

# Tutorial 1

## Introduction to gLAB tool suite

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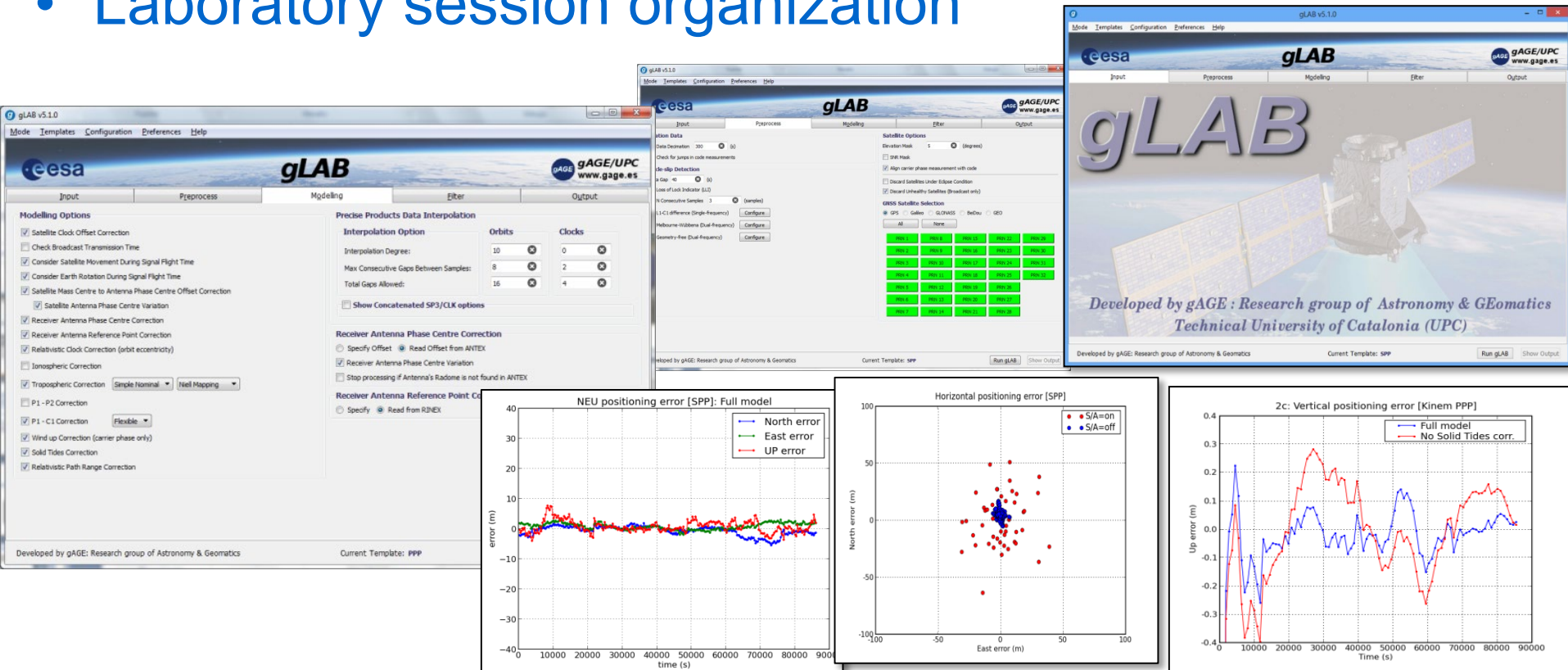
This authorship statement must be keep untouched at all times.

5th July 2021

# OVERVIEW



- Introduction
- The gLAB tool suite
- Examples of GNSS Positioning using gLAB
- Laboratory session organization



# Introduction

- This practical lecture is devoted to analyze and assess different issues associated with Standard and Precise Point Positioning with GPS data.
- The laboratory exercises will be developed with actual GPS measurements, and processed with the ESA/UPC GNSS-Lab Tool suite (gLAB), which is an interactive software package for GNSS data processing and analysis.
- Some examples of gLAB capabilities and usage will be shown before starting the laboratory session.
- All software tools (including *gLAB*) and associated files for the laboratory session are included in the USB stick delivered to lecture attendants.

# OVERVIEW



- Introduction
- The gLAB tool suite
- Examples of GNSS Positioning using gLAB
- gLAB software installation



# The gLAB Tool suite

- ▶ The GNSS-Lab Tool suite (gLAB) is an interactive multipurpose educational and professional package for GNSS Data Processing and Analysis.
- gLAB has been developed under the ESA contracts N. P1081434 and C4000113054.

## ▶ Main features:

- High Accuracy Positioning capability.
- Fully configurable.
- Easy to use.
- Access to internal computations.



# The gLAB Tool suite

- gLAB has been designed to cope with the needs of two main target groups:
  - Students/Newcomers: User-friendly tool, with a lot of explanations and some guidelines.
  - Professionals/Experts: Powerful Data Processing and Analysis tool, fast to configure and use, and able to be included in massive batch processing.

# The gLAB Tool suite

- Students/Newcomers:
  - Easiness of use: Intuitive GUI.
  - Explanations: Tooltips over the different options of the GUI.
  - Guidelines: Several error and warning messages. Templates for pre-configured processing.

The screenshot displays the gLAB v5.1.0 software interface. An "Errors found" dialog box is open in the center, displaying the following message:

**Errors found**

gLAB has found the following errors, please correct them before executing processing again:

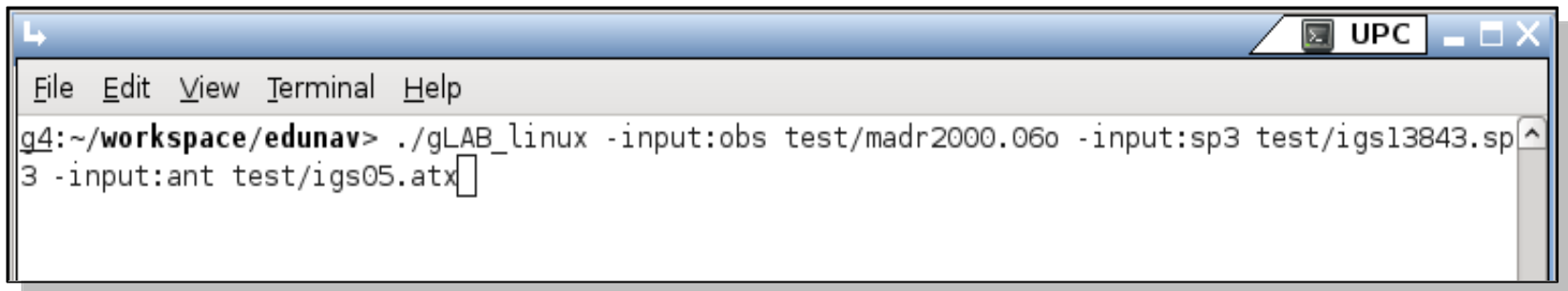
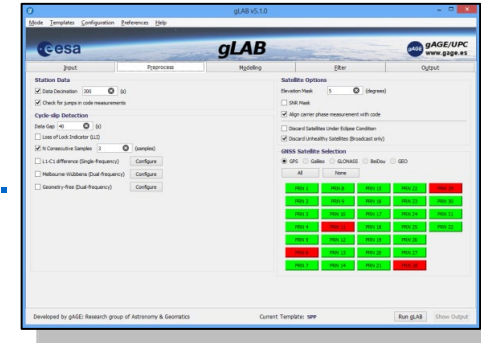
- INPUT: RINEX Observation file is a required input.
- INPUT: RINEX Broadcast navigation file is a required input if 'Broadcast' orbit and clock source is specified.

The background shows the main software window with various configuration options. A red box highlights the "Current Template: PPP" label at the bottom of the interface.



# The gLAB Tool suite

- Students/Newcomers:
  - Easiness of use: Intuitive GUI.
  - Explanations: Tooltips over the different GUI options.
  - Guidelines: Several error and warning messages. Templates for pre-configured processing.
- Professionals/Experts:
  - Powerful tool with High Accuracy Positioning capability.
  - Fast to configure and use: Templates and carefully chosen defaults.
  - Able to be executed in command-line and to be **included in batch processing**.

The image shows a terminal window with a menu bar (File, Edit, View, Terminal, Help) and a title bar (UPC). The terminal content shows a user at a prompt 'g4:~/workspace/edunav>' typing the command: './gLAB\_linux -input:obs test/madr2000.06o -input:sp3 test/igs13843.sp3 -input:ant test/igs05.atx'. The cursor is positioned at the end of the command line.

# The gLAB Tool suite

- In order to broad the tool availability, gLAB Software has been designed to work in Windows, Linux and Mac environments.



- The package contains:
  - Windows binaries (with an installable file).
  - Linux .tgz file.
  - Mac installable .dmg file.
  - Source code (to compile it in both Linux, Windows and Mac OS) under an Apache 2.0 and LGPL v3. licenses.
  - Example data files.
  - Software User Manual.
  - HTML files describing the standard formats.

# The gLAB Tool suite

## Read files capability:

- RINEX observation v2.11 & v3.00
- RINEX navigation message.
- SP3 precise satellite clocks and orbits files
- ANTEX Antenna information files.
- Constellation status.
- DCBs files.
- GPS\_Receiver\_Type files.
- SINEX position files.
- SBAS files: EMS, RINEX-B
- RTCM-v2x and RTCM-x3x

## Pre-processing module:

- Carrier-phase prealignment.
- Carrier-phase / pseudorange consistency check.
- Cycle-slip detection (customizable parameters)
  - Melbourne-Wübbena.
  - Geometry-free CP combination.
  - L1-C1 difference (single frequency).
- Pseudorange smoothing.
- Decimation capability.
- On demand satellite enable/disable.
- Elevation mask.
- Frequency selection.
- Discard eclipsed satellites.

## Modelling module:

- Fully configurable model.
- Satellite positions.
- Satellite clock error correction.
- Satellite movement during signal flight time.
- Earth rotation during signal flight time.
- Satellite phase center correction.
- Receiver phase center correction. (frequency dependent).
- Relativistic clock correction.
- Relativistic path range correction.
- Ionospheric correction (Klobuchar, NeQuick, IONEX).
- Tropospheric correction
  - Simple and Niell mappings.
  - Simple and UNB-3 nominals.
- Differential Code Bias corrections.
- Wind up correction.
- Solid tides correction (up to 2<sup>nd</sup> degree).
- SBAS Messages.
- RTCM messages.

# The gLAB Tool suite

## ▲ Filtering module:

- Able to chose different measurements to process (1 or more), with different weights. This design could be useful in future Galileo processing, where processing with different measurements may be desired.
- Fixed or elevation-dependant weights per observation.
- Troposphere estimation on/off.
- Carrier-Phase or Pseudorange positioning.
- Static/Kinematic positioning (full Q/Phi/PO customization).
- Able to do a forward/backward processing.
- Able to compute trajectories (no need for a priori position).

## ▲ Output module:

- Cartesian / NEU coordinates.
- Configurable message output.

## ▲ Other functionalities:

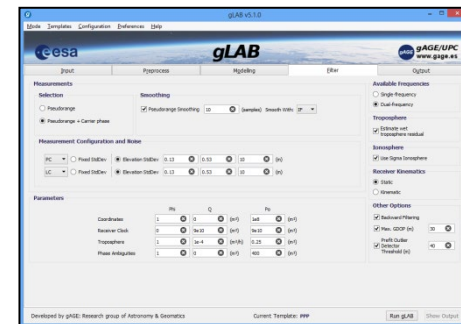
- Computation of satellite coordinates and clocks from RINEX and SP3 files.
- Satellite coordinates comparison mode. For instance RINEX navigation vs. SP3, or SP3 vs. SP3 (along-track, cross-track and radial orbit errors, clock errors, SISRE).
- Show input mode. No processing, only parsing RINEX observation files.

- Current version allows full GPS data processing, and partial handling of Galileo and GLONASS data.
- Future updates may include full GNSS data processing.

# GNSS learning material package

Includes three different parts, allowing to follow either a guided or a self-learning GNSS course:

- **GNSS Book:** Complete book with theory and algorithms (Volume 1), and with a Lab. course on GNSS Data Processing & Analysis (Volume 2).
- **gLAB tool suite:** Source code and binary software files, plus configuration files, allowing processing GNSS data from standard formats. The options are fully configurable through a GUI.



# OVERVIEW



- Introduction
- The gLAB tool suite
- Examples of GNSS Positioning using gLAB
- gLAB software installation

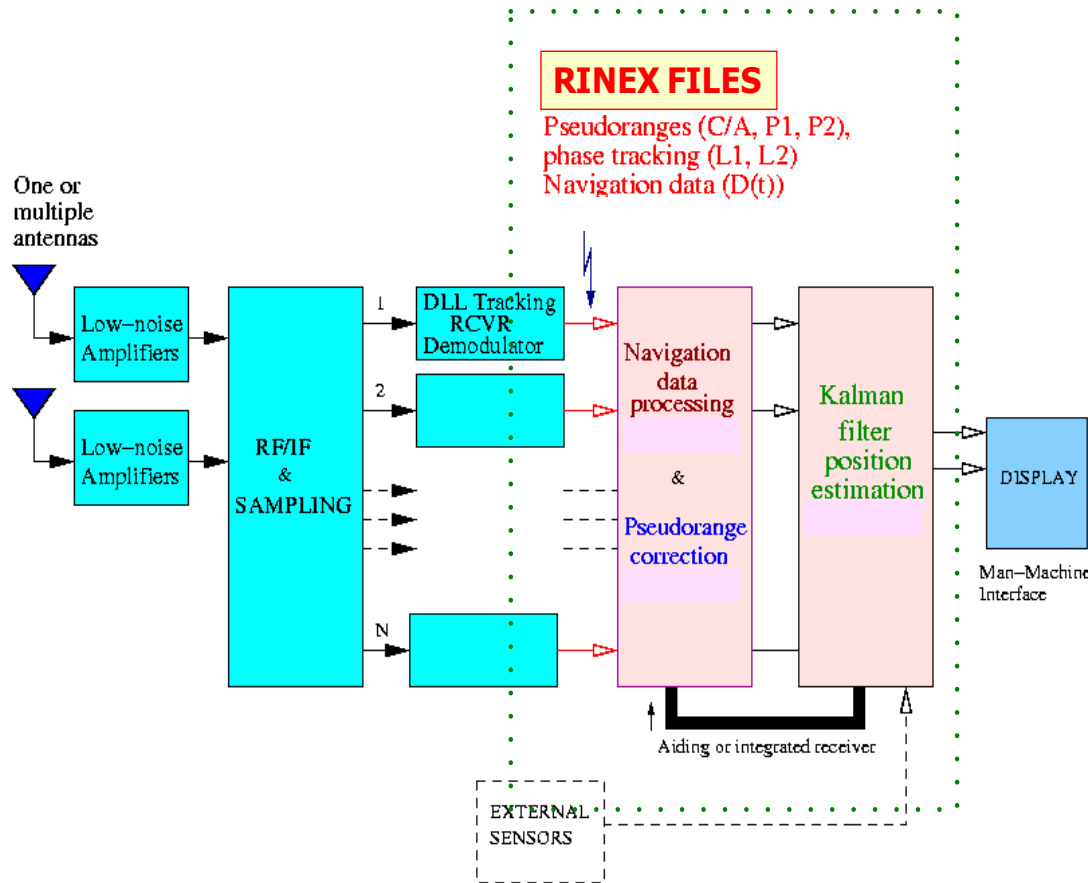


# Basic: Introductory Lab. Exercises

- Standard and Precise Point Positioning
  - To illustrate how easy to process GNSS data using gLAB, a GPS receiver will be positioned in the next examples using:
    - Example 1: Broadcast orbits and clocks (**SPP**, kinematic).
    - Example 2: Precise Orbits and clocks (**PPP**, static).
    - Example 3: Precise Orbits and clocks (**PPP**, kinematic).
  - Solutions will be compared with an accurate reference value of receiver coordinates to assess the positioning error.

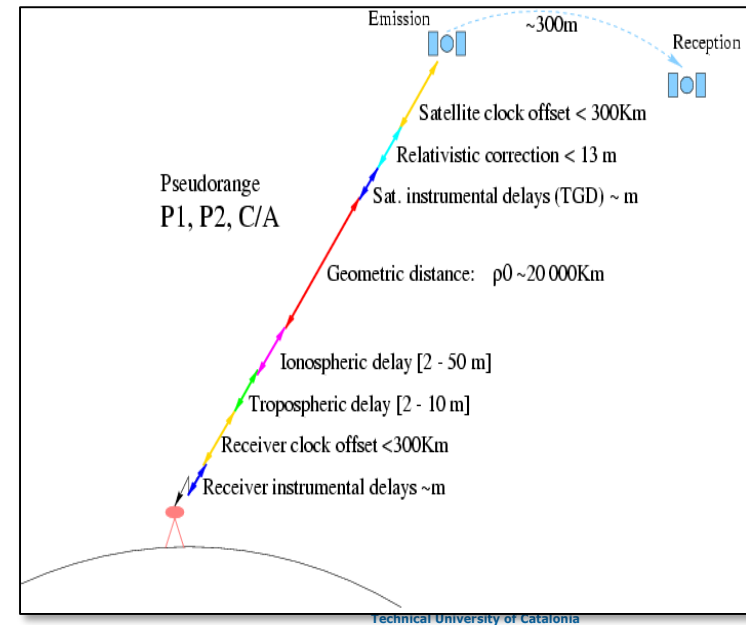
*Note: the receiver coordinates were kept fixed during the data collection.*

# We will work after the correlator: Our input data are code and carrier measurements and satellite orbits and clocks.



```

RINEX: observables
2 OBSERVATION DATA G (GPS) RINEX VERSION / TYPE
RGRINEX0 V2.4.1 UX AUSLIG 10-JAN-97 10:19 PGM / RUN BY / DATE
Australian Regional GPS Network (ARGN) - COCOS ISLAND COMMENT
BIT 2 OF LLI (+4) FLAGS DATA COLLECTED UNDER "AS" CONDITION COMMENT
-0.00000000103 HARDWARE CALIBRATION (S) COMMENT
-0.000000054663 CLOCK OFFSET (S) COMMENT
COCO MARKER NAME
AU18 MARKER NUMBER
mrh OBSERVER / AGENCY
126 auslig 93.06.25 / 2.8.33.2 REC # / TYPE / VERS
327 ROGUE SNR-8100 ANT # / TYPE
DORNE MARGOLIN T APPROX POSITION XYZ
-741950.3241 6190961.9624 -1337769.9813 COMMENT
0.0040 0.0000 0.0000 COMMENT
1 1 COMMENT
5 C1 L1 L2 P2 P1 COMMENT
SNR is mapped to signal strength [0,1,4-9] COMMENT
sig: >500 >100 >50 >10 >5 >0 bad n/a COMMENT
9 8 7 6 5 4 1 0 COMMENT
30 INTERVAL
1997 1 9 0 7 30.00000000 TIME OF FIRST OBS
1997 1 9 23 59 30.00000000 TIME OF LAST OBS
END OF HEADER
97 1 9 0 7 30.00000000 0 7 1 25 9 5 23 17 6
22127685.105 -14268715.899 8 -11118481.2845 22127685.4014 <===== 1
22672158.746 -11510817.892 7 -8969469.30045 22672158.5184 <===== 25
22594902.367 -12949753.825 7 -10090708.53945 22594903.7394 <===== 9
22731128.796 -11621184.951 7 -9055464.16945 22731130.0094 <===== 5
24610920.702 -924108.174 6 -720085.67045 24610920.0404 <===== 23
20718775.074 -18605935.474 9 -14498133.97346 20718775.6074 <===== 17
20842713.610 -19083282.892 9 -14870090.55546 20842713.4814 <===== 6
    
```







# Example 1: Standard Point Positioning (SPP)

SPP Template: Kinematic positioning with single freq. C1 code + broadcast orbits and clocks.

1

2

3

Run gLAB

1. Select the **SPP** Template

2. Upload the **RINEX** files:

- Measurement: `roap1810.09o`

- Navigation: `brdc1810.09n`

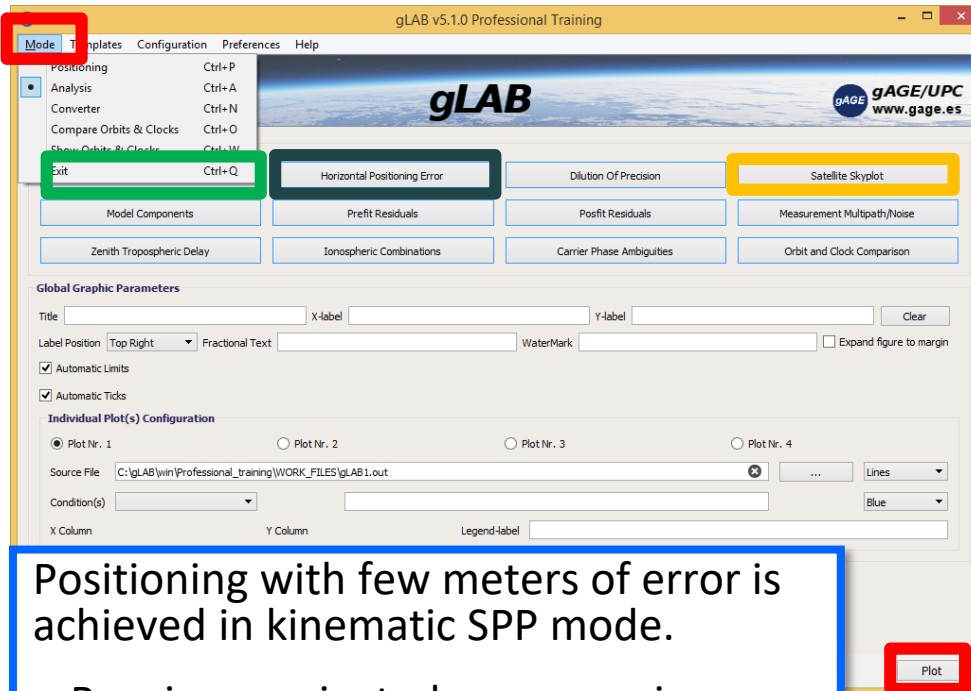
3. **RUN** gLAB

Default output file:  
**gLAB.out**

Note: Reference coordinates are from RINEX

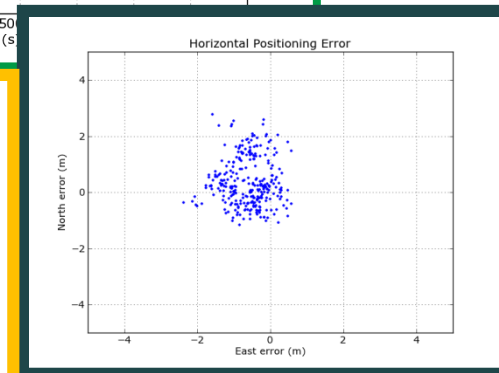
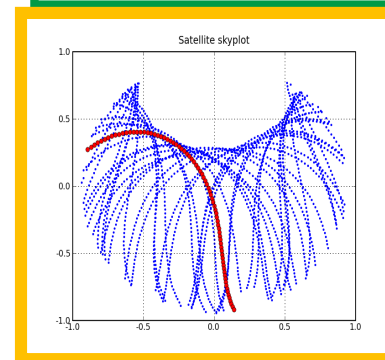
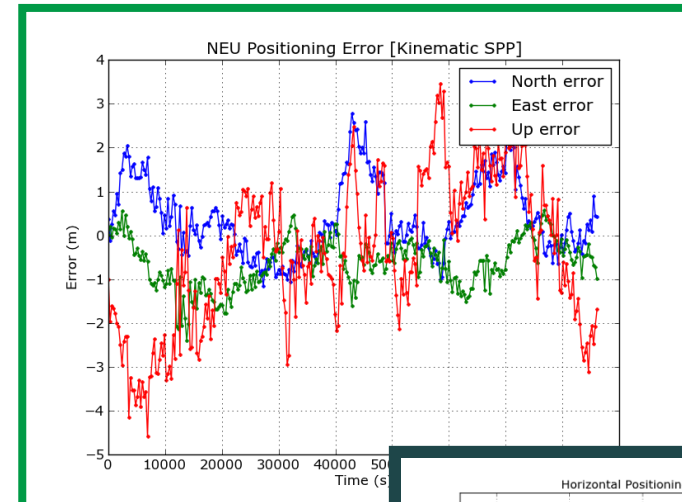
# Example 1: Standard Point Positioning (SPP)

## • Plotting Results



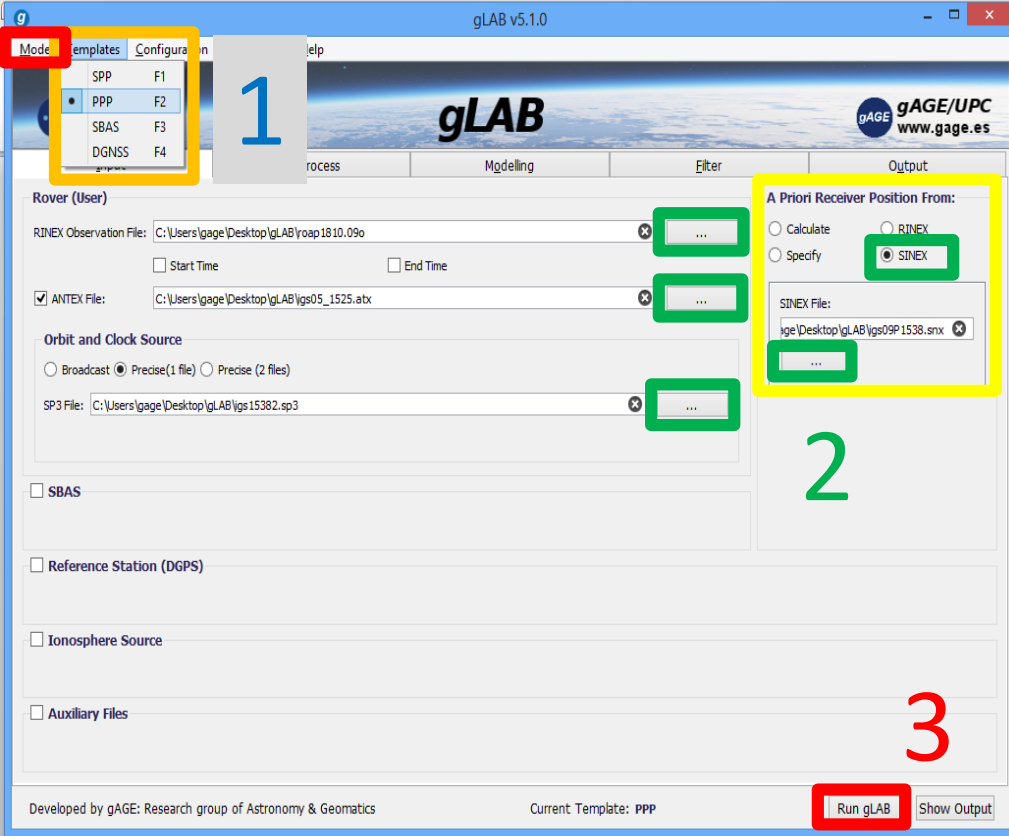
Positioning with few meters of error is achieved in kinematic SPP mode.

- Receiver navigated as a rover in pure kinematic mode.
- Single frequency C1 code is used.
- Broadcast orbits and clocks.



# Example 2: Static Precise Point Positioning (PPP)

**PPP Template:** Static positioning with dual freq. code & carrier (ionosphere-free combination PC,LC) + post-processed precise orbits & clocks.



1. Select the **PPP Template**
2. **Upload data files:**
  - Measurement: roap1810.09o
  - ANTEX: igs05\_1525.atx
  - Orbits & clocks: igs15382.sp3
  - SINEX: igs09P1538.snrx
3. **RUN gLAB**

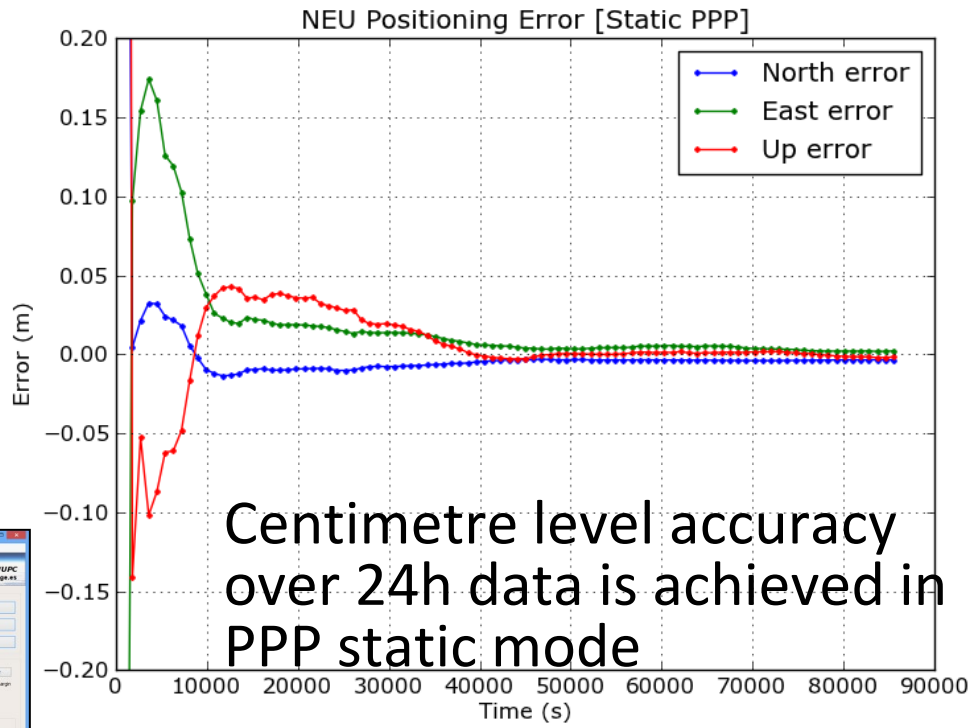
↓

Default output file:  
**gLAB.out**

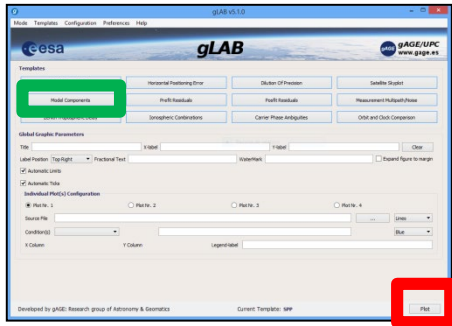
# Example 2: Static Precise Point Positioning (PPP)

- Plotting Results

- Coordinates are taken as constants in nav. filter.
- Dual frequency Code and Carrier measurements.
- Precise orbits and clocks.
- Measurements modelling at the centimetre level.



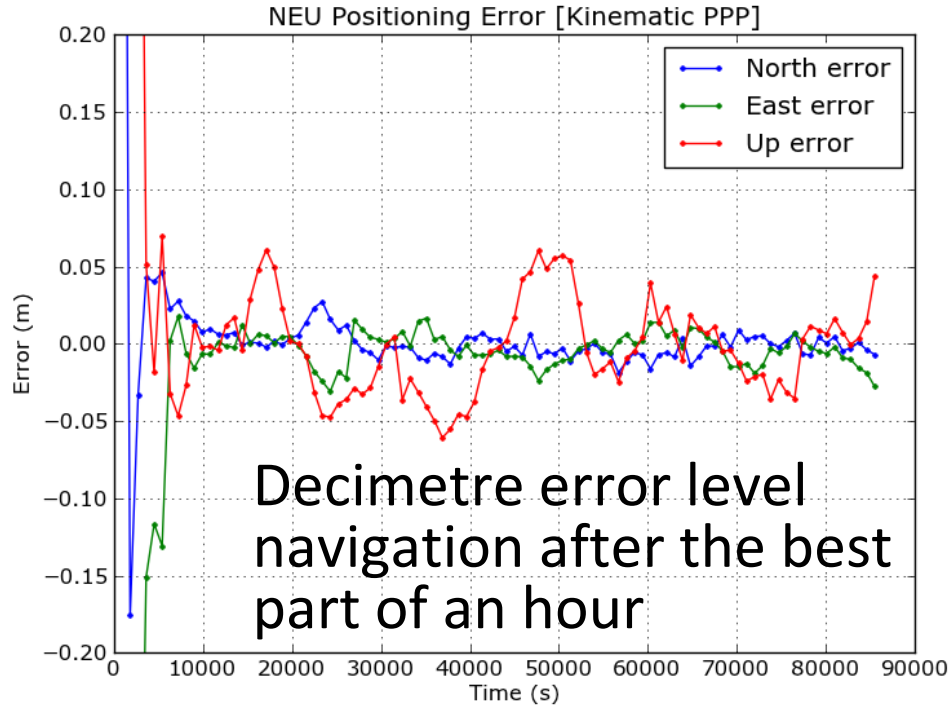
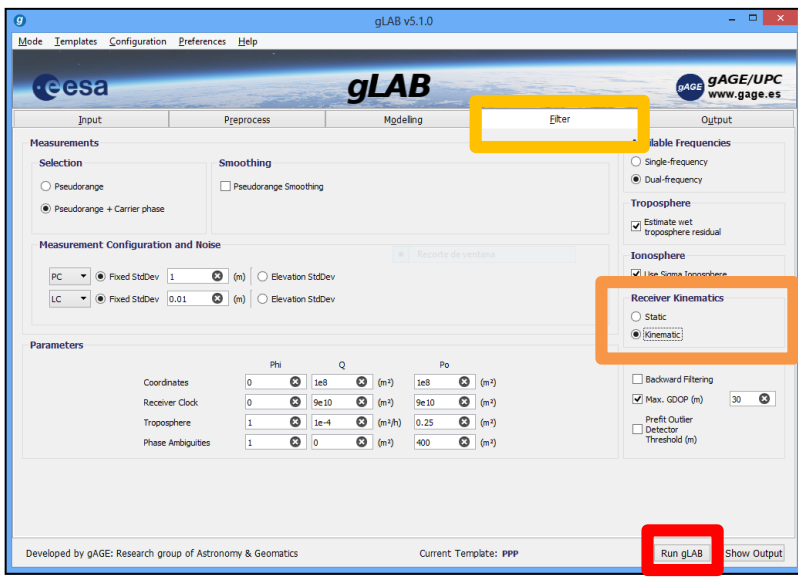
Centimetre level accuracy over 24h data is achieved in PPP static mode



# Example 3: Kinematic Precise Point Positioning

From default configuration of [PPP Template],

- Select **kinematics** in the [Filter] panel. **Run gLAB** and plot results.



Receiver navigated as a rover in a pure kinematic mode.

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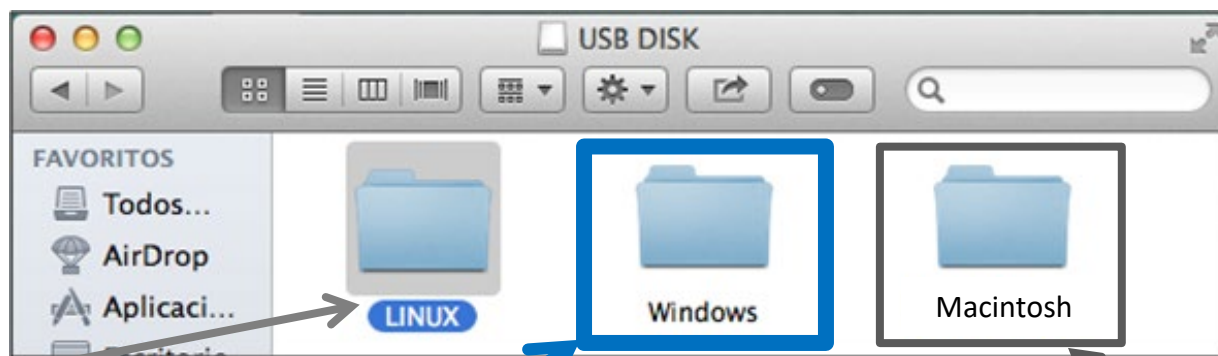



# Installing the software





This tutorial has been designed to be executed under **UNIX (Linux) Operative System (OS)**, which is a very powerful and robust environment.

Nevertheless, the necessary tools are provided for **Windows or Macintosh** users to install this software and to emulate a UNIX command line shell over Windows.



 **Linux** users can install the **native version** of the software

 **Windows** users can install the windows version of **gLAB** and the **Cygwin** emulator of a Linux command shell.

 **Macintosh** users can install the software with the “gLAB\_Install.pkg” file.



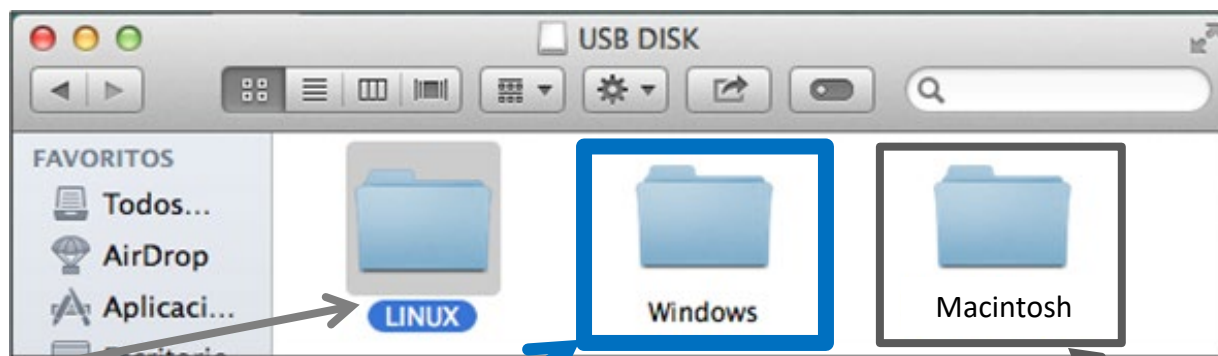



# Installing the software





This tutorial has been designed to be executed under **UNIX (Linux) Operative System (OS)**, which is a very powerful and robust environment.

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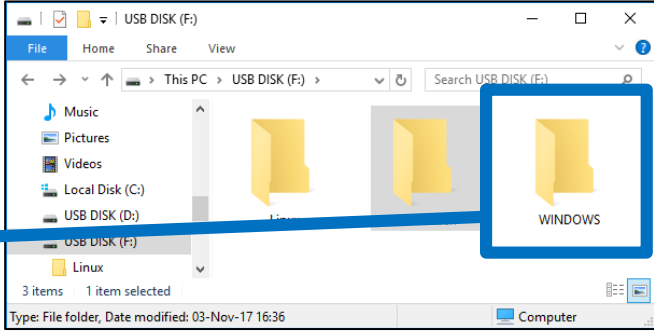


 **Linux** users can install the **native version** of the software

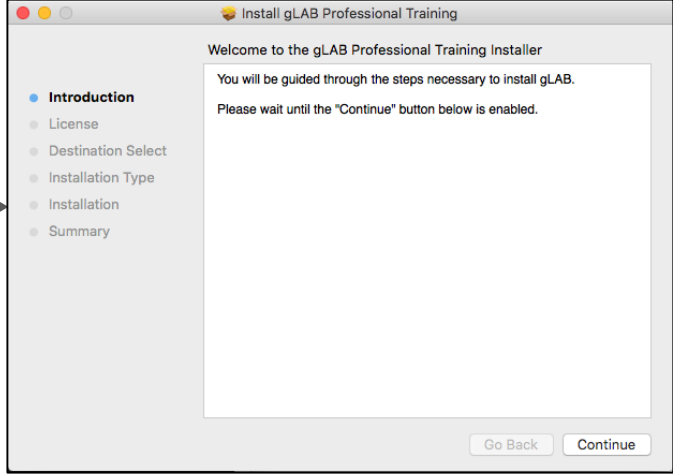
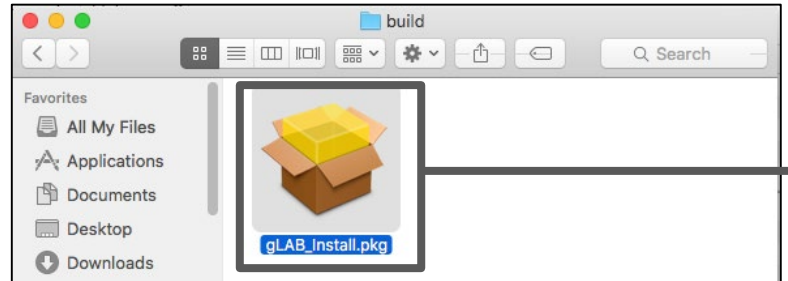
 **Windows** users can install the windows version of **gLAB** and the **Cygwin** emulator of a Linux command shell.

 **Macintosh** users can install the software with the “gLAB\_Install.pkg” file.

Inside the “**Windows**” folder, there is the installable *gLAB program*. Follow the instructions of Software Installation file.



Inside the “**Macintosh**” folder, there is the dmg file. Double click on the “gLAB\_Install.pkg” file, and follow the instructions.





# Installing the software



Please install the software **before** the first laboratory class on Thursday.

If you need help, send an email to [glab.gage@upc.edu](mailto:glab.gage@upc.edu), so we have time to solve any installation issue offline.

Due to the large number of attendees, installation questions will not be answered during the laboratory sessions.

Thanks!!



# Installing the software

## Windows users



The Medium and Advanced exercises of this tutorial have been designed to be executed under **UNIX (Linux) Operative System (OS)**. Which is a very powerful and robust environment.


Nevertheless, **Windows OS** users can do the laboratory session by using **Cygwin**, which is a tool that allows to emulate a UNIX command line shell over Windows.

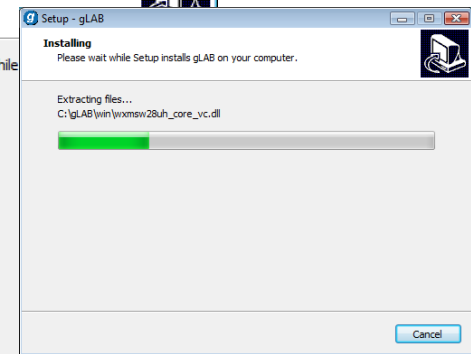
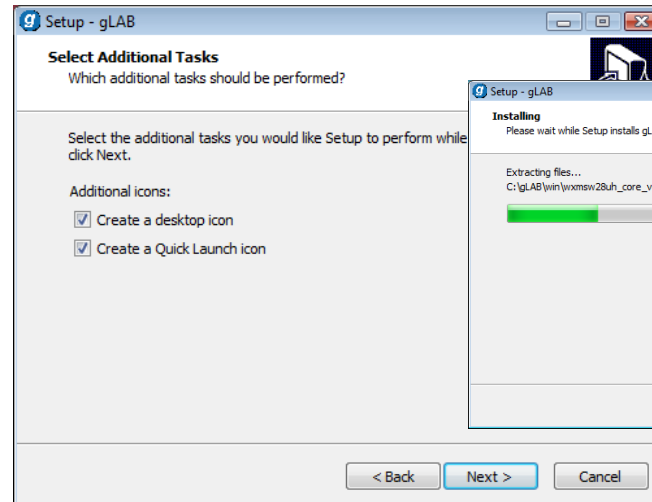
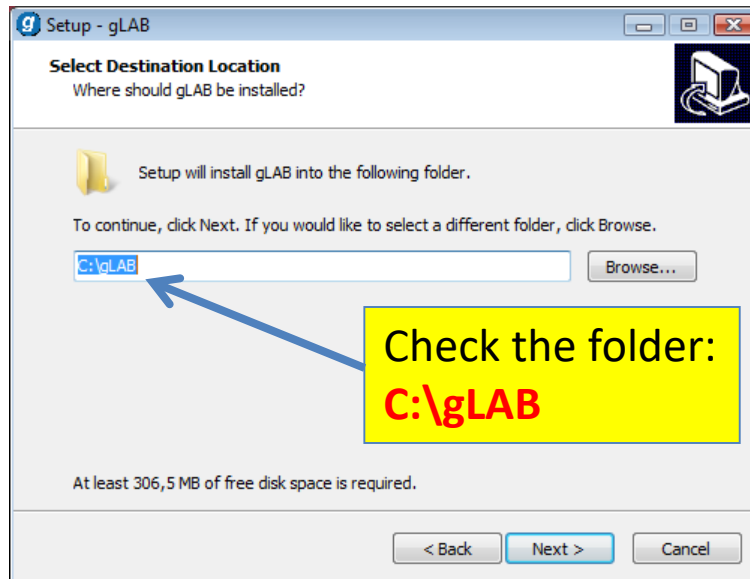
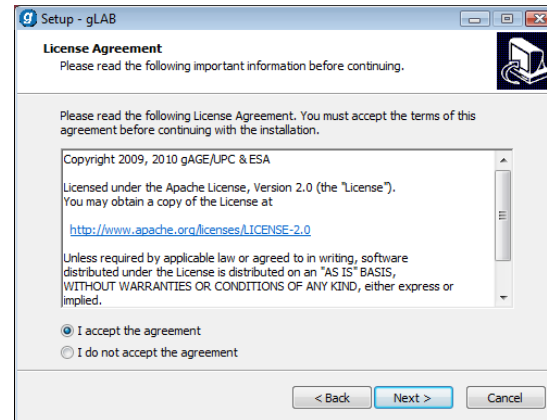
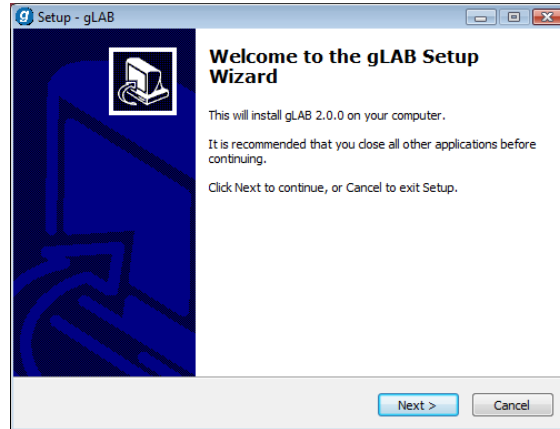
Indeed, after installing **Cygwin**, users can develop the laboratory session as if they were working on a UNIX system (as this tutorial was designed).



# Installing gLAB + Cygwin

1.- First step: Click over the icon

 gLAB\_v5.1.0\_WinSetup\_Prof\_training.exe





## 2.- Second Step: Completing the gLAB Setup Wizard

The image shows two overlapping windows from a Windows operating system. The top window is titled "Setup - gLAB" and is in the "Completing the gLAB Setup Wizard" stage. It contains the following text: "Setup has finished installing gLAB on your computer. The application may be launched by selecting the installed icons. Click Finish to exit Setup." Below this text are two checked checkboxes: "Launch Cygwin installation" and "Launch gLAB". A blue box highlights these checkboxes, with an arrow pointing to a yellow callout box that says "Cygwin and gLAB installation must be selected." The bottom window is titled "0% - Cygwin Setup" and shows a progress bar for "Installing base-files-4.2-2". The progress bar is partially filled with green. Below the progress bar are labels for "Total:" and "Disk:" with corresponding progress indicators. At the bottom of the window are buttons for "< Atrás", "Siguiente >", and "Cancelar".



Once the installation finish, the icons of **gLAB**, **Cygwin Terminal** and the **Professional training folder** will appear.

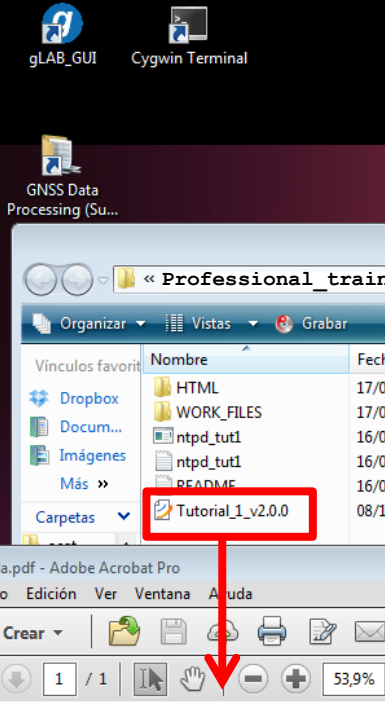
The image shows a Windows desktop environment. On the left, a Windows Explorer window is open to the path `gLAB > win > Professional_training`. The file list includes folders like `HTML`, `WORK_FILES`, and files like `ntpd_tut1`. A file named `Tutorial_1_v2.0.0` is highlighted with a red box and labeled "Tutorial slides".

On the right, the `gLAB v5.1.0` application window is open. The interface features the `eesa` and `gLAB` logos, a navigation bar with `Input`, `Preprocess`, `Modelling`, `Filter`, and `Output` tabs, and a large central image of a satellite. Below the image, it states: "Developed by gAGE: Research group of Astronomy & GEomatics Technical University of Catalonia (UPC)". At the bottom, there is a status bar with "Current Template: SPP" and buttons for "Run gLAB" and "Show Output". A terminal window at the bottom shows the command: `gAGE@gage-PC: /cygdrive/c/gLAB/win/Professional_training/WORK_FILES |`

Yellow arrows point from the `gLAB_GUI` icon in the desktop to the `gLAB` application window, and from the `GNSS Data Processing (Su...)` icon to the terminal window. A blue arrow points from the `Cygwin Terminal` icon to the terminal window.

UNIX (Linux) console to execute "command line" sentences

Suggested desk configuration to start working



The image shows the gLAB v5.1.0 software interface. The main window is titled 'gLAB' and has a menu bar with 'Mode', 'Templates', 'Configuration', 'Preferences', and 'Help'. The interface is divided into several sections:

- Station Data:** Includes 'Data Decimation' (300 s), 'Check for jumps in code measurements', and 'Cycle-slip Detection' options like 'Data Gap' (40 s), 'Loss of Lock Indicator (LLI)', 'N Consecutive Samples' (3), and 'L1-C1 difference (Single-frequency)'. There are 'Configure' buttons for the last three options.
- Satellite Options:** Includes 'Elevation Mask' (5 degrees), 'SNR Mask', 'Align carrier phase measurement with code', 'Discard Satellites Under Eclipse Condition', and 'Discard Unhealthy Satellites (Broadcast only)'. There is a 'GNSS Satellite Selection' section with radio buttons for 'GPS', 'Galileo', 'GLONASS', 'BeiDou', and 'GEO', and 'All'/'None' buttons.
- Satellite Selection Grid:** A grid of buttons for PRN numbers 1 through 32. PRN 11, 29, and 28 are highlighted in red, while others are green.
- Bottom Panel:** Shows 'Current Template: SPP', 'Run gLAB', and 'Show Output' buttons. Below this is a plot of 'error (m)' vs 'time (s)'. The plot shows three data series: 'North error' (blue), 'East error' (green), and 'Up error' (red). The errors are mostly within ±50m for the first 10,000s and then fluctuate around 0m. The x-axis is labeled 'time (s)' and ranges from 0 to 90,000. The y-axis is labeled 'error (m)' and ranges from -150 to 100. A scale factor 'x=3.1e+004, y=39' is shown at the bottom left of the plot.

## Tutorial 1 GNSS Data Processing Lab Exercises

Prof. Dr. Jaume Sanz Subirana and Prof. Dr. J. M. Juan Zornoza  
assisted by Dr. Adrià Rovira Garcia

Research group of Astronomy & Geomatics (gAGE)  
Universitat Politècnica de Catalunya (UPC)  
Barcelona, Spain



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# Thanks for your attention

Other Tutorials are available at  
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**GNSS Tutorials**

- **GNSS Course** (associated to the **GNSS Data Processing Book**)
  - About the course
  - **GNSS Data Processing: Theory Slides (Full compendium)**
    - Lecture 0: Introduction
    - Lecture 1: GNSS measurements and their combinations
    - Lecture 2: Satellite orbits and clocks computation accuracy
    - Lecture 3: Position estimation with pseudorange
    - Lecture 4: Introduction to DGNSS
    - Lecture 5: Precise positioning with carrier phase (PPP)
    - Lecture 6: Differential positioning with code pseudorange
    - Lecture 7: Carrier based differential positioning. Ambiguity resolution techniques
  - **GNSS Data Processing: Laboratory Exercises (Full compendium)**
    - Tutorial 0: UNIX environment, tools and skills. GNSS standard file formats [Format files description]
    - Tutorial 1: GNSS data processing laboratory exercises
    - Tutorial 2: Measurement analysis and error budget
    - Tutorial 3: Differential positioning with code measurements
    - Tutorial 4: Carrier ambiguity fixing
    - Tutorial 5: Analysis of propagation effects from GNSS observables based on laboratory exercises
    - Tutorial 6: Differential positioning and carrier ambiguity fixing
- Associated **Software and Data Files (Linux)**
  - CDROM zipped tar file. How to install the CDROM [Linux]
  - CDROM ISO. How to install the CDROM [Linux]
- Associated **Software and Data Files (Windows)**
  - **Instalable Toolkit (gLAB + Cygwin)**
  - **Data Files**
  - How to install the Software
- **Bootable USB stick (Linux live)**
  - **gAGE-GLUE** (to build-up a bootable USB stick). How to burn the gAGE-GLUE. **How to use the bootable USB stick.**
  - **How to start-up the laboratory session.**
- **Useful tools for Windows:** Windows users can install the next ports of Linux tools (instead of Cygwin) at [gnuwin32.sourceforge.net/packages.html](http://gnuwin32.sourceforge.net/packages.html):

**Personnel**

- ▷ Permanent Staff
- ▷ Researchers
- ▷ Former Researches

**Publications**

- ▷ Peer Reviewed Papers
- ▷ Meeting Proceedings
- Culture & Society
- PhD Dissertations

**Learning Material**

- ▽ Library
  - GNSS Books
  - GNSS Course and associated Tutorials
  - GNSS Format Descriptions
  - ▷ GNSS Webinars
- ▷ Software Tools

**Projects**

- ▷ gAGE/UPC
- ▷ gAGE-NAV, S.L.

**Patents**

- WARTK
- Fast-PPP
- Iono. Corrections
- Iono. Disturb. Mitig.
- Receiver orientation

**About us**

*gAGE is a research group of the Technical University of Catalonia (UPC). UPC is a public university located in Barcelona, Spain.*

**gAGE Brochure**

**Shortcuts**

- GNSS Data Processing Book
- **GNSS Course and associated Tutorials**
- GNSS Webinars
- gLAB Tool Suite
- ▷ gAGE Products
- ▷ Useful GNSS links
- Master MAST (UPC)
- Master Of Science (ENAC)
- gAGE upload file facility

**User login**

Username: \*

Password: \*

- Log in using OpenID
- Request new password

**Who's online**

There are currently 0 users and 8 guests online.

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