order to use these GUI-excluded features, the command-line DPC program should be used instead (see section 5 *GLAB* Data Processing Core (DPC)). In particular, the following cases are not covered by the GUI:

- The DPC is able to compare two different sets of orbit and clocks.
- Besides from ANTEX, the DPC can also read the GPSConstellationStatus.txt file (which can be found in [RD-12]), compiled and updated by Richard B. Langley. This file provides a dictionary between satellite PRN and SVN, and its corresponding GPS Block. This allows correcting the phase centers of the satellites.
- The GUI pseudorange smoothing configuration is only based on the smoothing window to use. DPC also allows to specify which measurement will smooth which (by means of the '-pre:smoothMeas' option).
- The GUI *Available Frequencies* option of Filter section, can only take two different values: Single or Dual Frequency. With the DPC it is possible the specify availability of each frequency (for example setting as available F1 and F5 of GPS) by means of the '-pre:availf' option.

4.5 PROCESSING EXAMPLE

The next example gives an overview of a simple processing using gLAB, following all the steps from selecting input files to generating plots to analyse the data. The sample will cover a precise static positioning to obtain the precise coordinates of a station.

After opening the gLAB, the splash screen is shown (Figure 4-10). Clicking the *Input* button will open the *Input* section (Figure 4-11). Clicking the *PPP Template* button will preconfigure the GUI for a basic PPP. Clicking the *Examine* button for the *RINEX Observation File* will allow selecting which RINEX observation file will be used.

Figure 4-10: GUI Splash screen

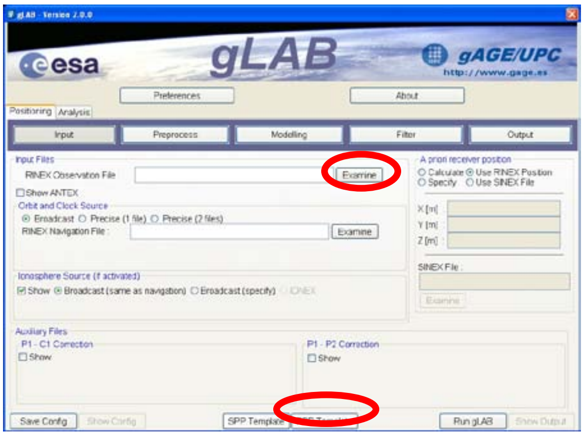

Figure 4-11: *Input* section

A file dialog will open (Figure 4-12), in order to go to the test directory (where all sample data files are found), the “Go Back one directory” button should be pressed, and afterwards doubleclick in “test” (Figure 4-13).

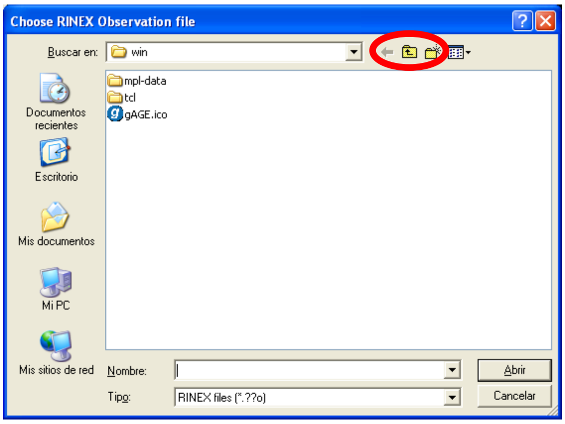

Figure 4-12: File Open dialog (1/3)

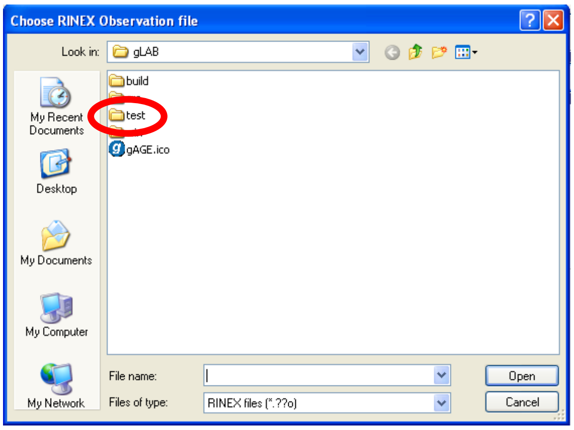

Figure 4-13: File Open dialog (2/3)

The directory where all the data is stored will be the one active (Figure 4-14). Double clicking on “madr2000.06o” will select this file and include it in the *Input* section (Figure 4-15). In order to include the rest of the required files, it should be clicked the *Examine* of *ANTEX File* (selecting the file “igs_pre1400.atx”), and the *Examine* of *SP3 File* (selecting the file “igs13843.sp3”).

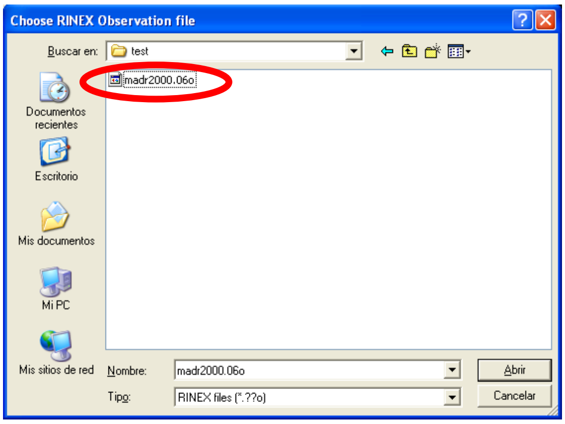

Figure 4-14: File Open dialog (3/3)

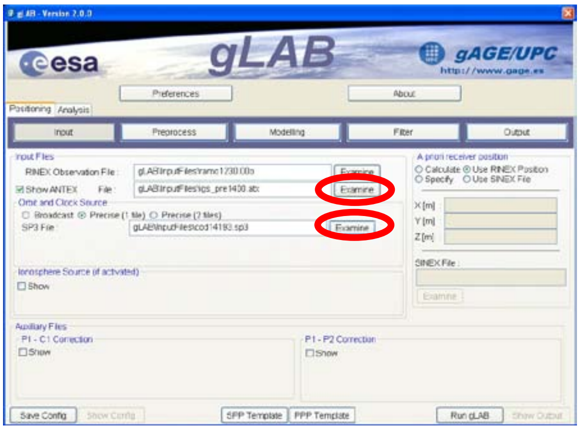

Figure 4-15: Updated *Input* section

Once input files are selected (Figure 4-16), *Filter* section button should be clicked in order to configure all the filter parameters. Once in this screen (Figure 4-17), the following parameters should be used (if not already checked):

- Navigation mode: PPP Template
- Estimate troposphere: Yes
- Available frequencies: Dual frequency
- Receiver Kinematics: Static
- Measurement selection: Pseudorange + Carrier phase

All these parameters are the default ones, so no special change should be done if the program has just started. After being sure all parameters are properly selected, the output file should be selected by clicking in the *Output* section.

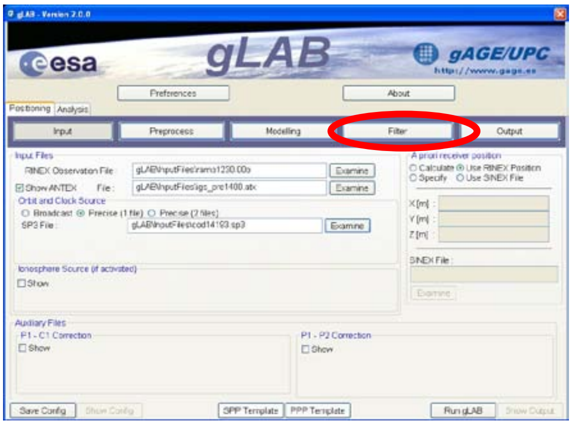

Figure 4-16: All input files are selected

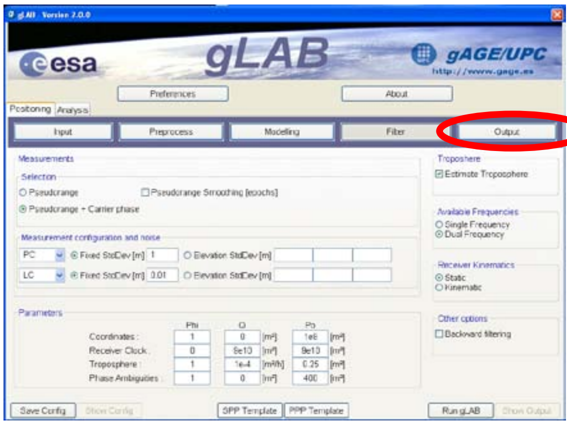

Figure 4-17: *Filter* section

In the *Output* section (Figure 4-18), the Examine button can be clicked to select the output file, Figure 4-19 shows the File Open dialog that will open. Writing “gLAB.out” and clicking enter will select this file name as output for the processing.

Figure 4-18: *Output* section

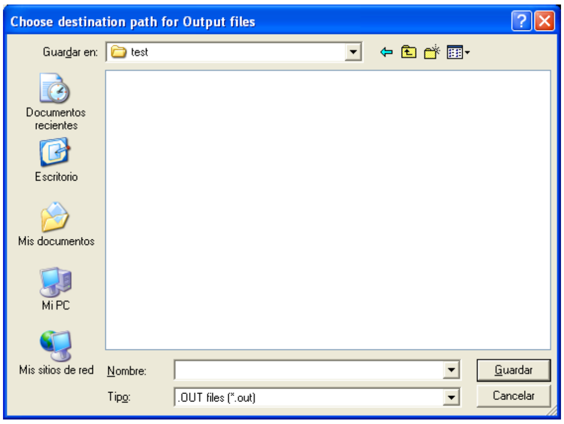

Figure 4-19: File open dialog for selecting the output file

After selecting the output (Figure 4-20) the *RUN* button will execute gLAB DPC with the selected options. While the DPC is running, the *RUN* button will be grey in order to avoid multiple clicks. After some seconds, the processing will end. To analyse the results click on the *Analysis* tab (Figure 4-21).

Figure 4-20: Output selected

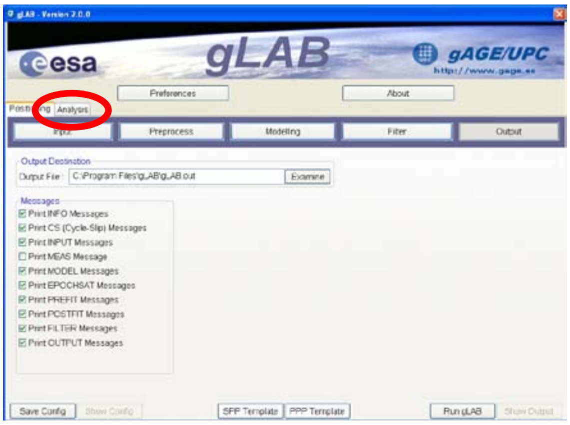

Figure 4-21: DPC has been executed

As explained in section 4.3 the *Analysis* tab (Figure 4-22) contains several templates in order to ease the generation of plots, in this sense, to plot the evolution of the receiver position in North/East/Up components the button *Receiver NEU position error* should be clicked. Figure 4-23 shows the configuration of the *Graphic Details* with this template. The *Source File* is the file selected in the *Output* section of the *Calculus* tab. Clicking the *Plot* button will generate this plot. While the program is processing the source file, the *Plot* button will be kept grey.

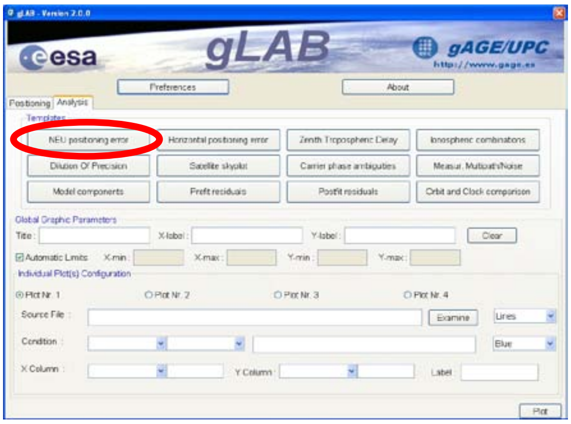

Figure 4-22: *Analysis* tab

Figure 4-23: Receiver NEU position error configuration

When the processing is finished, a window will open (Figure 4-24) showing the generated plot, and the *Plot* button will be again available.

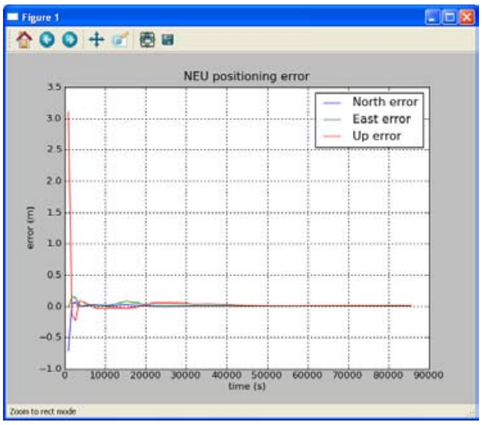

Figure 4-24: Plot sample

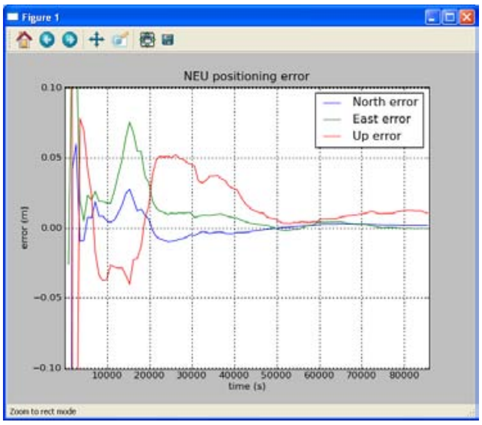

Figure 4-25: Plot sample (zoom)

The plotting utility allows zooming, moving and saving the current plot as a picture. All these functions can be accessed through the top toolbar. Figure 4-25 shows a zoom of the y axis. As would be expected for a PPP processing, the final position error is in the order of 1 cm.

5 *gLAB* DATA PROCESSING CORE (DPC)

The DPC is the processing tool of gLAB, it has been programmed in C with special care for the following objectives:

- Easy to use for an advanced user.
- Modularized, in order to incorporate future updates.
- Optimized for CPU and memory usage.

The options of the DPC are basically the same as the options of the GUI, with the exceptions taken in consideration in section 4.4 GUI Limitations. The DPC can be executed with the argument '-help', which will provide detailed information of the different arguments that can be used.

The following lines are an extract of the '-help' inline information:

Options:

-help	Shows this help
-examples	Shows some examples to call the program
-config	Shows some info on the configuration file
-messages	Shows the fields of each output message (see below, 'VERBOSE OPTIONS')

INPUT OPTIONS

-input:cfg <file>	Sets the input configuration file
-input:obs <file>	Sets the input RINEX observation file
-input:nav <file>	Sets the input RINEX navigation message file (only for standalone)
-input:sp3 <file>	Sets the input SP3 orbits and clocks file (only for PPP)
-input:orb <file>	Sets the input SP3 orbits (only for PPP)
-input:clk <file>	Sets the input clock file (only for PPP)
-input:con <file>	Sets the input constellation status file (default GPSConstellationStatus.txt)
-input:ant <file>	Sets the input ANTEX satellite/receiver antenna data file
-input:klb <file>	Sets the input RINEX navigation file for Klobuchar corrections, if this parameter is avoided, it is used the -input:nav file
-input:con <file>	Sets the input constellation status file (default GPSConstellationStatus.txt)
-input:ant <file>	Sets the input ANTEX satellite/receiver antenna data file
-input:klb <file>	Sets the input RINEX navigation file for Klobuchar corrections, if this parameter is avoided, it is used the -input:nav file
-input:dcb <file>	Sets the input DCB source as a .DCB file or a RINEX navigation file.
-input:rec <file>	Sets the input GPS Receiver Type file.
-input:snx <file>	Sets the input SINEX file for receiver position.

PREPROCESSING OPTIONS

-pre:dec #	# = number Decimate input data by # seconds In product comparison mode (see below, in 'WORK MODES'), it sets the time step of the comparisons
-pre:sat g#	Exclude satellite from processing g = character determining GNSS system (G->GPS) # = PRN number
-pre:elevation <val>	Elevation mask. Satellites below this threshold will be discarded (in degrees) [default 0]
-pre:eclipse <val>	Discard satellites under Earth eclipse [default: enabled for PPP, disabled for SPS]
-pre:availf g#	Mark frequencies available [default all] g = character determining GNSS system (G->GPS) # = frequencies available Sample: '-pre:availf G12' Frequencies 1 and 2 of GPS available '-pre:availf G1' Frequency 1 of GPS available, 2 unavailable
-pre:smooth <val>	Number of epochs of smoothing [default 0, which means disabled]
-pre:smoothMeas <n> <meas>	Smooth measurement in filter <n> with measurement type <meas> In general, <n> is a pseudorange and <meas> a carrier phase, see option '-filter:select' for more information in the selection of measurements to be used in the filter Sample: '-pre:smoothMeas 1 LC'
-pre:setrecpos <val>	<val> = RINEX Set the receiver apriori position as the one specified in the RINEX observation file [default] <val> = SINEX Set the receiver a priori position to be read from a SINEX file (to be specified by the '-input:snx' parameter) <val> = calculate The ceiver apriori position will be calculated by the program. This is especially useful when processing moving receivers (trajectories) or when the approximate receiver position is not known. With this option activated, the differential fields of the OUTPUT message will be zero. <val> = <x> <y> <z> Specify the receiver apriori position in meters Sample: '-pre:recpossrc 4789032.7143 176594.9690 4195013.2268'
-pre:setrectype <val>	<val> = gpsrt Set the receiver type as the one specified in the GPS_Receiver_Types file (provided by '-input:rec') [default if '-input:rec' provided] <val> = 0 Set the receiver type as 'Unknown' [default] <val> = 1 Set the receiver type as 'Cross-correlated'. In this mode, P2 will be corrected with the DCB of P1-C1 <val> = 3 Set the receiver type as 'Consistent measurements'.
-pre:prealign <val>	Prealign carrier phase measurements with its corresponding pseudorange [default on]\n");

-pre:cs:li	Use the carrier phase geometric-free combination (Li) for cycle-slip detection (2 frequencies) [default]
--pre:cs:li	Do not use carrier phase geometric-free combination (Li) for cycle-slip detection (2 frequencies). Li combination is a slow varying function which only has ambiguity and ionosphere. Each epoch and satellite an expected Li value is computed and compared against the measured one, if this difference is above a certain threshold, a cycle-slip is marked. This threshold is (max - (max-min)*exp(-dt/T_0)), being dt the time between epochs
-pre:cs:li:min <val>	Minimum threshold between estimated and measured Li values [default 0.034]
-pre:cs:li:max <val>	Maximum threshold between estimated and measured Li values [default 0.08]
-pre:cs:li:t0 <val>	Time constant to set the threshold between maximum and minimum [default 60]
-pre:cs:bw	Use Melbourne-Wübbena (BW) for cycle-slip detection (2 frequencies) [default]
--pre:cs:bw	Do not use Melbourne-Wübbena (BW) for cycle-slip detection (2 frequencies) BW combination is a mixed combination between carrier phase and pseudoranges. This combination is free of ionosphere and geometry, thence constant, but it is affected by the receiver noise and multipath (due to the pseudorange measurements used). If this noise is low enough, it is straight forward to detect cycle-slips, but in noisy environments BW is not able to detect cycle-slips. The algorithm using BW computes the mean and the standard deviation of the last epochs in order to obtain an estimated value and the noise level of the combination. The estimated value is compared against the measured value, and the noise level is used for the threshold of this difference. Difference must be lower than standardDeviation multiplied by a number (slope). This threshold has minimum (min) and maximum (max) saturation values.
-pre:cs:min <val>	Minimum threshold between estimated and measured BW values in relation to its standard deviation [default 0.9]
-pre:cs:max <val>	Maximum threshold between estimated and measured BW values in relation to its standard deviation [default 18]
-pre:cs:slope <val>	Relation between estimated and measured BW values in relation to its standard deviation [default 9]
-pre:cs:l1c1	Use the L1-C1 combination for cycle-slip detection (1 frequency)
--pre:cs:l1c1	Do not use the L1-C1 combination for cycle-slip detection (1 frequency) [default] The L1-C1 averages the difference between carrier phase and pseudorange measurements in F1 for several epochs. This cycle-slip detection method is very useful for single-frequency receivers, as it only requires measurements from one frequency. As a counterpart, the ionospheric term is different for C1 and L1

thence, this combination will tend to diverge. It becomes necessary to set a smoothing window to limit this divergence (-pre:cs:l1c1:window). This makes that this method becomes a bit limited with data rates too low. Ideally this method should be used with rates of 1Hz or higher

-pre:cs:l1c1:slope <val> Relation between estimated and measured L1-C1 values in relation to its standard deviation [default 5]

-pre:cs:l1c1:window <val> Number of epochs to limit the L1-C1 ionosphere divergence [default 100]

-pre:cs:l1c1:max <val> Maximum standard deviation for the threshold calculation in the L1-C1 [default 15] (m)

MODELING OPTIONS (use -model:... to activate, --model:... to deactivate)

-model:iono <val> <val> = no Do not correct ionosphere [default in PPP] (equivalent to '--model:iono')
<val> = Klobuchar Correct measurements with klobuchar model [default in standalone]

-model:trop:nominal <val> <val> = Simple Compute a simple tropospheric nominal depending on receiver's height over the sea level. [default in PPP]
<val> = UNB3 Troposphere nominals are calculated from the receiver's height and estimates of five meteorological parameters: pressure, temperature, water vapour pressure, temperature lapse rate and water vapour lapse rate. It is adopted by SBAS systems (AD-07). [default in SPP]

-model:trop:mapping <val> <val> = Simple Compute the mapping as the obliquity factor described in Black and Eisner, 1984. This mapping only depends on satellite elevation and it is common for wet and dry components. [default in SPP].
<val> = Niell Compute the mapping described in A.E. Niell, 1996. This mapping considers different obliquity factors for the wet and dry components [default in PPP].

-model:satclocks Correct the measurements with the satellite clock error estimations [default on]

-model:relclock Correct the measurements with the relativistic clock model [default on]

-model:satmovinflight Consider satellite movement during signal flight time [default on]

-model:earthrotinflight Consider Earth rotation during signal flight time [default on]

-model:satphasecenter Correct satellite phase center to mass center corrections [default on]

-model:recphasecenter <val> <val> = no Do not correct antenna receiver phase center [default]
<val> = ANTEX Use the ANTEX file to correct the antenna phase center
<val> = <nfreq> <dN> <dE> <dU>

	Set dN, dE, dU as the antenna phase center for the frequency <nfreq> <nfreq> = Frequency number (typical for GPS, 1 and 2) <dN> = North correction [in meters] <dE> = East correction [in meters] <dU> = Up correction [in meters] Sample: '-model:recphasecenter 1 0 0 0.11 -model:recphasecenter 2 0 0 0.128' Typical AOAD/M_T antenna phase center correction, 11 cm and 12.8 cm in the Up component for frequencies 1 and 2
-model:radomestrict	When using ANTEX to correct the receiver phase center, this option will force a perfect match between the antenna name and radome reported in the receiver RINEX file and the ones in the ANTEX file. If this option is disabled, and the radome is not found, the corrections will be used considering the radome \"NONE\" [default off]
-model:arp <val>	<val> = no Do not apply any Antenna Referece Point (ARP) correction [default] <val> = RINEX Use as ARP the information on the RINEX file (field 'ANTENNA: DELTA H/E/N') <val> = <dN> <dE> <dU> Set dN, dE, dU as the ARP <dN> = North correction [in meters] <dE> = East correction [in meters] <dU> = Up correction [in meters]
-model:tgd <val>	<val> = no Do not correct Differential Code Biases between frequencies <val> = brdc Use RINEX Navigation file (P2 - P1) or TGD [default] <val> = dcb Use Precise .DCB files (P1-P2) and (P1-C1).
-model:dcb:p1c1<val>	<val> = no Do not correct Differential Code Biases between P1 and C1 codes. Do not identify C1 and P1 never <val> = flexible Do not correct the Differential Code Biases between P1 and C1 codes [default on]. Identify C1 and P1 when one of them is missing. <val> = strict Correct the Differential Code Biases between P1 and C1 codes. Identify C1 and P1 when applicable (defined by the receiver type)
-model:dcb:p1p2 <val>	<val> = no Do not correct Differential Code Biases between codes P1 and P2 (equivalent to '--model:dcb:p1p2') <val> = RINEX Correct Differential Code Biases between codes P1 and P2 using TGDs from the RINEX navigation file [default in SPP, off in PPP] <val> = DCB Correct Differential Code Biases between codes P1 and P2 from a precise DCB file. Identify C1 and P1 when applicable (defined by the receiver type).

-model:windup	Correct the wind up term for carrier phase measurements [default on]
-model:solidtides	Correct the Earth surface deformation due to solid tides [default on]
-model:relpath	Correct the path range delay term due to the gravitational gradient between receiver and transmitter [default on]
-model:orbit:deg <val>	Precise orbit interpolation degree (default 10)
-model:clock:deg <val>	Precise clock interpolation degree (default 0 - no interpolation)
-model:satellitehealth	Only valid when using broadcasted products. Use the healthy flag of the navigation message [default on]

FILTERING OPTIONS

-filter:trop	Estimate the troposphere of the station [default in PPP with carrier phase] ('--filter:trop' to disable it)
-filter:nav <nav>	<nav> = static Process supposing a static receiver [default] <nav> = kinematic Process supposing a moving receiver
-filter:meas <meas>	<meas> = pseudorange Use only pseudorange for positioning <meas> = carrier phase Use pseudorange and carrier phase for positioning [default]
-filter:select <num> <meas1> <meas2> ...	Select the measurements or combinations to include in the filtering <num> = Number of measurements/combinations <measN> = List of measurements/combinations [Defaults]: PPP - Pseudorange => 1 PC [Defaults]: PPP - Carrier phase => 2 PC LC [Defaults]: Standalone - Pseudorange => 1 C1C [Defaults]: Standalone - Carrier phase => 2 C1C L1P
-filter:fixedweight <n> <val>	Apply the specified standard deviation to the measurement 'n', to be used as weight in the filter. <n> = Measurement number <val> = Standard deviation of the measurement (m) In particular, the filter shall apply as weight = 1/(<val>^2) Sample: '-filter:fixedweight 1 2' Set 2 meters of standard deviation to measurement 1 in filter '-filter:fixedweight 2 0.01' Set 1 centimeter of standard deviation to measurement 2 in filter Defaults: PPP: Pseudorange->1m Carrier phase->0.01m Standalone: Pseudorange->2m Carrier phase->0.10m
-filter:elevweight <n> <a> <b> <c>	Apply the specified values to compute the standard deviation of the measurement 'n' std = a + b * e^(elevation/c) <n> = Measurement number <a> = Minimum standard deviation of the measurement [weight at elevation 90º] (m) <b> = Multiplier to e [standard deviation at elevation 0º] (m) <c> = Elevation constant (degrees)

	Again, the filter shall apply as weight = 1/(std^2) Sample: '-filter:elevweight 1 0.3 8 10' Apply the standard deviation: 0.3+8*e^(elevation/10) Note: '-filter:elevweigth 1 x 0 y' equals to '-filter:fixedweight 1 x'
-filter:phi:dr <val>	Specify the Phi value for position unknowns [defaults static:1 kinematic:0]
-filter:phi:clk <val>	Specify the Phi value for clock unknown [default 0]
-filter:phi:trop <val>	Specify the Phi value for troposphere unknown [default 1]
-filter:phi:amb <val>	Specify the Phi value for ambiguity unknowns [default 1]
-filter:q:dr <val>	Specify the Q noise value for position unknowns [defaults static:0 kinematic:inf] (m^2)
-filter:q:clk <val>	Specify the Q noise value for clock unknown [default inf] (m^2)
-filter:q:trop <val>	Specify the Q noise variation value for troposphere unknown [default 1e-4] (m^2/h)
-filter:q:amb <val>	Specify the Q noise value for ambiguity unknowns [default 0] (m^2)
-filter:p0:dr <val>	Specify the P0 initial value for position unknowns [default inf] (m^2)
-filter:p0:clk <val>	Specify the P0 initial value for clock unknown [default inf] (m^2)
-filter:p0:trop <val>	Specify the P0 initial value for troposphere unknown [default 0.5^2] (m^2)
-filter:p0:amb <val>	Specify the P0 initial value for ambiguity unknowns (for prealigned carrier phases) [default 20^2] (m^2)
-filter:backward	Specify that the filter does a backward processing after the forward one is finished. This meas that it process the data backwards. The \"turn point\" is defined as the latest point where orbits and clocks are available or when the observation RINEX ends (whatever is first) ('--filter:backward' to disable it)[default disabled]

OUTPUT OPTIONS

-output: <file>	Sets the output file [default stdout]
--output: <file>	Sets the output to stdout [default]
-output:satvel <val>	<val> = inertial Prints the inertial velocity in the messages where satellite velocity is given <val> = ITRF Prints the ITRF velocity in the messages where satellite velocity is given

VERBOSE OPTIONS (use -print:... to activate, --print:... to deactivate)

-print:info	Print INFO messages [default on]
-print:cycleslips	Print CS messages [default off]
-print:input	Print INPUT messages [default off]
-print:meas	Print MEAS messages [default off]
-print:model	Print MODEL messages [default off]
-print:satellites	Print EPOCHSAT messages [default off]
-print:satsel	Print SATSEL messages [default off]
-print:prefit	Print PREFIT messages [default off]

-print:postfit	Print POSTFIT messages [default off]
-print:filter	Print FILTER messages [default off]
-print:output	Print OUTPUT messages [default on]
-print:satdif	Print SATDIFF messages in comparison mode (see below) [default on]
-print:satstat	Print SATSTAT messages in comparison mode (see below) [default on]
-print:satstattot	Print SATSTATTOT messages in comparison mode (see below) [default on]
-print:all	Print all messages
-print:none	Do not print anything
	More information on print messages can be seen with the '-messages' option

WORK MODES

gLAB can work in three different modes:

- *Positioning Mode*: 'Standard' mode, where all the processing is done, and a solution for a receiver is provided as OUTPUT messages. The minimum parameters required for this mode are an input observation file ('-input:obs') and orbit and clock products ('-input:nav', '-input:SP3' or '-input:orb'/'-input:clk'). Using precise products will also require the use of an ANTEX file (‘-input:ant’).
- *Show Input Mode*: This mode only reads an input RINEX observation file and print its measurements. The parameter required for this mode is '-input:obs', and specifically, no orbit and clock products should be provided (if provided, gLAB will switch to Positioning Mode)
- *Product Comparison Mode*: This mode reads and compares two different sources of orbit and clock products. In order to use this modes, '-input:obs' must be avoided, and two different orbit and clock products should be provided. This mode outputs the SATDIFF, SATSTAT and STASTATTOT messages
- *Show Product Mode*: This mode reads a single source of orbit and clock products. In order to use this mode, '-input:obs' must be avoided, and a single orbit and clock product should be provided. This mode output SAT messages.

5.1 PROCESSING EXAMPLE

The following example gives an overview of a simple processing using the gLAB DPC component. The sample covers a precise static positioning to obtain the precise coordinates of a station and provides exactly the same results as the sample generated in section 4.5.

Opening a command line window in the gLAB directory (in Windows this can be directly done by the option “Command line in directory” in the program group installed in the Start menu). Using this option a command line window will open (Figure 5-1) in the proper directory.

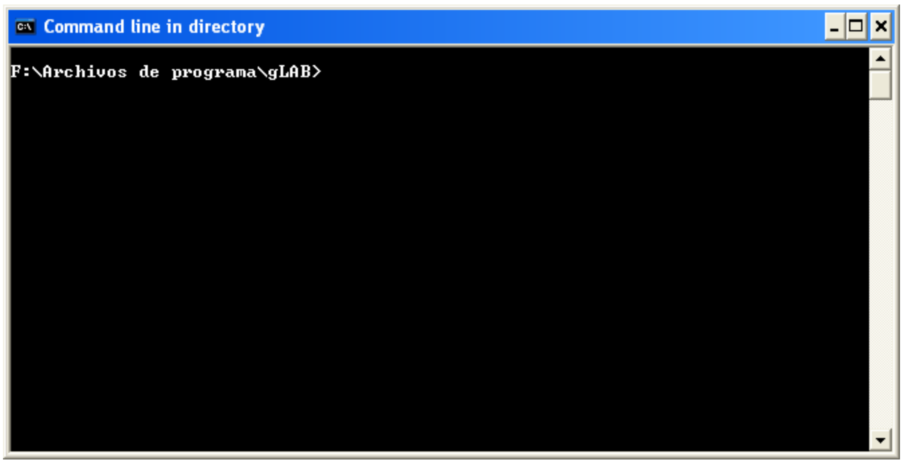

Figure 5-1: Command line screenshot

In order to generate the selected processing, the following command should be executed:

```
win\gLAB.exe -input:obs test\madr2000.06o -input:ant test\igs_pre1400.atx -input:SP3 test\igs13843.SP3 -output gLAB_DPC.out
```

After a few seconds the file “gLAB_DPC.out” will be generated with the all the output details.

6 *gLAB* DATA ANALYSIS TOOL (DAT)

The DAT is an advanced plotting utility prepared to graph different combinations of columns taking into account several user-defined conditions. Figure 6-1 shows a screenshot of the DAT.

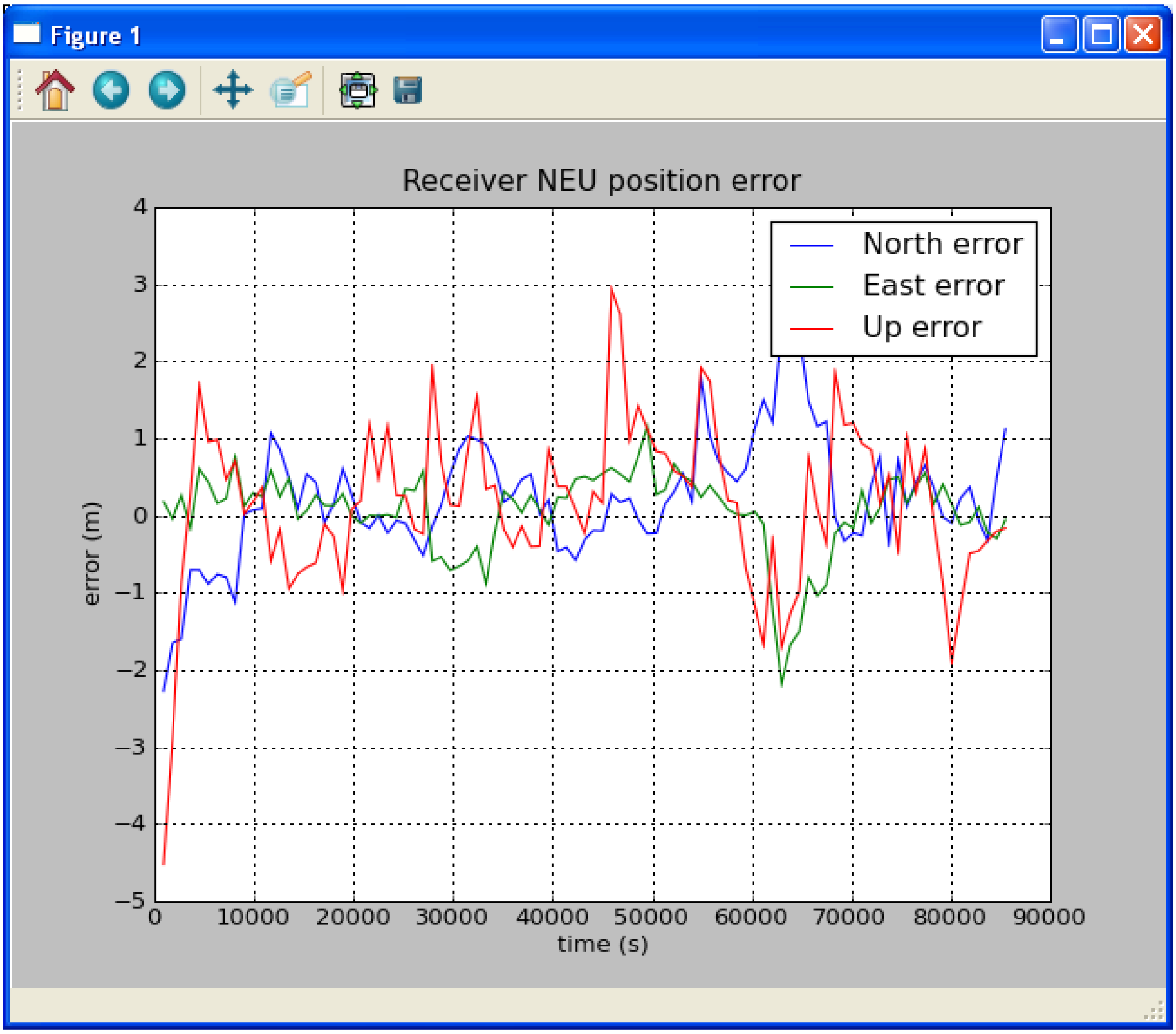

Figure 6-1: DAT screenshot. It can be seen the position error for a PPP kinematic positioning for a single-frequency receiver.

The available options are:

GRAPHIC GENERAL OPTIONS:

The General Options are the ones that can be specified once per graphic, and will affect the entire graphic window:

-h, --help	Show this help message and exit
-t, --title, --tit	Set the title of the Graphic
--Xlabel, --xlab, --xl	Set the x-axis label
--Ylabel, --ylab, --yl	Set the y-axis label
--Xmin, --xmin, --xn	The minimum value for the x axis to be plot, if no value is provided, automatic limits are set.
--Xmax, --xmax, --xx	The maximum value for the x axis to be plot, if no value is provided, automatic limits are set.
--Ymin, --ymin, --yn	The minimum value for the y axis to be plot, if no value is provided, automatic limits are set.
--Ymax, --ymax, --yx	The maximum value for the y axis to be plot, if no value is provided, automatic limits are set.

Example:

graph.py -t "Graphic title" --xl "time (s)" --yl "Altitude [m]" --xmin -3.0 --ymax 5.0

PLOT DEPENDENT OPTIONS:

The Plot Dependent Options are specific to each plot.
One new plot is considered from the point that a '-f' or '--file' is found.
All the options coming after this parameter belong to that specific plot.

-f, --file Set the input filename for the specific plot

-x, -X, --Xcol Set the source of the x axis:
-x 4 or -x '$4' : will take as x axis the 4th column of the input file.

Operations can be done in this parameter, such as:
-x '($4-$5)': This will take the difference between the 4th and the 5th column

Mathematical functions and constants are supported:

	-x '(math.sin($12*math.pi/180)'
-y, -Y, --Ycol	Set the source of the y axis Identical properties than x column
-c, --cond	Specify the plotting condition: -c ($6>=10) Include the 6th column if it is equal or greater than 10 -c ($1==\"OUTPUT\") Include the 1st column by a specific string: surrounding the string by \" Mathematical functions, booleans and constants are supported: -c ($1==\"POSTFIT\")&(math.e($12+$5)>5.0)
-l, --label, --plotlabel	Sets the label for the current plot
-s, --style	Sets the style for the current plot. The following styles are supported: '.' circle marker [DEFAULT] '-' solid line style '--' dashed line style '-.' dash-dot line style 'o' point marker 's' square marker 'p' pentagon marker '+' plus marker 'x' x marker
--color, --cl	Sets the color for the current plot. The following colors are supported: 'b' blue [DEFAULT] 'g' green 'r' red 'c' cyan 'm' magenta 'y' yellow 'b' black 'w' white

Example:

graph.py -f /home/gLAB/Example -x '(math.sin($1*math.pi/180))' -y 2 -c -l "Plot Label" --style p --color cyan

Each graphic window can contain several plots with the same scale. The General Options are the ones that can be specified only once per graphic, and will affect the entire graphic window. The Plot Dependent Options can be specific to each plot. One new plot is considered from the point that a '-f FILENAME' / '—file=FILENAME' is found. All the options coming after this parameter are considered to belong to that specific plot.

6.1 SETTING THE AXIS

As seen in section 4.3 Analysis (DAT Interface) in general the axis source will be one column, and this can be specified that way:

-x 4

This will take as x axis the 4th column of the input file. This can also be expressed as:

-x '$4'

This also means 4th column of the input file (The ' signs have been included for linux users. Windows users do not need to used them). Operations can be done in this parameter, such as:

-x '($4-$5)'

This will take as x axis origin the difference between the 4th and 5th columns. This operation is also valid:

-x '($4*2-1)'

Mathematical functions and constants can be also used here, such as:

-x '(math.sin($12*math.pi/180)*(90-$11)/90)'

6.2 SETTING THE CONDITIONS

As seen in section 4.3 Analysis (DAT Interface), the conditions are a way to insert one or more conditionals in order to select which lines of the source file are going to be used in the plotting.

The rules for this are as follows:

-c ($6>=10)

This will only include the line if the 6th column is equal or greater than 10. It is also possible to specify a ser of conditions using AND [&] and OR [|] operators, such as:

-c ($6>=10)&($6<=20)|($8==2)

It is possible to specify that a column matches a specific string by surrounding the string by \", such as:

-c ($1==\"OUTPUT\")

It is possible to specify mathematical operations and constants, as: math.pi, math.e, math.sin() and math.cos(), as example:

-c ($1==\"POSTFIT\")&(math.cos($11+5)>0.707)

It is possible to specify a specific character inside a column, by using $x[y], being x the column and y the character position beginning by 0, such as:

-c ($1==\"POSTFIT\")&($7[0]==\"P\") [First character of seventh column is 'P']

It is possible to operate between columns, such as:

-c (($9-$11)<2)

Linux users, should use the ‘ signs to surround the parameter. Besides they should use “ instead of \” when comparing strings. Sample:

-c ‘($1=="OUTPUT”)’

This is due to the difference when treating arguments between Windows and Linux Operating Systems.

6.3 PROCESSING EXAMPLE

The following example gives an overview of a simple plot generated using the gLAB DAT component. The sample uses a .out file generated by the DPC. In particular, uses the one generated in the example of section 5.1.

This example generates the same plot that would generate the template button of *Receiver NEU position error* of the GUI (Analysis tab).

Opening a command line window in the gLAB directory (in Windows this can be directly done by the option “Command line in directory” in the program group installed in the Start menu. Using this option a command line window will open (Figure 5-1) in the proper directory.

In order to generate the plot, the following command should be executed:

```
win\graph.exe -t "Receiver NEU position error" --xl="time (s)"
--yl="error   (m)"   -f   gLAB_DPC.out   -x   4   -y   18   -c
"($1=='OUTPUT')" -l "North error" -f gLAB_DPC.out -x 4 -y 19 -
c "($1=='OUTPUT')" -l "East error" -f gLAB_DPC.out -x 4 -y 20
-c "($1=='OUTPUT')" -l "Up error"
```

This will generate the plot seen in Figure 4-24.

End of Document