Bureau Gravimétrique International
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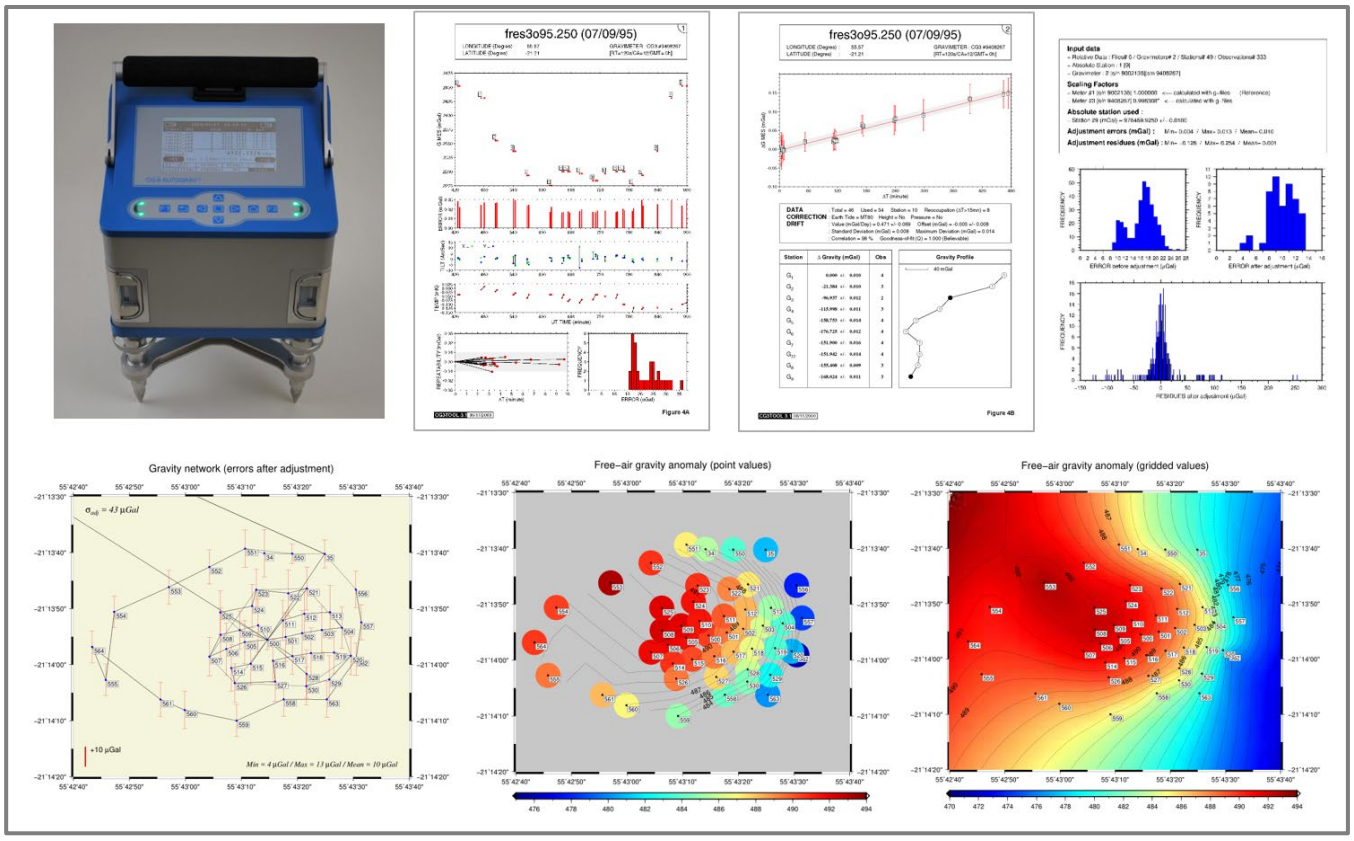
CG6TOOL

User's manual (vers. 2022.12)



Interactive computer program to process Scintrex CG3/CG5/CG6 gravity data

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CONTENTS

CONTEXT

CG6TOOL is an interactive computer program to process Scintrex CG3/CG5/CG6 gravity data. The program is based on an interactive user JAVA interface and uses GMT (Generic Mapping Tools) facilities. CG6TOOL is an updated and extended version of the CG3TOOL software initially developed in 1996 by the authors for processing Scintrex CG3 gravity data. The aim of CG3TOOL was to allow for an objective evaluation of data and to provide a higher resolution in data reduction. The main functions included the reduction of daily data files by applying standard or accurate corrections (earth-tide, free-air gradient, and instrumental drift). The interactive procedures and the program output have been designed to ease data handling and as well as to provide useful information for further purposes of data interpretation or modeling. As CG3TOOL was only running on Unix Sun workstations, the authors started in 2014 the development of a new version (CG5TOOL) based on Eclipse platform. Later, the following updates have been done :

- 2019 : With the release of CG6 instruments and new formats, CG5TOOL become **CG6TOOL**
- 2020 : The new version of CG6TOOL run under **Windows NT** OS (but only with gmt6)
- 2021 : New graphics formats are available (jpg, png and pdf) but only with gmt6 version
- 2022 : File names no longer have to respect a particular coding, and observations files can concern a circuit over several consecutive days. Alphanumeric station names are accepted. Possibility to process profiles that do not loop (e.g. between two bases with known values).

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Original paper : Gabalda, G., Bonvalot, S., Hipkin, R., 2003. Interactive computer program to process Scintrex CG-3/3M gravity data for high resolution applications. Computers & Geosciences, 29, 2, pp. 155–171. https://doi.org/10.1016/S0098-3004(02)00114-0

DISCLAIMER OF WARRANTY

CG6TOOL is provides “AS IS”, with no warranty. The authors and their belonging institutions assume no responsibility. CG6TOOL is provided as free software to the scientific community and you are no allowed to distribute CG6TOOL without the permission of the authors.

PREREQUISITES

In order to use CG6TOOL, it is necessary to install **Java**, **GMT** (the graphical and mathematical “Generic Mapping Tool” free library, available from the web), and initialize environment variables:

- **CG6TOOL**: Java Archive file and CG6TOOL script must be installed into $CG6TOOL. Don’t forget to set your **PATH** to include $CG6TOOL.
- **CG6VIEWER**: A Postscript viewer. Only **gv** or **gs** (Ghostscript) have been tested. This variable isn’t used with GMT6
- **CG6READER**: To read the *pdf* files (evince by default). Not used on Windows NT
- **GMT_VERSION** : GMT4, GMT5 or GMT6 (default)
- **DIR_GSHHG** : Path to the coastlines database directory

CG6TOOL.gmt

In order to initialize its variables and depending on the version used (gmt4, gmt5 or gmt6), GMT needs a configuration file, respectively **.gmtdefaults4**, **gmt.conf** and **gmt.conf**. These files are respectively created using the files CG6TOOL.gmt4, CG6TOOL.gmt5 and CG6TOOL.gmt6 which must also be present in the ***$CG6TOOL/init*** directory. There are automatically created when needed and can be modified by the user.

Starting CG6TOOL

- ***Linux environment***

  If your PATH includes $CG6TOOL then run **CG6TOOL** or you can create a Desktop ***launcher*** (with the ***CG6TOOL.jpg*** icon) with the command: ***java –jar <jar_full path>***

- ***Windows NT* environment**

  Double-click the JAR file or using a shortcut (associate with CG6TOOL.ico) on your desktop.

INPUT DAILY DATA FILES

CG6TOOL directly handles Scintrex digital data files acquired in the operating 'field' mode and uploaded from the instrument through the serial port.

All observations must be stored in files (containing both one header and time series).

Other data type may exist:

- s-file [site] created by the user
- c-file [computed] and r-file [result] produced by CG6TOOL.

Scintrex CG3/3M file

```
------------------------------------------------------------------------------
SCINTREX V7.2       AUTOGRAV / Field Mode            R7.21 REMOTE/Hires
                                                        Ser No:    110193.
Line:      0.  Grid:      1.   Job:      1.  Date: 02/04/11  Operator:       1.

GREF.:                   -3000. mGals          Tilt x sensit.:           293.2
GCAL.1:                 6015.752               Tilt y sensit.:           296.5
GCAL.2:                      0.                Deg.Lat.:                -33.45
TEMPCO.:                -0.1253mGal/mK         Deg.Long.:                70.66
Drift const.:                0.                GMT Difference:           0.hr
Drift Correction Start  Time: 23:24:12         Cal.after x samples:         12
                        Date: 02/03/06         On-Line Tilt Corrected = "*"
------------------------------------------------------------------------------
Station  Grav.      SD.   Tilt x  Tilt y    Temp.    E.T.C.  Dur  # Rej     Time
    1. 2289.7584* 0.048    -0.3    -1.0    -2.01   0.015    100     2  13:37:20
    1. 2290.2210* 0.026    -2.5    -2.2     1.05  -0.067    100     2  23:28:00
    2. 2231.5532* 0.042    -0.6     1.2     0.22   0.062    100     0  14:56:56
    3. 2232.8674* 0.040    -3.9     2.0     0.24   0.068    100     3  15:11:14
    4. 2230.3552* 0.075     0.8    -0.9     0.47   0.077    100     2  15:43:18
    5. 2227.6992* 0.078     1.6     0.2     0.35   0.080    100     0  16:00:48
    5. 2227.7088* 0.067    -3.9    -0.1     0.34   0.080    100     2  16:03:27
    6. 2226.3028* 0.072     1.4     0.7     0.29   0.080    100     0  16:16:21
    6. 2226.2930* 0.070    -0.2    -1.7     0.31   0.080    100     2  16:18:32
    7. 2226.7656* 0.047    -4.5    -0.6     0.36   0.079    100     4  16:36:08
```

Header parameters required :

- *File type:* *- - - - - (First line)*
- *SER No*: Serial number of the instrument
- *Date:* Date of data acquisition
- *Deg.Lat.:* Latitude
- *Deg.Long.:* Longitude (+ to the West)
- *GMT Difference :* *Difference between UTC and measurement time*

Scintrex CG5 file

```
/          CG-5 SURVEY
/          Survey name:          Pyrope
/          Instrument S/N:       9136
/          Client:               Default
/          Operator:             Default
/          Date:                 2014/ 6/ 2
/          Time:                 07:56:56
/          LONG:                 1.5000000 E
/          LAT:                  42.8000000 N
/          ZONE:                 31
/          GMT DIFF.:            0.0

/          CG-5 SETUP PARAMETERS
/          Gref:                           0.000
/          Gcal1:                9109.393
/          TiltxS:               670.647
/          TiltyS:               660.069
/          TiltxO:               84.648
/          TiltyO:               61.302
/          Tempco:               -0.141
/          Drift:                0.000
/          DriftTime Start:      01:06:34
/          DriftDate Start:      2000/01/01

/          CG-5 OPTIONS
/          Tide Correction:   YES
/          Cont. Tilt:        NO
/          Auto Rejection:    YES
/          Terrain Corr.:     NO
/          Seismic Filter:    YES
/          Raw Data:          YES
/---LINE---STATION----ALT.----GRAV.---SD.--TILTX--TILTY-TEMP---TIDE---DUR-REJ-----TIME----DEC.TIME+DATE--TERRAIN---DAT
1.000 245.000  0.0000 4253.907 0.034   -25.4 -24.4 -17.38 -0.001  90  23 07:30:35  5143.31240  0.0000 2014/06/05
1.000 245.000  0.0000 4253.909 0.016    -5.4 -11.4 -17.43 -0.001  90   7 07:33:31  5143.31444  0.0000 2014/06/05
1.000 246.000  0.0000 4308.860 0.035    72.0  32.4 -17.34 -0.005  90  22 08:54:40  5143.37070  0.0000 2014/06/05
1.000 246.000  0.0000 4308.835 0.014    27.3  11.2 -17.35 -0.006  90  22 08:57:13  5143.37220  0.0000 2014/06/05
1.000 246.000  0.0000 4308.833 0.010    18.0  11.9 -17.40 -0.006  90   6 09:00:04  5143.37445  0.0000 2014/06/05
1.000 262.000  0.0000 4240.207 0.017    -2.2   8.0 -17.36  0.025  90  10 16:24:03  5143.68227  0.0000 2014/06/05
1.000 262.000  0.0000 4240.222 0.011    -6.5   0.6 -17.34  0.025  90   0 16:26:21  5143.68387  0.0000 2014/06/05
1.000 262.000  0.0000 4240.225 0.009    -0.3  -4.6 -17.35  0.025  90   0 16:28:39  5143.68546  0.0000 2014/06/05
1.000 245.000  0.0000 4253.972 0.051    -5.9 -12.4 -17.29  0.025  90   3 16:49:53  5143.70019  0.0000 2014/06/05
1.000 245.000  0.0000 4253.979 0.068     3.6  -1.9 -17.29  0.025  90   4 16:52:41  5143.70213  0.0000 2014/06/05
```

Header parameters required :

- *File type:* *CG-5 SURVEY*
- *Instrument S/N :* Serial number of the instrument
- *Date:* Date of data acquisition
- *LAT:* Latitude
- *LONG:* Longitude (+ to the East)
- *GMT DIFF.:* *Difference between UTC and measurement time*
- Tide Correction : Earth tide correction (available or not)

WARNING: Files with coordinates are not accepted but it is possible to transform them using the tool “Import Data” (*cf p.49*)

Scintrex CG6 file

```
/          CG-6 SURVEY
/          Survey name:          AZER_AA
/          Instrument Serial Number:      018100125
/          Created:              2019-05-07-10:32:20
/
/          CG-6 Calibration
/          Operator:             GG
/          Gcal1 [mGal]:         7996.315000
/          Goff [ADU]:           -8388608.000000
/          Gref [mGal]:          0.0000
/          X Scale [arc-sec/ADU]:          0.031125
/          Y Scale [arc-sec/ADU]:          0.031014
/          X Offset [ADU]:       -85356.959885
/          Y Offset [ADU]:       -75699.919233
/          Temperature Coefficient [mGal/mK]:       -0.128600
/          Temperature Scale [mK/ADU]:   -0.000111
/          Drift Rate [mGal/day]:        -0.119628
/          Drift Zero Time:      2018-10-31 12:00:18
/          Firmware Version:     R-20170705-1
/Station  Date        Time      CorrGrav  Line  StdDev  .../...  LatGPS      LonGPS      ElevGPS  Corrections[drift-temp-na-tide-tilt]
1001      2019-05-07  10:32:20  3370.5900 0     0.0797  .../...  40.378101   48.973633   544.1    11011
1001      2019-05-07  10:33:20  3370.5901 0     0.0724  .../...  40.378105   48.973633   544.2    11011
```

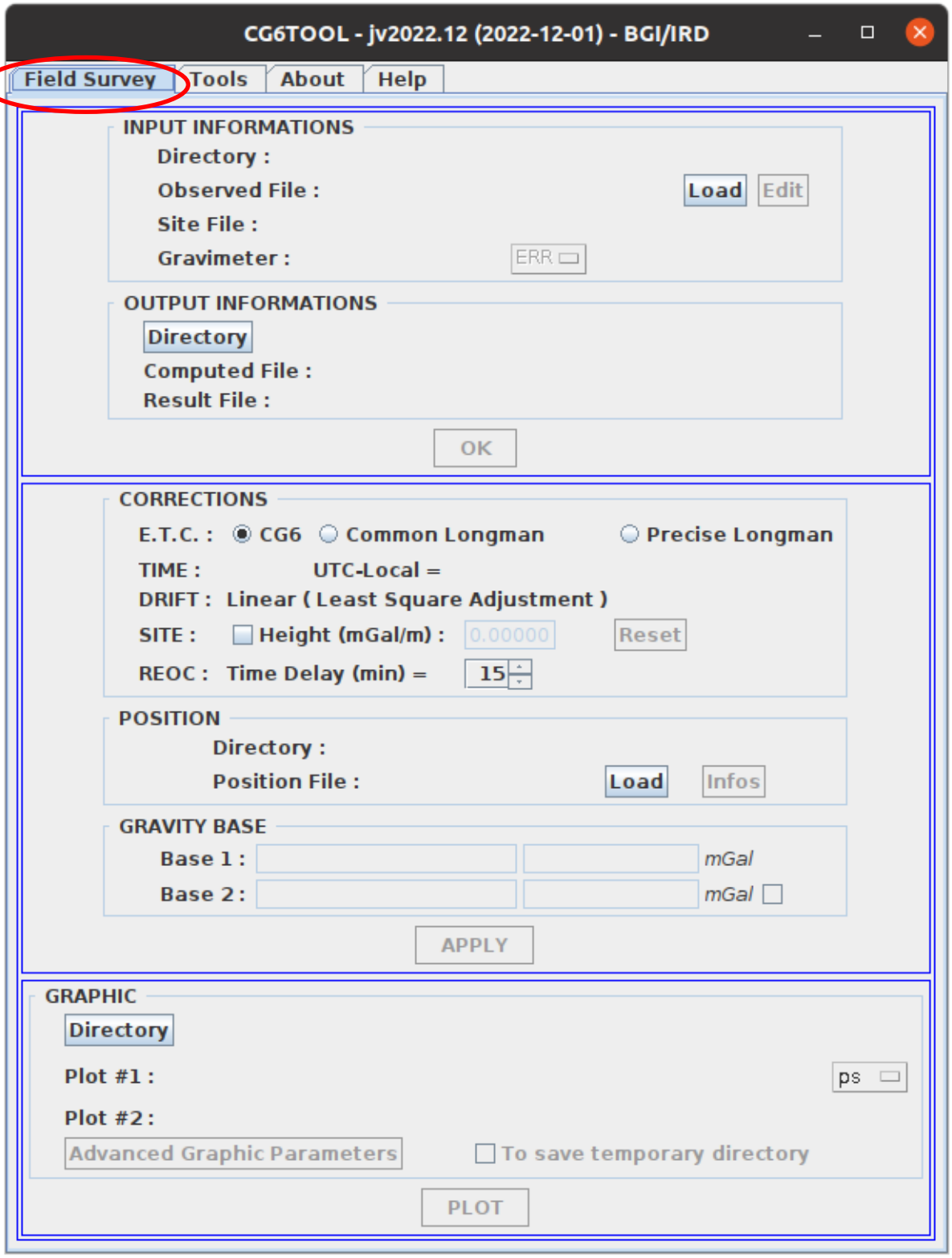
Observation: Below all the parameters of the CG6 format:

Station Date Time CorrGrav Line StdDev StdErr RawGrav X Y SensorTemp TideCorr TiltCorr TempCorr DriftCorr MeasurDur InstrHeight LatUser LonUser ElevUser LatGEXT LonGEXT ElevGEXT Corrections[drift-temp-na-tide-tilt

Header parameters required:

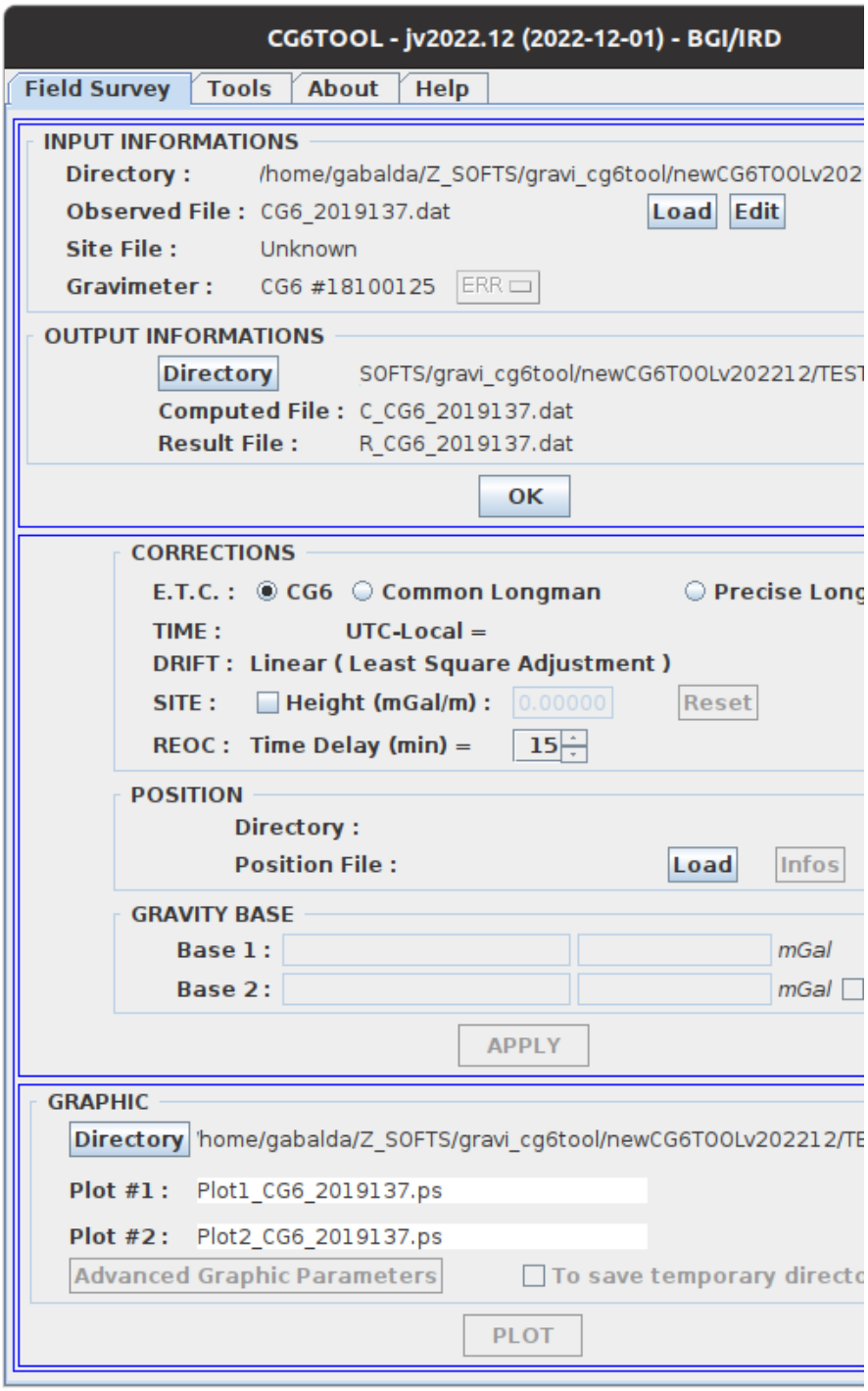
- *File type:* *CG-6 SURVEY*
- *Instrument Serial Number*: Serial number of the instrument

When you run **CG6TOOL** (and CG6TOOL environment variable defined) …

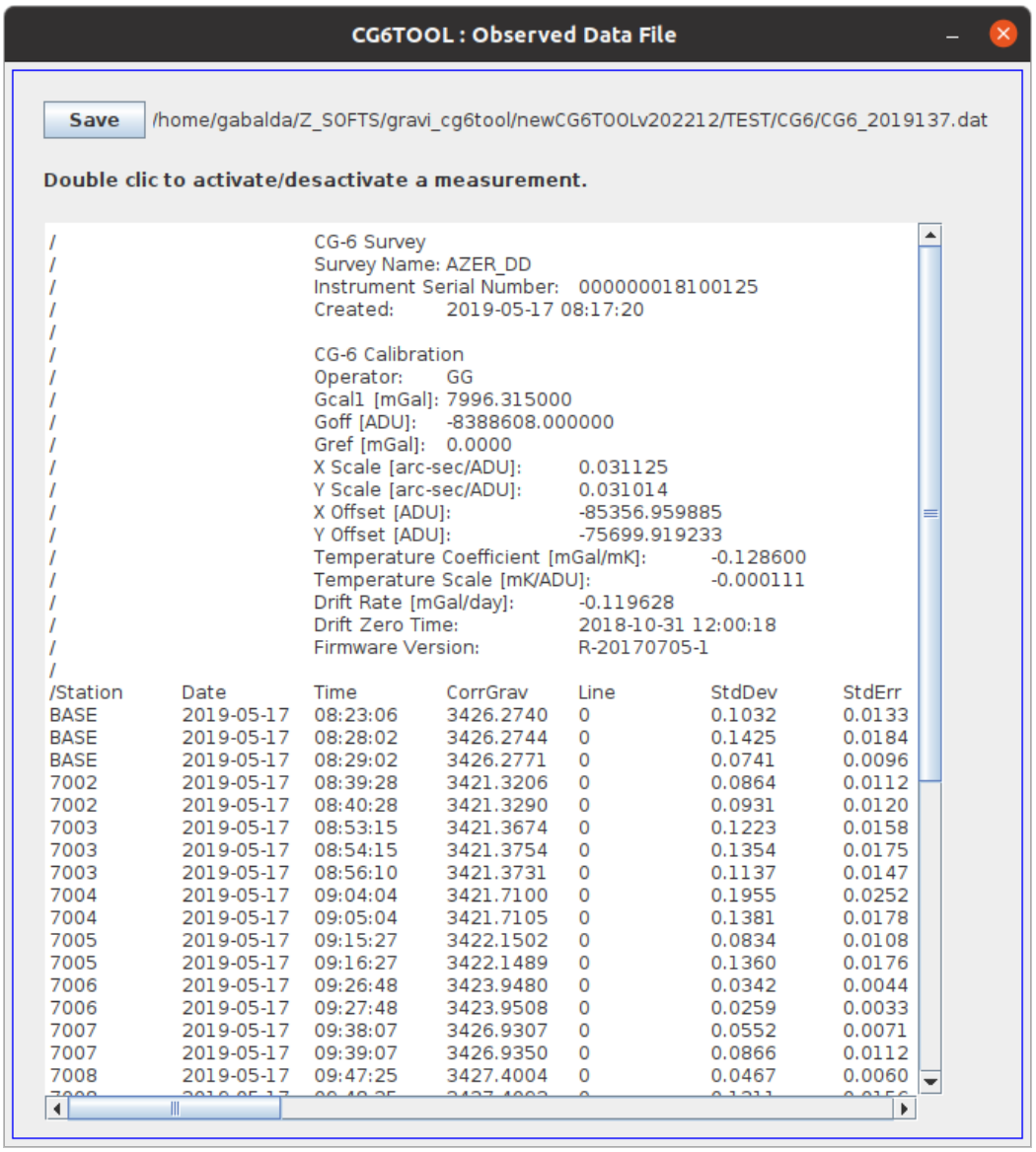


1. Select raw data file

Click the <**Load**> button and select an observation file.
As soon as a file is selected, CG6TOOL is updated with the output files names.



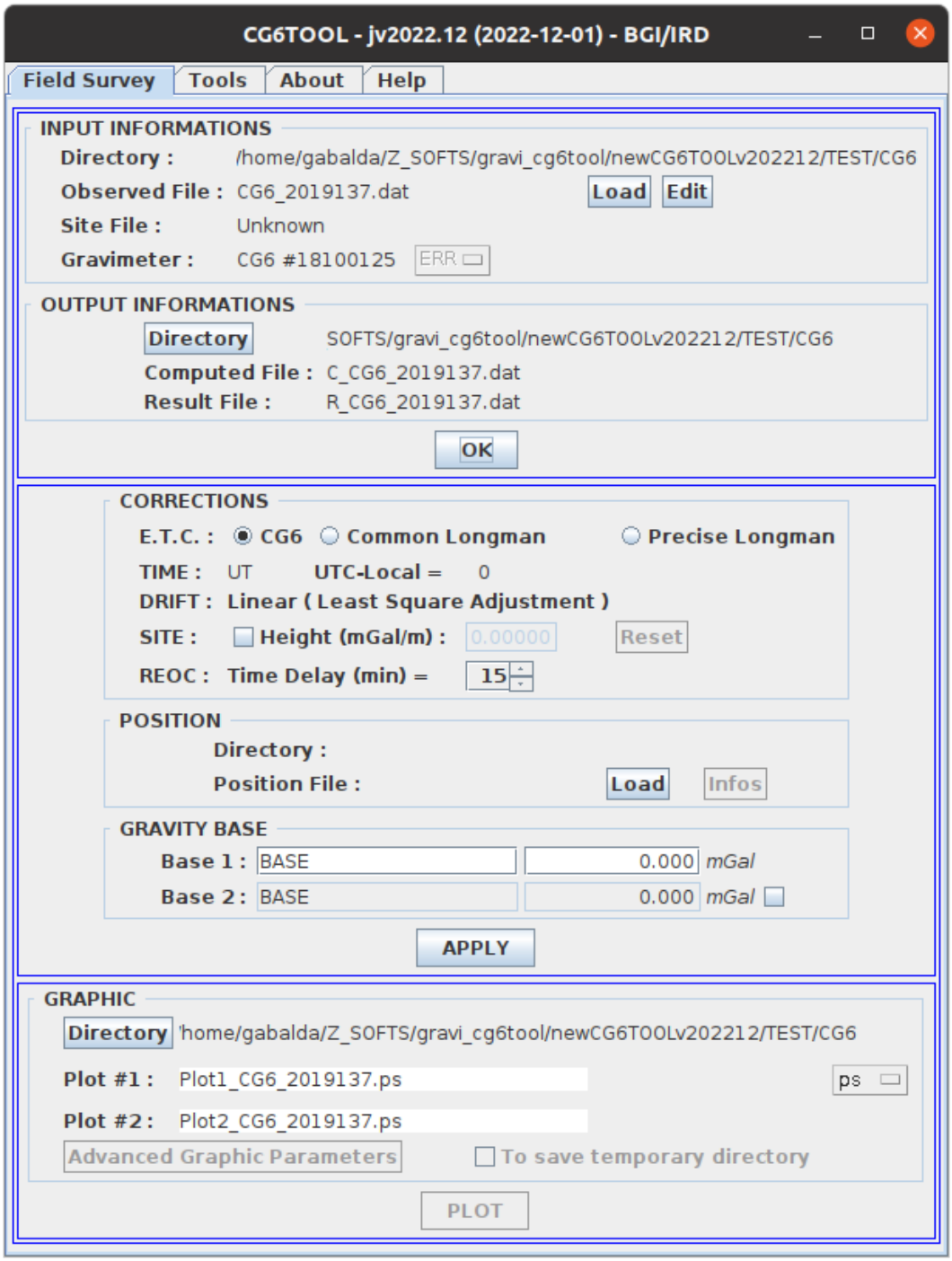
At this step the raw data file can be edited by pressing the <**Edit**> button.



- **Double click** to deactivate/activate a measurement (insert/remove "#").
- <**Save**> to keep the changes

2. Load the selected file

Click the <**OK**> button. If there are errors while loading several messages can appears else the <**APPLY**> button will be available.



3. Processing

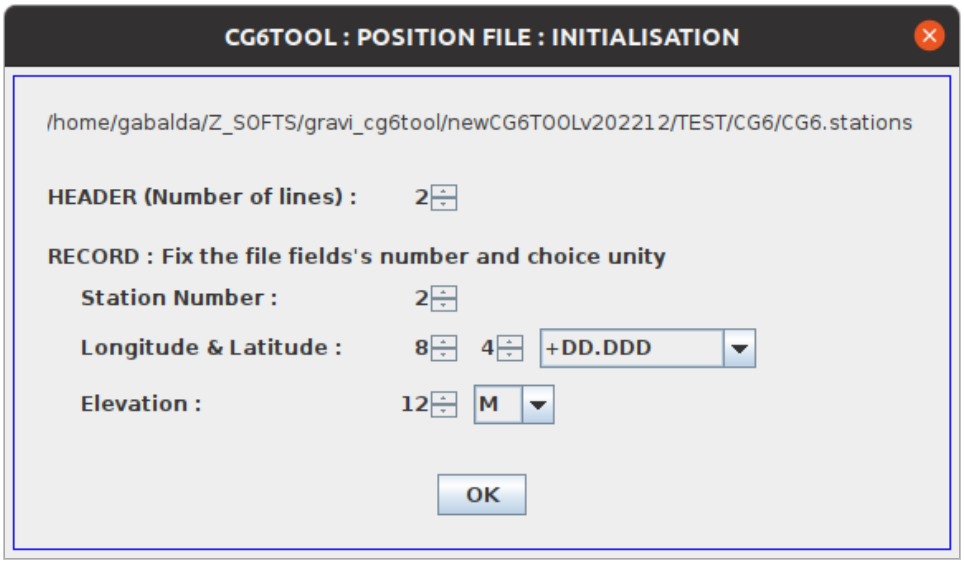
Several corrections (Earth tide correction, height correction, reoccupation time delay) and options (coordinates file, gravity base value) are proposed:

- **E.T.C.: CG6 / Common Longman / Precise Longman**
  - ✓ **CG6** : CG6TOOL use the value computed by the gravimeter
  - ✓ **Common Longman** : a new value is computed from the Longman (1959) algorithm and the header coordinates
  - ✓ **Precise Longman** permits to calculate a correction for each site with coordinates read in a "position" file (see below).
- **SITE : Height**

  Height correction is also applied to remove the height variations in the instrument leveling or to reduce the height to benchmark level. These corrections use a site file (one site file by observation file). This file can be created in the "Tools" page (Create/Modify Site File). By default the gradient is 0.3086 mGal/m.
- **REOC : Time Delay**

  The instrumental linear drift correction is calculated from the reoccupied sites when the time between two measurements on the same site is beyond this delay (15 minutes by default).
- **POSITION** (*See chapter "POSITION FILE for more explanations*)

  This option allows loading a file with precise station coordinates in order to compute the earth tide correction in each site when the common header coordinates is not adequate. At this step, the user must initialize the format of the file. After this information are available with the <**Infos**> button.



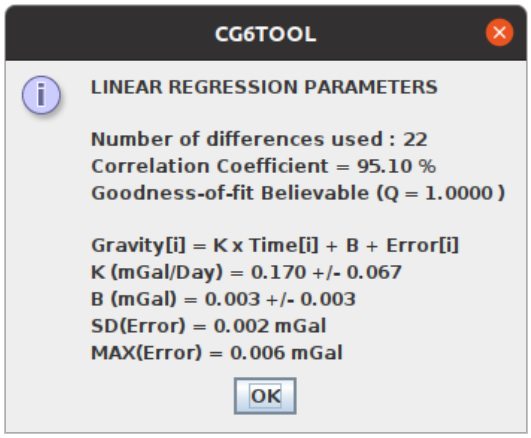
- **GRAVITY**

  This option allows you to assign a gravity value to 1 or 2 stations in the circuit. By default *Base 1* is the first station of the circuit and *Base 2* the last. In the case of profiles that do not loop, the use of 2 bases makes it possible to obtain a "realistic" drift and so "acceptable" results.

Once validated processing options, click on <APPLY> button.

If the **Precise Longman** earth tide correction has been selected and no "position" file was loaded, the user must upload a "position file".

Then, CG6TOOL will provide information about the instrumental drift correction.



Click <**OK**> button to continue.

CG6TOOL will produce two files:

- c-file [computed] with all corrected measurement sorted by time.
- r-file [result] with one record per station

CG6TOOL Computed file: C_<Observed File>

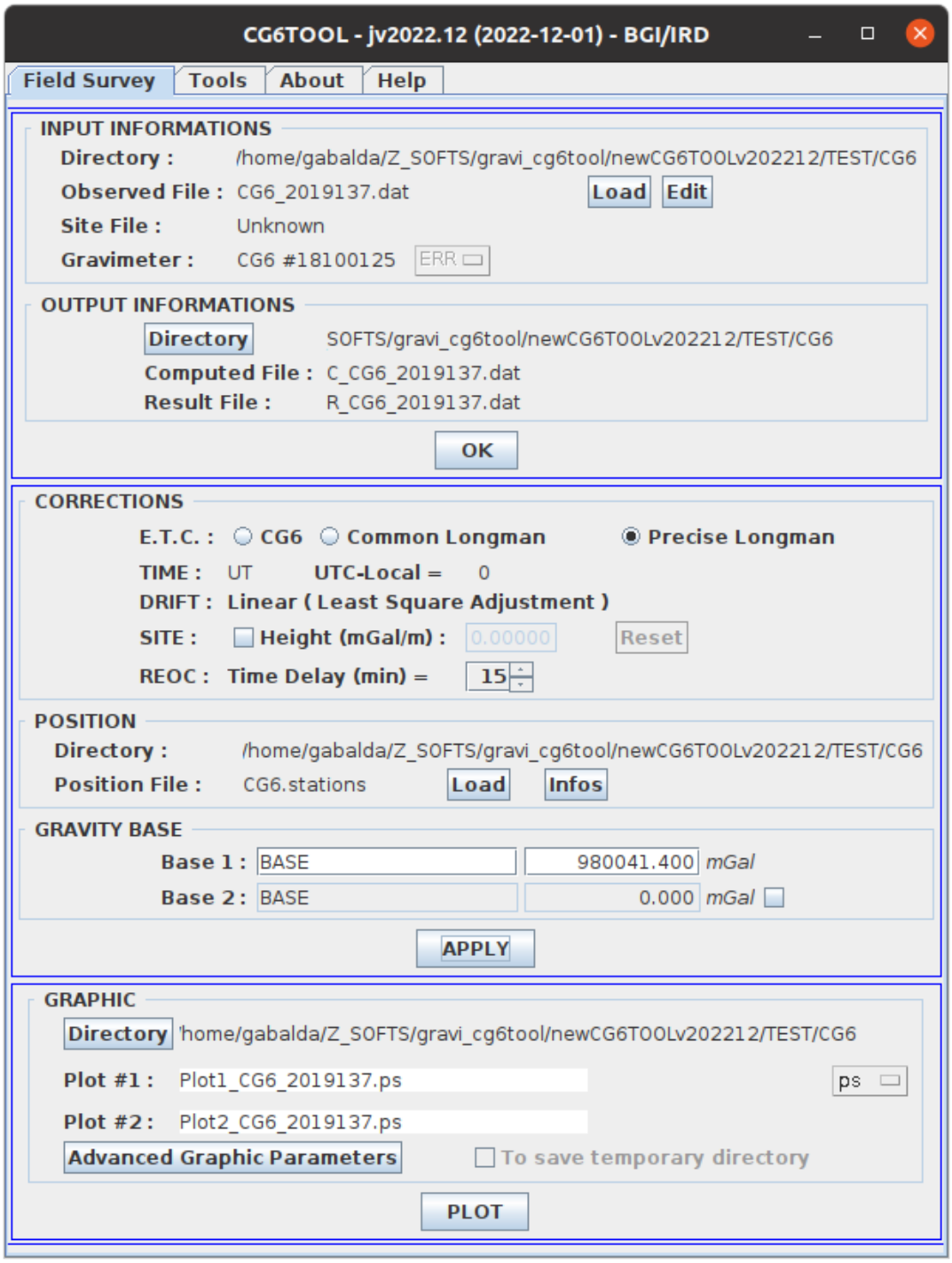
```
# INFO      : CG6TOOL 2022.12 (2022-12-01) - FIELD COMPUTED FILE
# CREATOR   : gabalda
# DATE      : Thu Nov 24 17:49:52 CET 2022
# GRAVIMETER : CG6 #18100125
# DATA      : Observed = 37 / Used = 37
# CORRECTION : Earth Tide = Precise Longman / Height = No
# FORMAT    : STATION / VALUE (mGal) / ERR (mGal) / DUR (s) / # REJ / X (Arc s) / Y (Arc s) / TEMP (mK)
# FORMAT    : ETC (mGal) / JUL DAY / TIME (mn) / DDMMYY / HHMMSS / UT-Local (h) / SC (mGal) / GRAV (mGal)
 BASE   3426.150 0.013  60   0   -8.4   -1.3  2.51  0.124 137  503.1000 170519 082306   0  0.000      0.0000
 BASE   3426.152 0.018  60   0   -7.8   -1.8  2.45  0.123 137  508.0333 170519 082802   0  0.000     -0.0002
 BASE   3426.154 0.010  60   0   -6.3   -1.3  2.44  0.123 137  509.0333 170519 082902   0  0.000      0.0024
 7002   3421.201 0.011  60   0   10.6   -4.5  2.61  0.120 137  519.4667 170519 083928   0  0.000     -4.9552
 7002   3421.209 0.012  60   0   10.0   -7.5  2.57  0.120 137  520.4667 170519 084028   0  0.000     -4.9470
... / ...
7015   3423.639 0.013  60   0   13.9  -17.2  2.54  0.007 137  688.3167 170519 112819   0  0.000     -2.6503
BASE   3426.311 0.016  60   0    3.2    -9.1  2.54 -0.011 137  709.1500 170519 114909   0  0.000      0.0024
BASE   3426.312 0.009  60   0    4.4  -13.4   2.52 -0.011 137  710.1500 170519 115009   0  0.000      0.0027
BASE   3426.313 0.017  60   0   -2.6   -7.7   2.47 -0.012 137  711.4333 170519 115126   0  0.000      0.0023
BASE   3426.314 0.009  60   0   -3.9  -13.2   2.46 -0.013 137  712.4333 170519 115226   0  0.000      0.0027
```

CG6TOOL Result file: R_<Observed File>

```
# INFO      : CG6TOOL 2022.12 (2022-12-01) - FIELD RESULT FILE
# CREATOR   : gabalda
# DATE      : Thu Nov 24 17:49:52 CET 2022
# GRAVIMETER : CG6 #18100125
# DATA      : Total = 37 / Used = 37 / Station = 15 / Reoccupation (DT>15mn) =  1
# CORRECTION : Earth Tide = Precise Longman / Height = No
# REFERENCE  : Station BASE (980041.400 mGal)
# DRIFT     : Value (mGal/Day) = 0.170 +/- 0.067 / Offset (mGal) = 0.003 +/- 0.003
#           : Standard Deviation (mGal) = 0.002 / Maximum Deviation (mGal) = 0.006
#           : Correlation = 95 %  /  Goodness-of-fit (Q) = 1.000 Believable
# FORMAT    : STATION / VALUE (mGal) / ERROR (mGal) / REITERATION / REOCCUPATION
 BASE 980041.4000 0.0010  7  1
 7002 980036.4465 0.0048  2  0
 7003 980036.4919 0.0040  3  0
 7004 980036.8292 0.0025  2  0
 7005 980037.2676 0.0025  2  0
 7006 980039.0663 0.0028  2  0
 7007 980042.0468 0.0031  2  0
 7008 980042.5147 0.0039  3  0
 7009 980036.5543 0.0026  2  0
 7010 980036.5085 0.0026  2  0
 7011 980037.3576 0.0026  2  0
 7012 980039.3811 0.0038  2  0
 7013 980041.7948 0.0026  2  0
 7014 980038.9337 0.0025  2  0
 7015 980038.7466 0.0025  2  0
```

And update CG6TOOL page.

<**PLOT**> and <**Advanced Graphic Parameters**> buttons will be available.



4. Drawing

The user can produce results graphics clicking the <**PLOT**> button. **CG6TOOL** uses the standard graphical and mathematical **Generic Mapping Tools** (GMT) free library to create well-documented plot files automatically generated by a script.

All the parameters are automatically calculated but it is possible to change them through the graphic interface clicking the <**Advanced Graphic Parameters**> button as well as through the script.

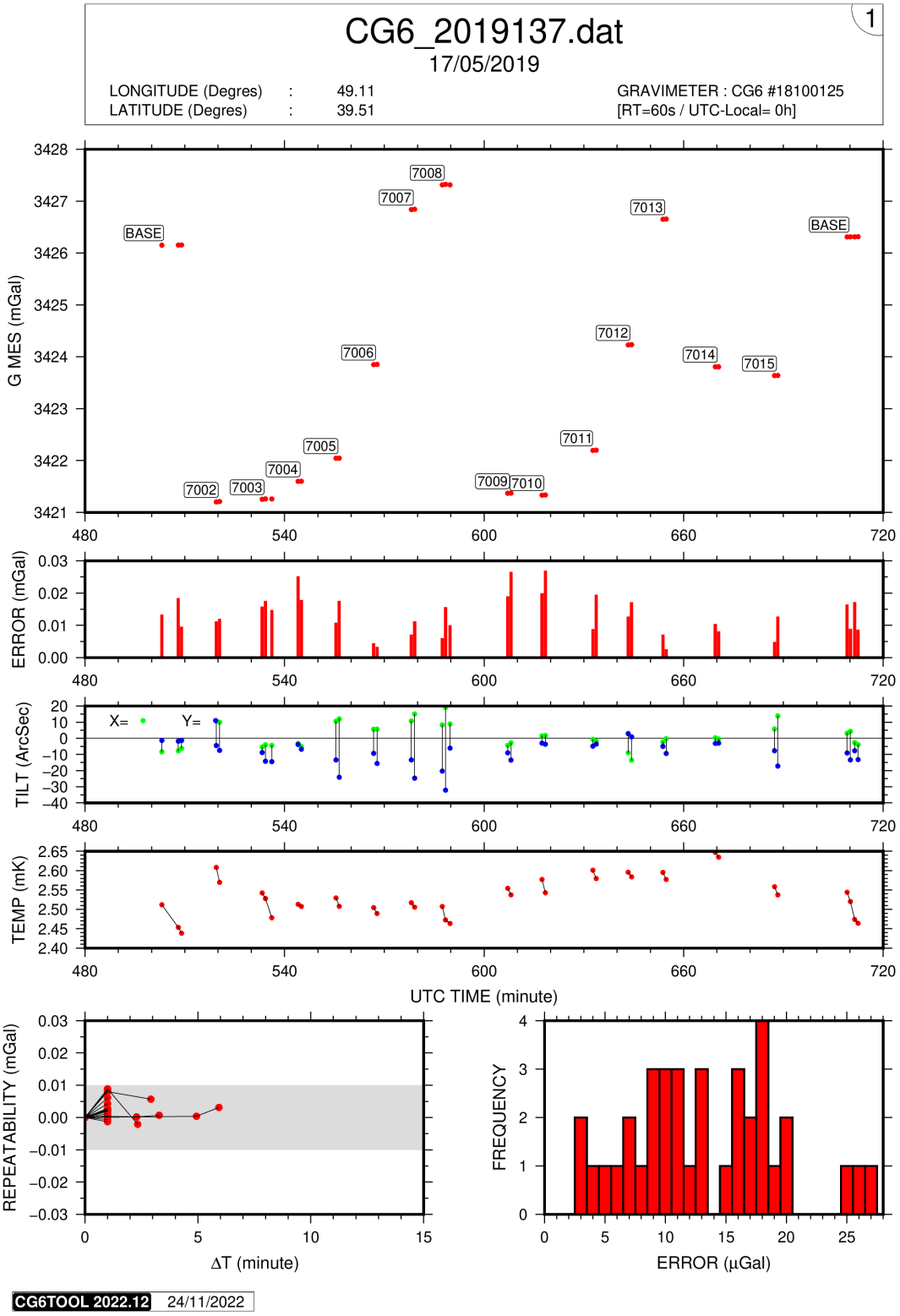
Indeed, this script created with a generic name expressed in the following form: _tmp_cg6tool_GMT_***o-file.ext*** where ***o-file*** is the raw data file and ***ext*** the extension file-name (**csh** under Linux and **bat** under Windows NT).

The script can also be customized by the user.

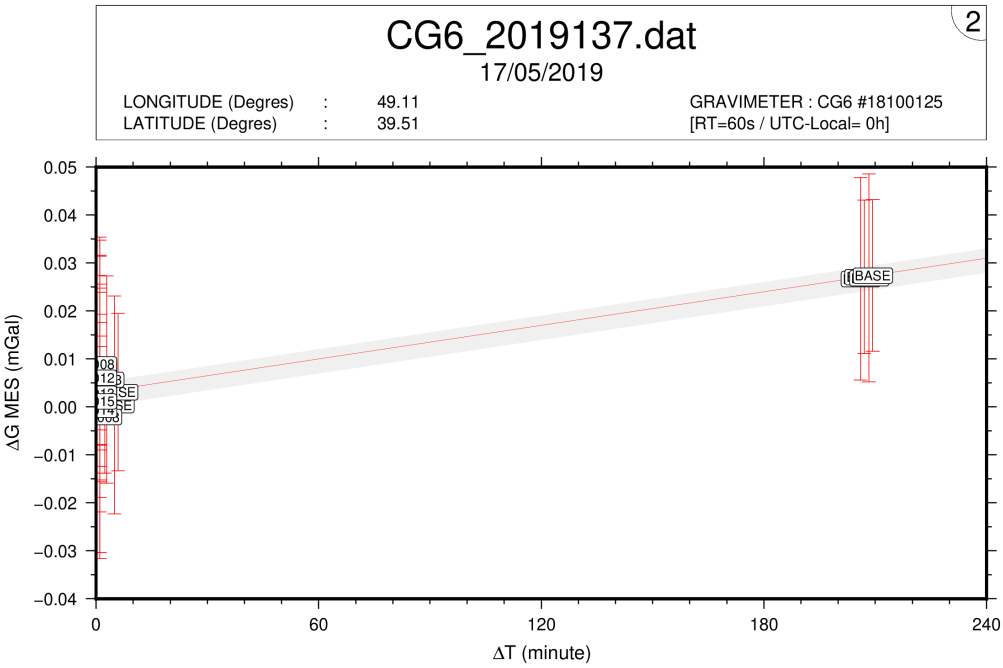
The script and all the temporary files used for the GMT drawing are stored in a temporary directory whose generic name is _tmp_***user_yyyy-mm-dd-hhnnss*** where ***user*** is the operator name, ***yyyy-mm-dd*** and ***hhnnss*** the script creation date and time.

This temporary directory can be saved by checking the checkbox "**To save temporary directory**".

The two (or three) output graphic files are automatically displayed using the viewer define by **CG6VIEWER** variable or according the extension (ext, jpg, png or pdf).

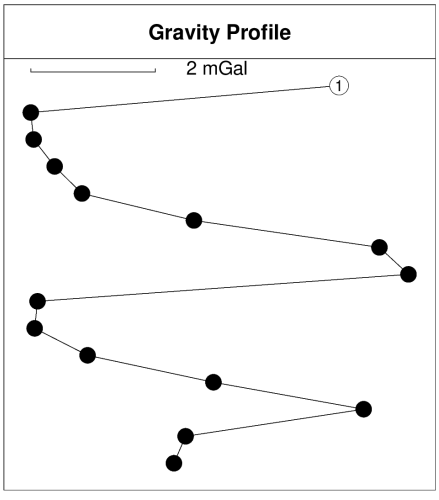


The first plot contains the time series related to a single gravity survey (corrected measures, error, tilts and temperatures). The repeatability of consecutive measurements and the histogram of the standard errors are also displayed for a quick evaluation of short-term repeatability and the noise level, respectively. General information on the survey are also displayed in the header.



DATA : Total = 37 / Used = 37 / Station = 15 / Reoccupation (DT>15mn) = 1
CORRECTION : Earth Tide = Precise Longman / Height = No
DRIFT : Value (mGal/Day) = 0.170 +/- 0.067 / Offset (mGal) = 0.003 +/- 0.003
: Standard Deviation (mGal) = 0.002 / Maximum Deviation (mGal) = 0.006
: Correlation = 95 % / Goodness-of-fit (Q) = 1.000 Believable

Station	Gravity (mGal)	Obs
BASE	980041.400 +/- 0.001	7
7002	980036.446 +/- 0.005	2
7003	980036.492 +/- 0.004	3
7004	980036.829 +/- 0.002	2
7005	980037.268 +/- 0.003	2
7006	980039.066 +/- 0.003	2
7007	980042.047 +/- 0.003	2
7008	980042.515 +/- 0.004	3
7009	980036.554 +/- 0.003	2
7010	980036.509 +/- 0.003	2
7011	980037.358 +/- 0.003	2
7012	980039.381 +/- 0.004	2
7013	980041.795 +/- 0.003	2
7014	980038.934 +/- 0.002	2
7015	980038.747 +/- 0.002	2



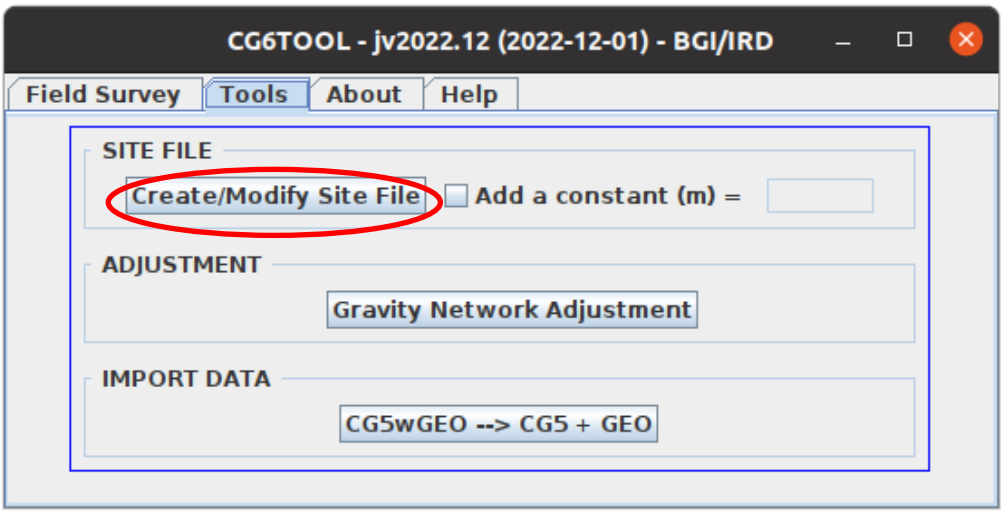
CG6TOOL 2022.12 24/11/2022

The second Plot file displays the final gravity value computed for each site after the user-defined corrections have been applied. The upper graph shows the actual values of the repeated measurements at the same locations and the best model of the instrument drift obtained by a linear least-squares fitting of the observed data. Statistics and solutions for the drift model are provided to evaluate the goodness of fit and the data quality. The lower graph contains the table of the mean corrected gravity value for each station with the corresponding gravity profile.

CG6TOOL allows correcting the height variations in the instrument leveling or for reducing the height to benchmark level.

This correction uses a site file (one ***s-file*** by o-file) which can be created in the "**Tools**" tab. It contains the following information:

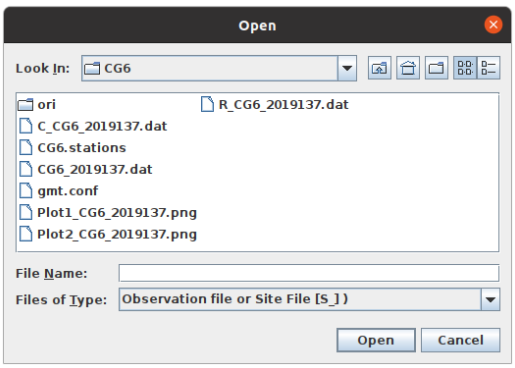
- ✓ Station name
- ✓ Date
- ✓ Time (hh:mm)
- ✓ Height (m)



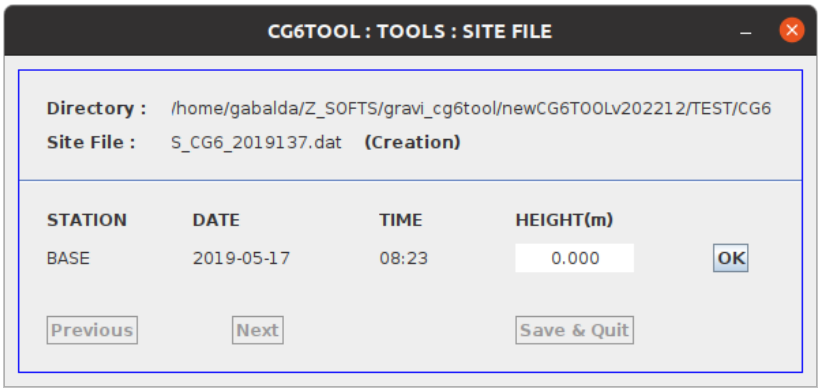
At this step, three options are possible:

- **Create** a s-file from an observation file with different height values for each station
- **Modify** an existing s-file
- **Create** a s-file from an observation file with the same height value for all station

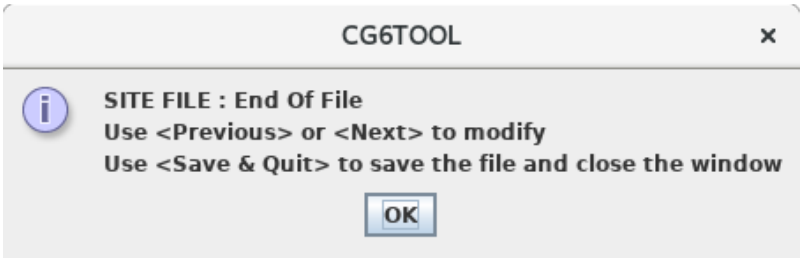
1. **Creation of new s-file with different height values for each station**
   - Click on the <**Create/Modify Site file**> button and select ***o-file***.



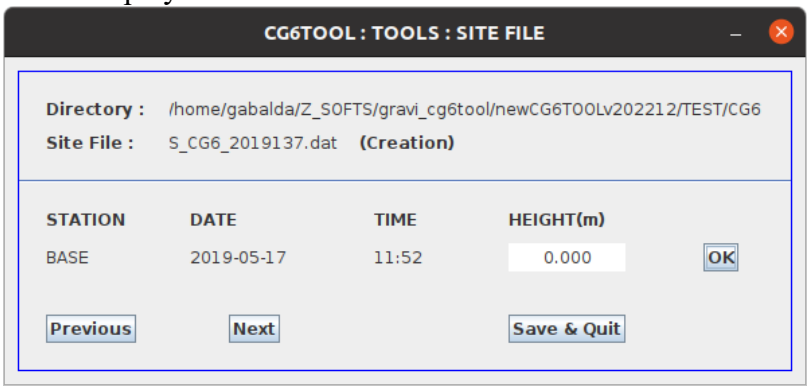
   - Provide a valid height value for each measurement and valid with **OK** button.



   - The end of the o-file is notified after the last measurement



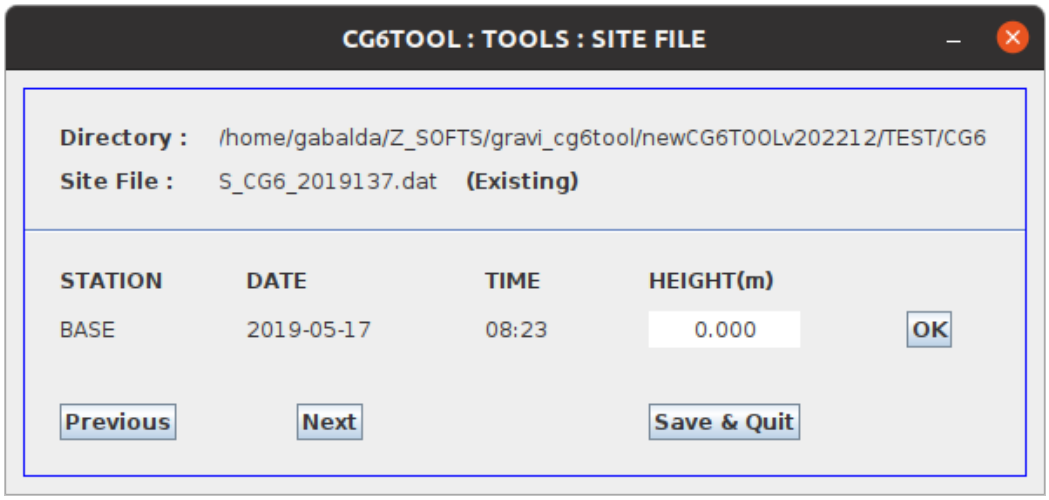
   - At this step all the entered height values can be changed. Press **Previous** or **Next** buttons to display the measurements and **OK** button to validate.



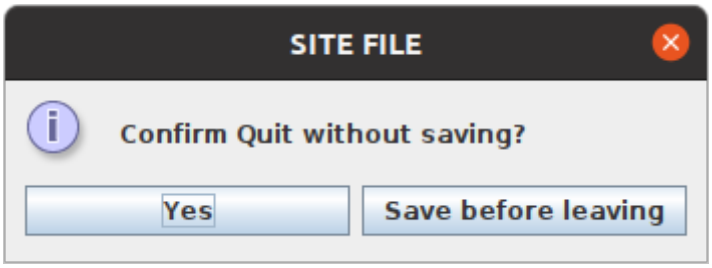
   - Do not forget to save the site file before leaving with **Save & Quit**

2. Modification of old s-file

- Click on the <**Create/Modify Site file**> button and select ***s-file***.

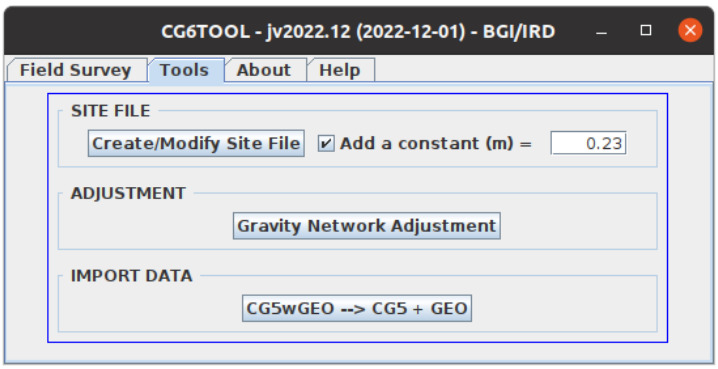


- At this step all the entered height values can be changed. Press **Previous** or **Next** buttons to display the measurements and **OK** button to validate.
- Do not forget to save the site file before leaving with **Save & Quit**
- If you quit without saving, the following dialog box is displayed to confirm the choice:

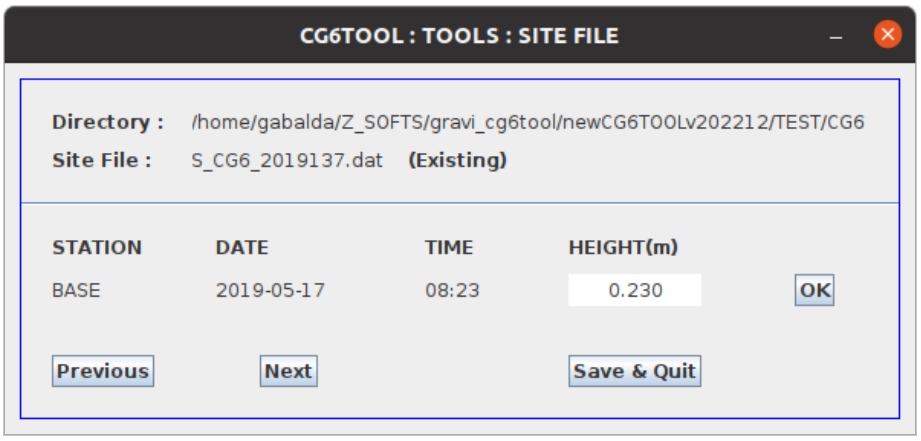


3. Creation of new s-file with the same height value for all stations

- Check <**Add a constant (m)**> and initialize the field with a correct value



- Click on the <**Create/Modify Site file**> button and select ***o-file***.



- The same value entered (here 0.23m) is assigned to all observations.
- **Previous** and **Next** are used to scan all the heights entered, which can be modified again and then validated by **OK**.
- If a height is modified without validation, a confirmation is requested:

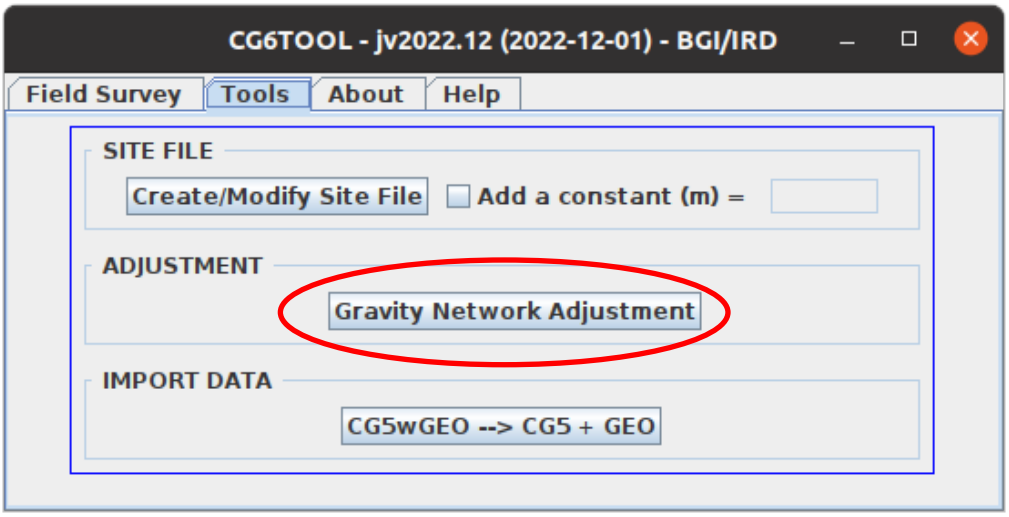
- As before, **Save & Quit** button to save the file.

With the aim to bring together a large number of observations acquired during survey using one or several instruments **CG6TOOL** include an adjustment program.

The program is designed to estimate the gravity values at each site connected by relative measurements using one or several instruments. It requires processed data files (***c-file*** or ***r-file***) containing the reduced gravity observations (earth tide, instrumental drift and optionally height corrections) and also one (or more) ***absolute value***.

In order to compute the free-air and simple Bouguer anomaly in various reference systems (IAG80, IGSN71 or Potsdam 1930) and also to create maps a ***coordinates file is needed***.

This program "**Gravity Network Adjustment**" is available in the "**Tools**" tab



1. **Configuration file : *config-file***

   In order to process an adjustment, CG6TOOL needs to load a configuration file. This text file must be created by the user with the name extension "**config**".

   It provides all the information necessary for the adjustment data.

   - Each command is recognized by the **keyword** at the beginning of the line. They must begin in column one and the keywords answers must begin after one or several blank.
   - The order of the commands in the file is not important.
   - The character "**#**" is used in order to disable a keyword or comment a line.
   - Only two keywords are required to adjust data:
     - ✓ **IRELFIL** *full filename* CG6TOOL c-file or r-file file
     - ✓ **ABSOLUT** *number measure error* Absolute station
   - Two others keywords are required to create maps and compute anomalies:
     - ✓ **IPOSFIL** *full filename* Coordinates filename
     - ✓ **IPOSFMT** *n sta lon lat alt [tc] lonlat_unit alt_unit [tc_unit]* Format

   See below for a complete list of keyword and the chapter "**POSITION FILE**" for more explanation about the coordinates file format.

2. Keywords used in the configuration file

Below we consider that the "config" full filename is: **dir/gna.config**.

The code entered in the last column below indicates the maximum possible number of occurrences of the keyword: unique (1) or several (n)

In [**bold**], the default value

2.1. Network Information

✓	**COMMENT**	***text***	Commentary used as a title in the drawing	1
✓	**REPORT**	***filename***	Output report filename [**dir/gna.pdf** by default]	1

2.2. Input Information

✓	**IRELFIL**	***filename***	CG6TOOL c-file or r-file	**N**
✓	**IPOSFIL**	***filename***	Coordinates file	**1**
✓	**IPOSFMT**	***n1 i2 i3 i4 i5 fmt1 fmt2***	Coordinates file format	**1**
✓	**ABSOLUT**	***station measure error***	Absolute station parameters	**N**
✓	**GRAVPAR**	***serialnumber scalingfactor***	Gravimeter parameters	N

2.3. Adjustment Information

✓	**OADJFIL**	***rootname***	Root of the result file name [**dir/gna** by default]	1
✓	**ADJNSIG**	***filter***	To keep only residues less than **ADJNSIG** x σ	1

2.4. Free-air and Bouguer anomalies

✓	**ANODENS**	***density***	Mean density of the earth's crust (g/cm^3) [2.67 by default]	1
✓	**ANOGRAD**	***gradient***	Vertical gradient of gravity (mGal/m) [0.3086 by default]	1
✓	**ANOGEOS**	***system***	Geodetic system (IAG8, IGSN71, POTS30) [IAG80 by default]	1

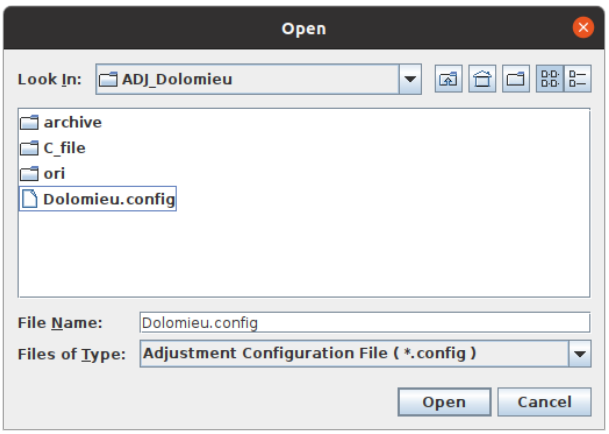
2.5. Drawing Information

✓	**PLOTCMD**	***script***	script name used to draw [**dir/gna.csh or .bat** by default]	1
✓	**PLOTFIL**	***rootname***	Root of the graphic files [**dir/gna** by default]	1
✓	**PLOTREG**	***w e s n***	Coordinates of the data region	1
✓	**PLOTSFK**	***flag***	To plot the scaling factor k (0=No/1=Yes) [1 by default]	1
✓	**PLOTERR**	***flag***	To plot the errors (0=No/1=only post/2=all) [2 by default]	1
✓	**PLOTRES**	***flag***	To plot the residues (0=No/1=extremes/2=all) [2 by default]	1
✓	**PLOTFAA**	***flag***	Flag to plot the free-air anomaly (0=No/1=Yes) [1 by default]	1
✓	**PLOTBGA**	***flag***	Flag to plot the Bouguer anomaly (0=No/1=Yes) [1 by default]	1
✓	**PLOTANO**	***size***	Anomaly square size in .gmtdefault unit [1.0 by default]	1
✓	**GCPTFAA**	***table***	Free-air GMT Color palette [**dir/gna_haxby_faa.cpt** by default]	1
✓	**GCPTBGA**	***table***	Bouguer GMT Color palette [**dir/gna_haxby_bga.cpt** by default]	1
✓	**CONTFAA**	***flag [Aannot] [Ccont]***	To specify the free-air contour [1 by default]	1
✓	**CONTBGA**	***flag [Annot] [Ccont]***	To specify the Bouguer contours [1 by default]	1
✓	**BOUGUER**	***type***	S(imple) or (Complete) [1 by default]	1

3. Configuration file loading

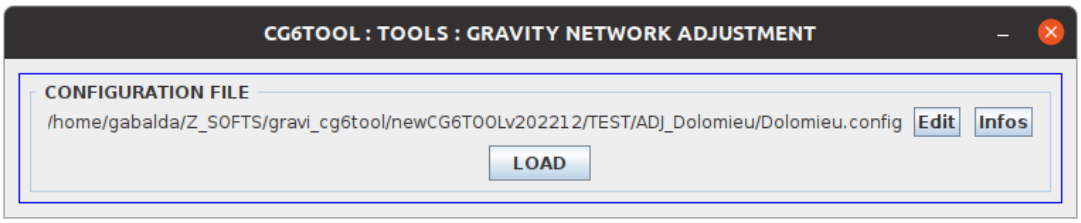
3.1. Select the configuration file

- Click the <**Gravity Network Adjustment**> button and select a ***config-file***.



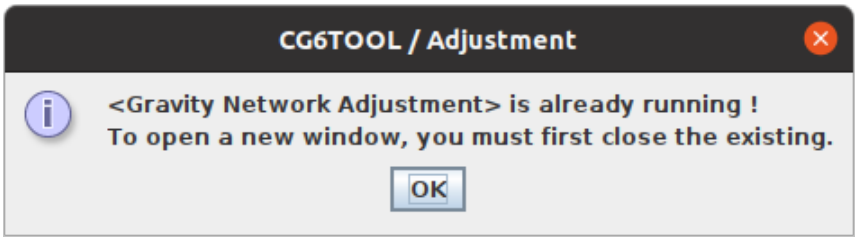
As soon as a file is selected, information about the processing is saved in a **log file** whose generic name is CG6TOOL_ADJ_***user_yyyy-mm-dd-hh***h***nn***m***ss***s.log where ***user*** is the operator name, ***yyyy-mm-dd*** and ***hhnnss*** the creation date and time.

CG6TOOL provide a new window:

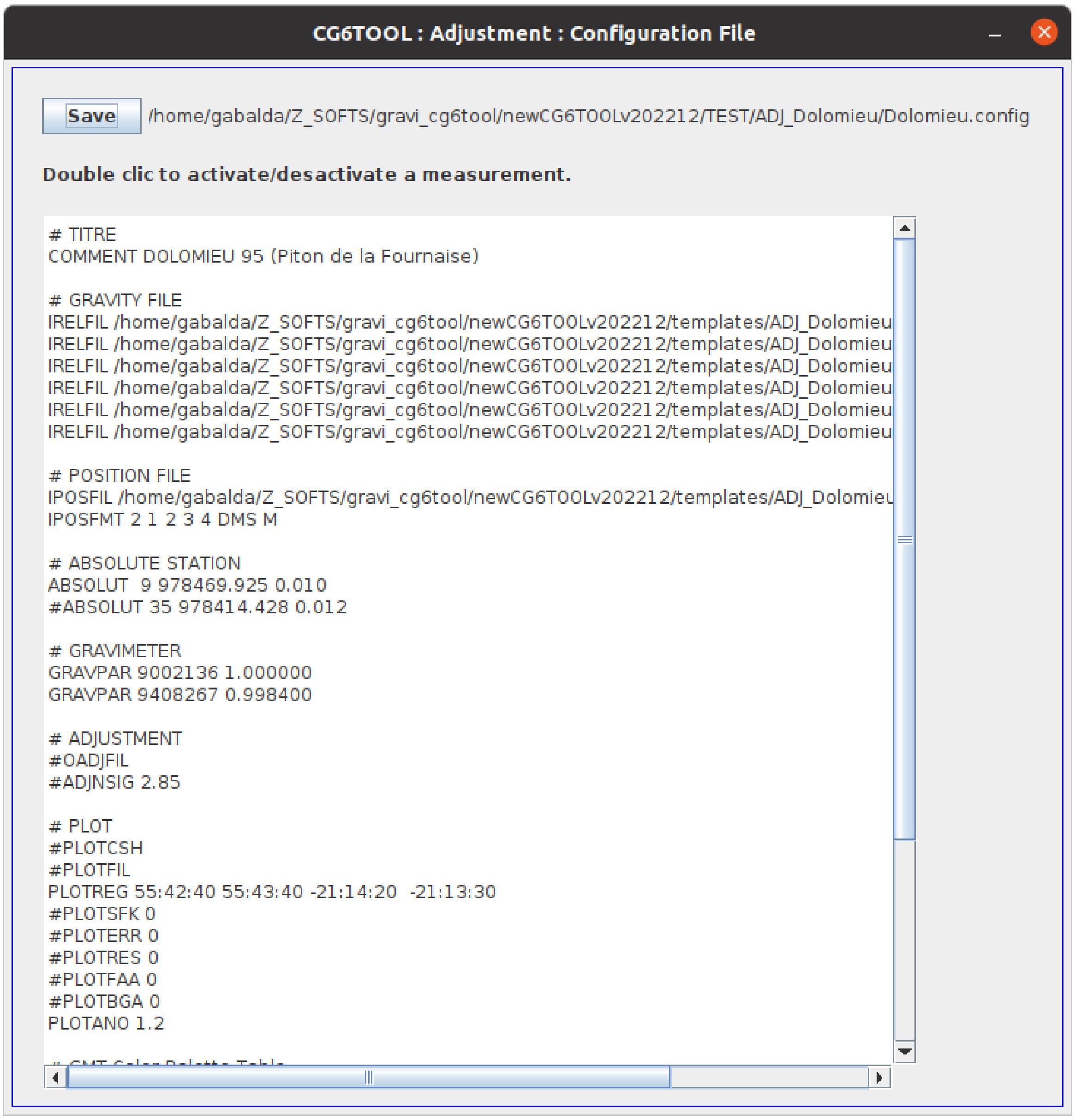


- At this step, three possibilities are proposed:
  - ✓ To edit the configuration file which name is displayed (<**Edit**> button)
  - ✓ To display information about the usable keywords (<**Infos**> button)
  - ✓ To load and verify the configuration file (<**LOAD**> button)

- From now CG6TOOL does not allow to run a new adjustment by clicking <**Gravity Network Adjustment**> button.

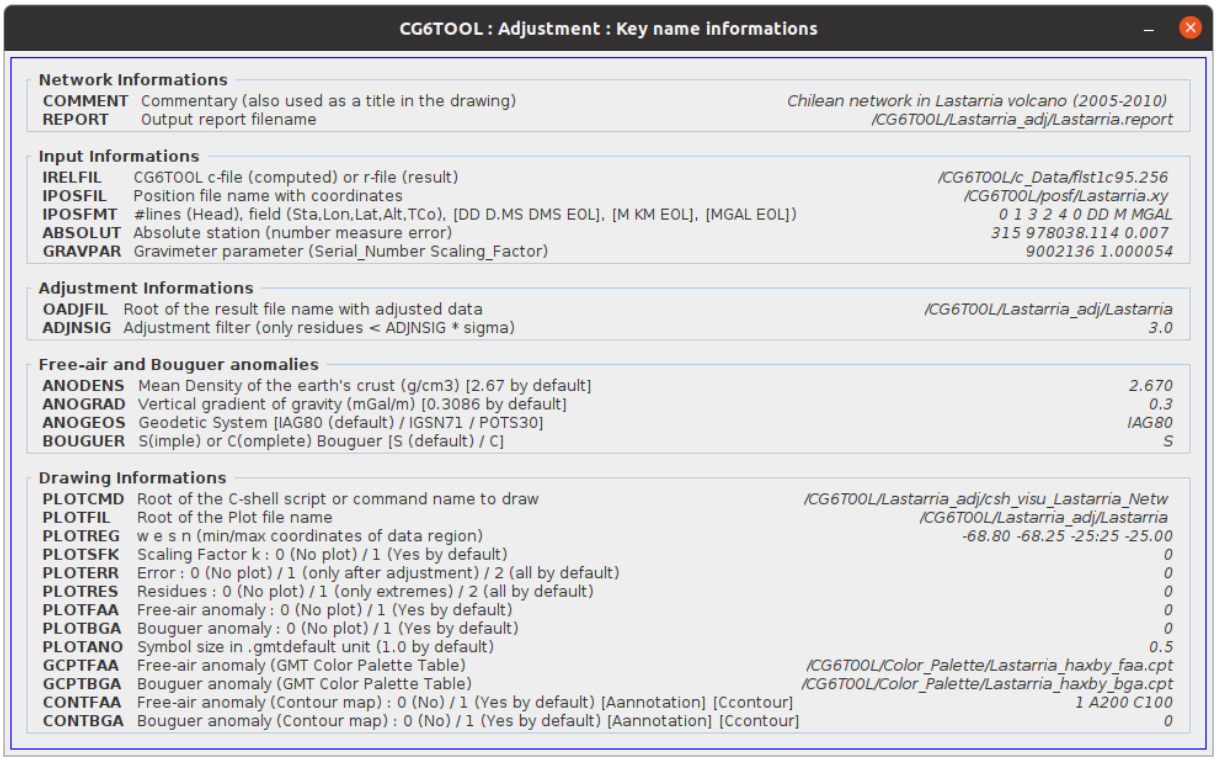


3.2. Edit the configuration file



- ❖ In the editor, **double click** on a line to deactivate/activate a keyword. When a keyword is deactivate (or missing) the default value is used.
- ❖ **Save** button to keep the modifications

3.3. Display the information about the keywords



On the first column the **keyword** written in bold
Then some explanations of the usefulness of the keyword
At the end of the line, an example of the used

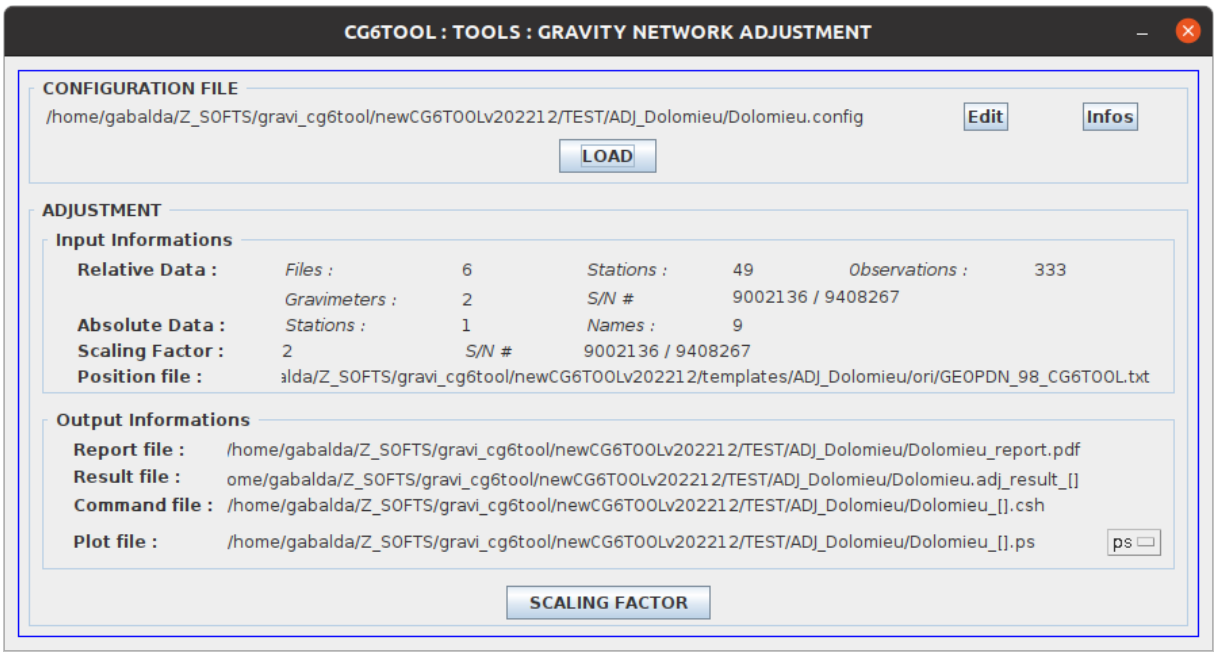
Only these keywords are “understood” by CG6TOOL

3.4. Load the configuration file

Click on <**OK**> button to process. CG6TOOL reads the *config-file*, verifies the keywords and load all the data. At this step, if the keywords used to initialize the file names are missing, CG6TOOL will provide a message:

If the user is agree to continue, the graphic interface is updated with all the known information about the data to be adjusted.

From now if the *config-file* is edited and saved, CG6TOOL makes disappear these information and it is necessary reload the data by clicking **LOAD** button.

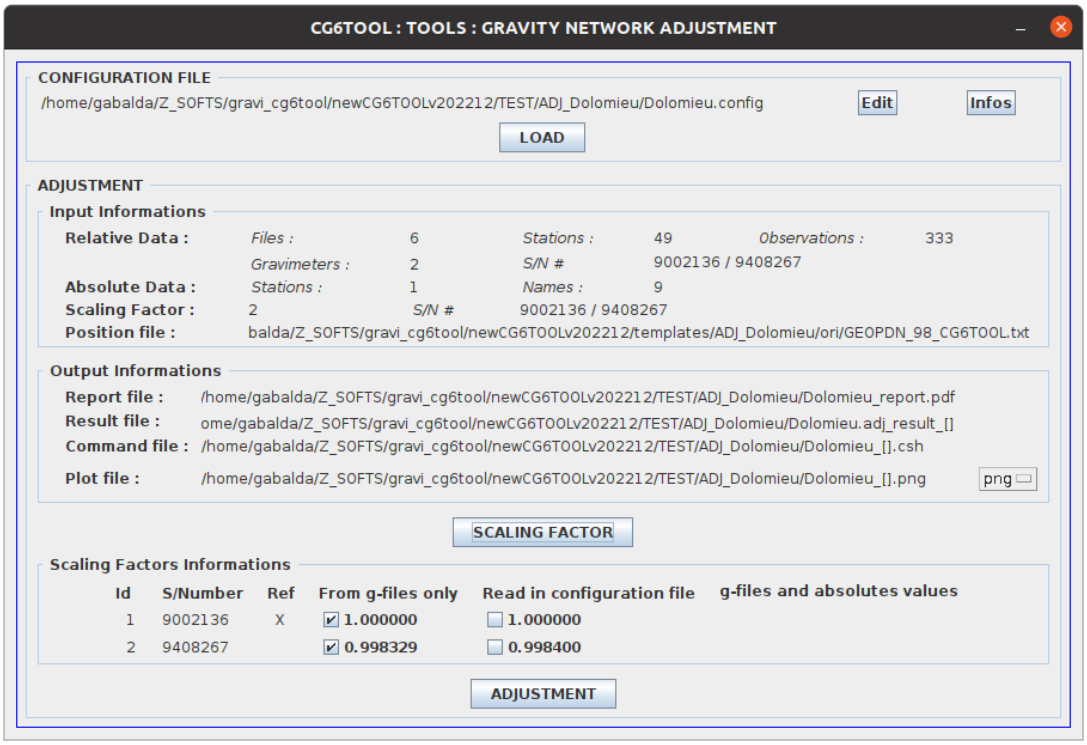


4. Scaling Factor

Click on <**SCALING FACTOR**> button to continue the processing.
CG6TOOL updates the graphic interface with information about scaling factors:

- Calculated with the relative data only if more than one gravimeter is used and if there are common stations.
- Read from the *config-file* (keyword **GRAVPAR**)
- Calculated with relative and absolute data (keyword **ABSOLUT**)

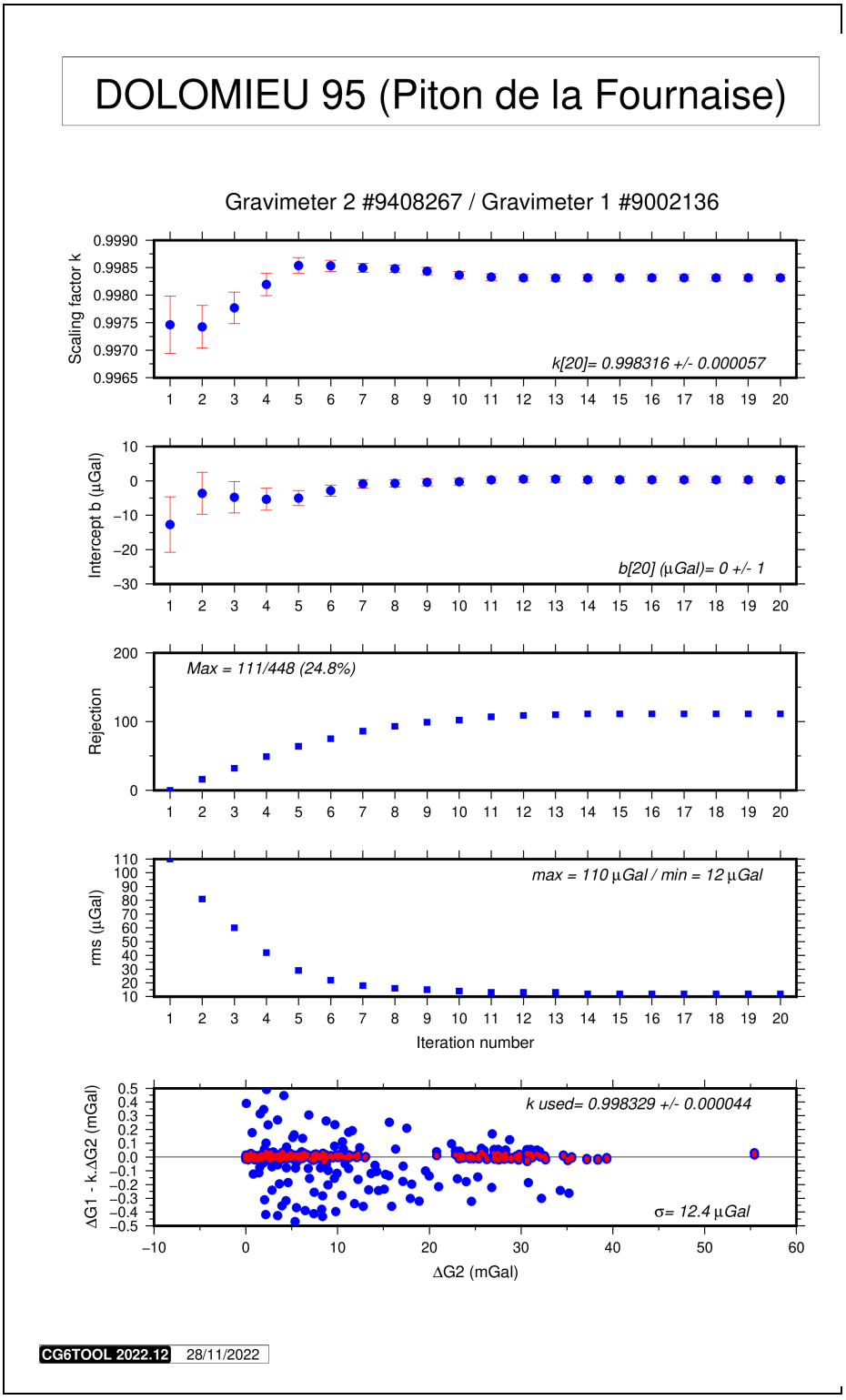
The correction factors of the gravity meters with respect to the primary instrument (if exist) read from the *config-file* or from the instrument used in the first relative file (**IRELFIL**) are determined by a least-square adjustment procedure.



To help the Scaling factors choice used in the adjustment, CG6TOOL will produce graphic files (using GMT library) automatically generated by a script.

Scripts and grafic files are created with a generic name expressed in the following form: ***gna***_sf_Gc***snc***vsGr***snr***.***ext*** where ***gna***, ***snc***, ***snr*** and ***ext*** *are* the configuration base name file, the serial number of the calibrated instrument, the serial number of the reference instrument and the extension (csh, bat, ext, jpg, png ou pdf), respectively. The script can also be customized by the user.

- ❖ These files are not created if **PLOTSFK** keyword value is zero
- ❖ A star (*) after a scaling factor indicate than the hypothesis (***Intercept equal to zero***) has been rejected with a significance level of 5% (Student Test).



This plot contains the successive parameters of the correction factor of the gravity meter #9408267 with respect to the instrument #90023136 (scaling factor, intercept, number of rejection and rms). Twenty iterations are calculated and the data outliers (***residual greater than 3 standard deviation***) are rejected.
The lower graph contains the result of applying the final scaling factor calculated with an intercept equal to zero.
For the red dots, the residual is less than 3 standard deviation.

5. Adjustment

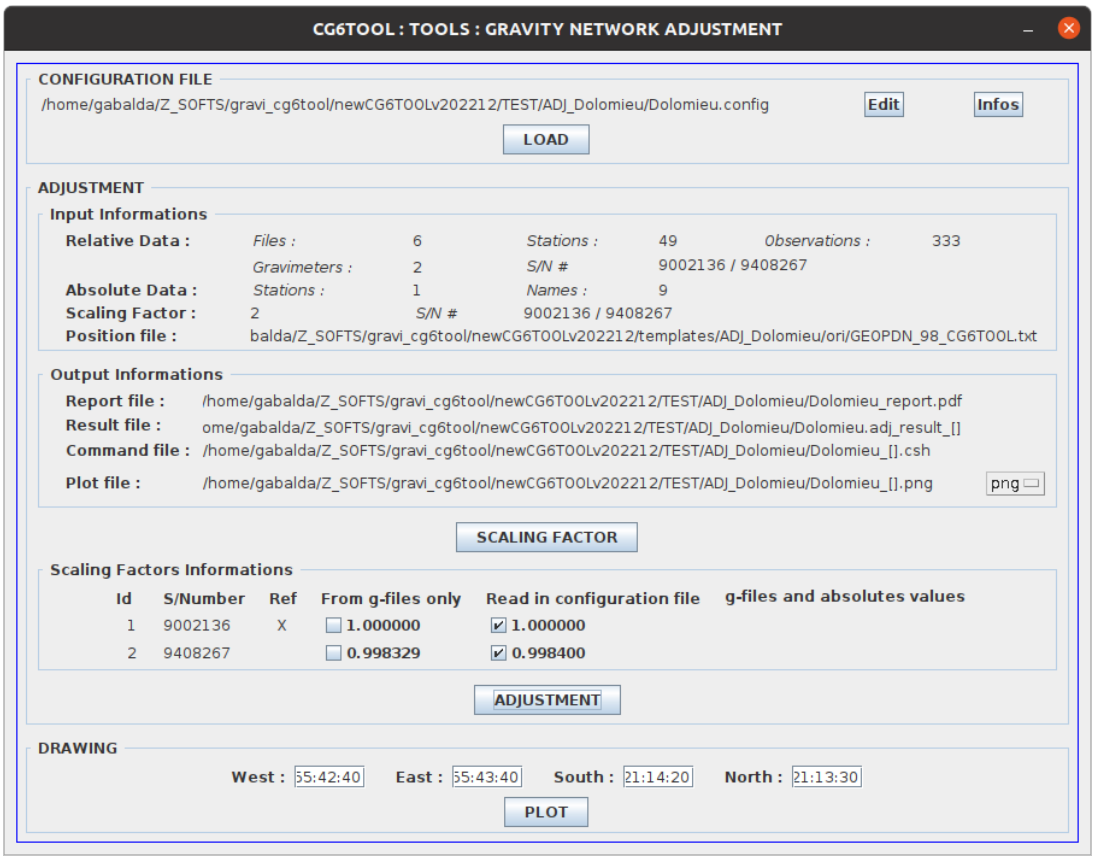
Click on <**ADJUSTMENT**> button to continue the processing.

- Gravity data are adjusted (one, two or three iterations)
  - ✓ Only one iteration if CG6TOOL can provide an gravity value for each station of the network before the adjustment
  - ✓ Two iteration when a first initialization adjustment is necessary
  - ✓ Another iteration is realized if **ADJNSIG** keyword is defined

- Adjusted file is created (*see below*)
  - ✓ The adjusted data filename has a generic name : ***adjfile***.adj_result_***filter*** where ***adjfile*** is **OADJFIL** value (or ***gna*** by default) and ***filter*** is "nofilter" or "filtered" (if **ADJNSIG** value)

CG6TOOL can display an information windows if **PLOTREG** defines a region smaller than the region defined by the data:

- The graphic interface is updated with the region of interest:



CG6TOOL adjusted file: Dolomieu.adj_result_nofilter

```
#  INFO      : CG6TOOL 2022.12 (2022-12-01) - ADJUSTMENT RESULT FILE
#  CREATOR    : gabalda
#  DATE      : Mon Nov 28 16:48:21 CET 2022
#  LOG FILE   : /home/gabalda/Z_SOFTS/gravi_cg6tool/CG6TOOLv202212/ADJ_Dolomieu/CG6TOOL_ADJ_gabalda_2022-11-28-15h53m42s.log
#  CONFIGURATION FILE
# /home/gabalda/Z_SOFTS/gravi_cg6tool/CG6TOOLv202212/ADJ_Dolomieu/Dolomieu.config
#  ADJUSTMENT
# Input informations
#   - Relative Data : Files# 6 / Gravimeters# 2 / Stations# 49 / Observations# 333
#   - Absolute Station : 1 [9]
#   - Gravimeter used:  [s/n 9002136][s/n 9110193]
#   - Position file : /home/gabalda/Z_SOFTS/gravi_cg6tool/CG6TOOLv202212/ADJ_Dolomieu/ori/Reseau_GEOPDN_98
# Output informations
#   - Result file  : /home/gabalda/Z_SOFTS/gravi_cg6tool/CG6TOOLv202212/ADJ_Dolomieu/ori/Dolomieu.adj_result_nofilter
#   - Script file  : /home/gabalda/Z_SOFTS/gravi_cg6tool/CG6TOOLv202212/ADJ_Dolomieu/ori/Dolomieu_[].csh
#   - Graphic file : /home/gabalda/Z_SOFTS/gravi_cg6tool/CG6TOOLv202212/ADJ_Dolomieu/ori/Dolomieu_[].ps
# Absolute station informations
#   - Station 9 = 978469.9250 +/- 0.0100 mgal
# Scaling Factors informations
#   - Meter #1 [s/n 9002136] 1.000000   <-- read in configuration file     (Reference)
#   - Meter #2 [s/n 9110193] 0.998400   <-- read in configuration file
# Result informations
#   - Root-Mean-Square residual : 0.040 mGal
#   - Filter : No
#   - Errors (mGal)   : Min= 0.009  /  Max= 0.033  /  Mean= 0.025
#   - Residues (mGal) : Min= -0.117  /  Max= 0.251  /  Mean= 0.001
#
# FREE-AIR & BOUGUER
#   - Mean density      : 2.670 g/cm3
#   - Vertical gradient : 0.3086 mGal/m
#   - Geodetic system   : IAG 1980
#   - Bouguer anomaly   : Simple
#   - free-air anomaly (mGal) : Min= 475.986  /  Max= 493.1592  /  Mean= 487.348
#   - Bouguer anomaly (mGal)  : Min= 196.080  /  Max= 223.977  /  Mean= 209.525
#
# FORMAT : Gravity, Error, Free-air, Bouguer (mGal), Coordinates (DD, m)
#  Sta     Gravity   Error   Reit    Longitude    Latitude  Altitude Free-air  Bouguer
# ================================================================================
550  978416.0095 0.0120     6   55.7219647 -21.2278319  2520.000  483.734  201.645
551  978417.7471 0.0229     4   55.7196333 -21.2275817  2525.500  487.184  204.479
552  978411.4271 0.0217     4   55.7178622 -21.2284867  2557.600  490.715  204.417
553  978405.3228 0.0216     4   55.7158503 -21.2294914  2585.500  493.159  203.738
554  978388.9882 0.0197     5   55.7131353 -21.2307136  2630.000  490.483  196.080
…/…
529  978430.6556 0.0282     5   55.7238125 -21.2340617  2469.470  482.407  205.974
520  978431.6287 0.0227     8   55.7248803 -21.2328953  2461.070  480.859  205.366
519  978434.8900 0.0266     5   55.7240517 -21.2327336  2459.560  483.664  208.340
518  978437.3177 0.0306     4   55.7229053 -21.2327619  2461.230  486.605  211.095
34   978417.9166 0.0297     2   55.7205872 -21.2278153  2519.660  485.537  203.486
```

6. Drawing

CG6TOOL can produce results graphics clicking the <**PLOT**> button. CG6TOOL uses the standard graphical and mathematical **Generic Mapping Tools** (GMT) free library to create graphic files automatically generated by scripts that can be customized by the user. The generic script name is ***cshfile_type.ext*** where ***cshfile*** is **PLOTCMD** value (or ***gna*** by default) and ***ext*** is *csh* (Linux) or *bat* (Windows). See below for the different ***type*** values

West, east, south and north specify the map limits and the user may specify them in **decimal degrees** or in **D:M:S** (degrees, minute and second) format.

By default CG6TOOL will produce:

- 9 graphic files. The generic name is ***plotfile_type.ext*** where ***plotfile*** is **PLOTFIL** value (or ***gna*** by default) and ***ext*** the graphic format (ext, jpg, png or pdf).
  - ✓ ***plotfile***_info_histo.ext : Information and histogram (*see figure 6.1*)
  - ✓ ***plotfile***_err_raw.***ext*** : Network with errors bars (before adjustment) (*see figure 6.2*)
  - ✓ ***plotfile***_err_adj.***ext*** : Network with errors bars (after adjustment) (*see figure 6.3*)
  - ✓ ***plotfile***_res_max.***ext*** : Network with residues extremes (*see figure 6.4*)
  - ✓ ***plotfile***_res_mean.***ext*** : Network with residues means (*see figure 6.5*)
  - ✓ ***plotfile***_faa_dot.***ext*** : Network with free-air anomaly (point) (*see figure 6.6*)
  - ✓ ***plotfile***_faa_grd.***ext*** : Network with free-air anomaly (grid) (*see figure 6.7*)
  - ✓ ***plotfile***_bga_dot.***ext*** : Network with simple Bouguer anomaly (point) (*see figure 6.8*)
  - ✓ ***plotfile***_bga_grd.***ext*** : Network with simple Bouguer anomaly (grid) (*see figure 6.9*)

- 2 grid files. The generic name is ***gna***_[faa,grd].grd where ***gna*** is the base name of the configuration file.
  - ✓ ***gna***_faa.grd : grid file created with the GMT command ***surface*** and free-air data
  - ✓ ***gna***_bga.grd : grid file created with the GMT command ***surface*** and Bouguer data

- 2 GMT Color Palette Table. The generic name is ***gna***_haxby_[faa,grd].cpt.
  - ✓ ***gna***_haxby_faa.cpt : cpt file created with the GMT command ***makecpt*** and free-air data
  - ✓ ***gna***_haxby_bga.cpt : cpt file created with the GMT command ***makecpt*** and Bouguer data

- ❖ Maps with errors are not created if **PLOTERR** keyword value is zero
- ❖ Maps with residues are not created if **PLOTRES** keyword value is zero
- ❖ Maps with free-air are not created if **PLOTFAA** keyword value is zero
- ❖ Maps with Bouguer are not created if **PLOTBGA** keyword value is zero

- ❖ Free-air CPT file is not created if **GCPTFAA** keyword is used
- ❖ Bouguer CPT file is not created if **GCPTBGA** keyword is used
- ❖ No «**free-air**» levels (gridded values) if **CONTFAA** keyword value is zero
- ❖ No «**Bouguer**» levels (gridded values) if **CONTBGA** keyword value is zero

DOLOMIEU 95 (Piton de la Fournaise)

Survey adjustment results

Input data

- Relative Data : Files# 6 / Gravimeter# 2 / Stations# 49 / Observations# 333
- Absolute Station : 1 [9]
- Gravimeter used : [s/n 9002136][s/n 9408267]

Scaling Factors

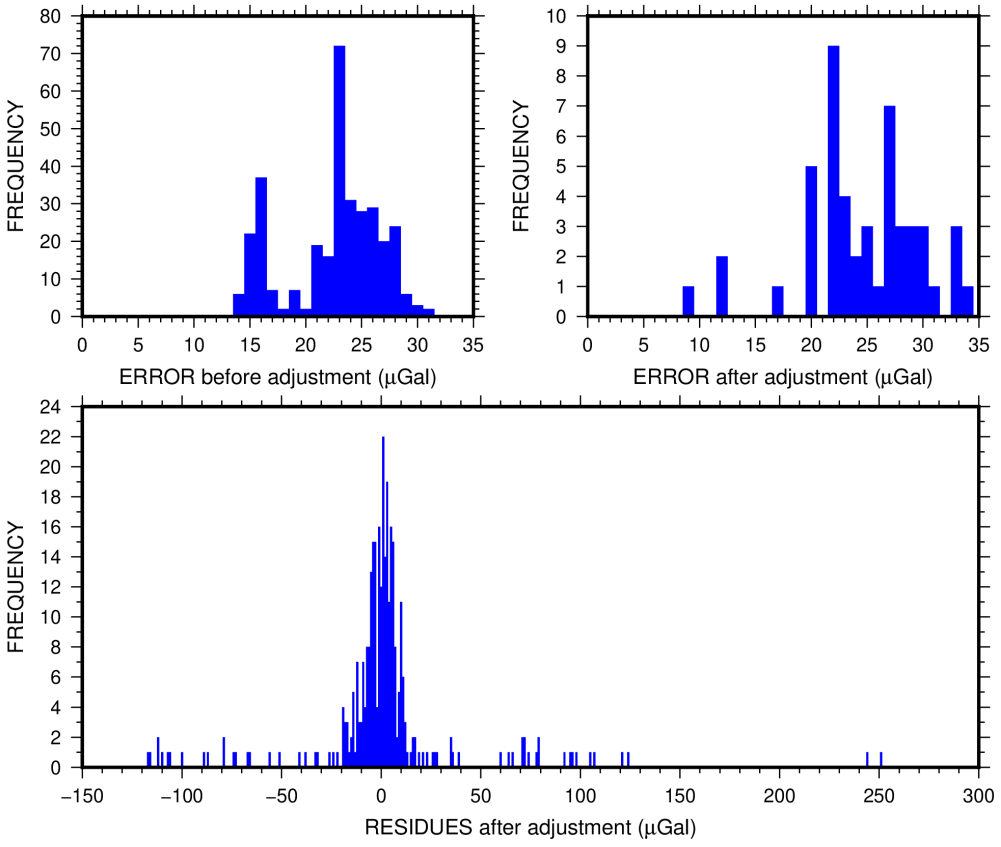
- Meter #1 [s/n 9002136] 1.000000 :-- read in configuration file (Reference)
- Meter #2 [s/n 9408267] 0.998400 :-- read in configuration file

Absolute station used :

- Station 9 = 978469.9250 +/- 0.0100 mGal

Adjustment errors (mGal) : Min= 0.009 / Max= 0.034 / Mean= 0.025

Adjustment residues (mGal) : Min= -0.117 / Max= 0.251 / Mean= 0.001



CG6TOOL 2022.12 28/11/2022

Figure 6.1: Information and histogram

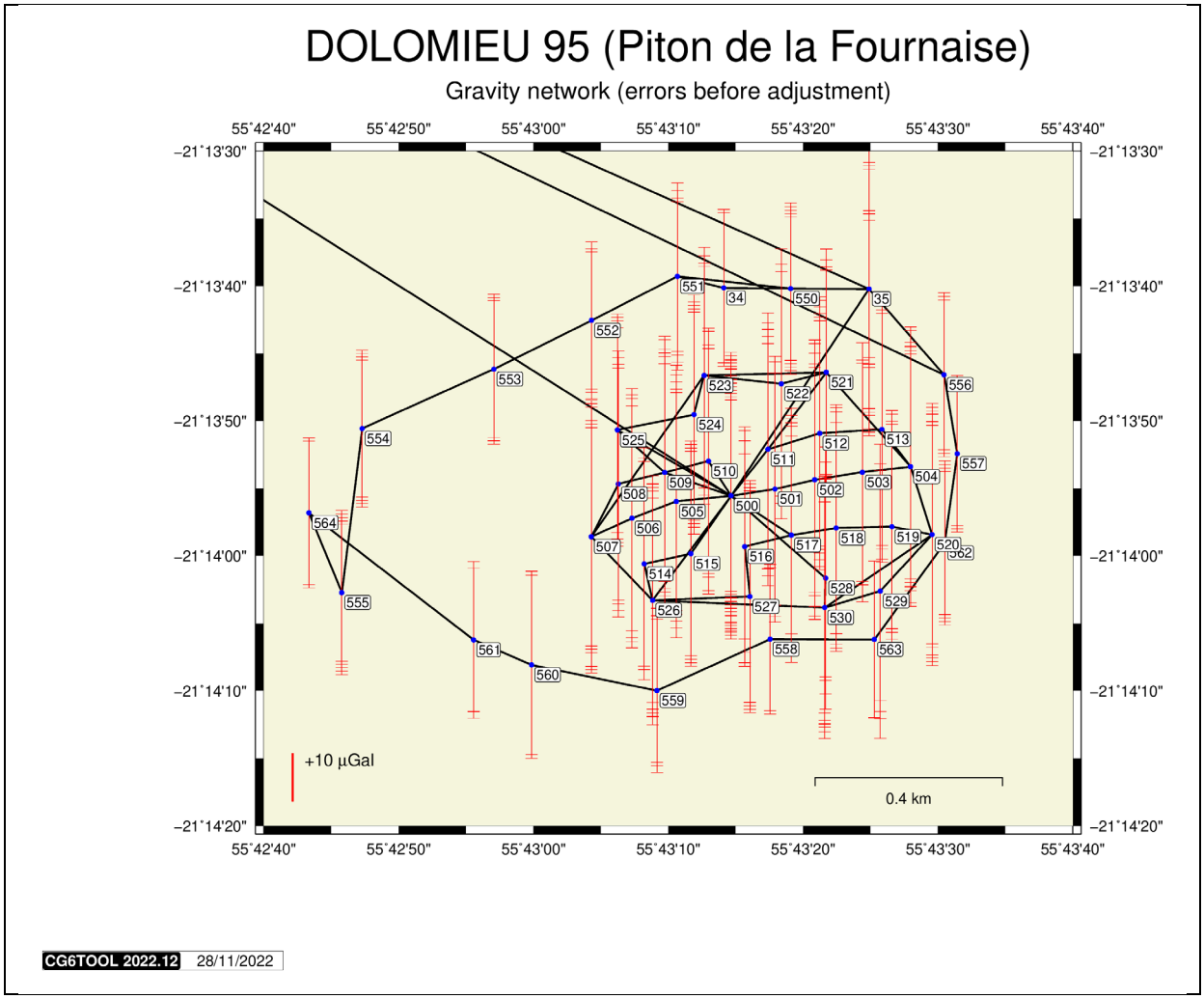


Figure 6.2: Network with errors bars (before adjustment)

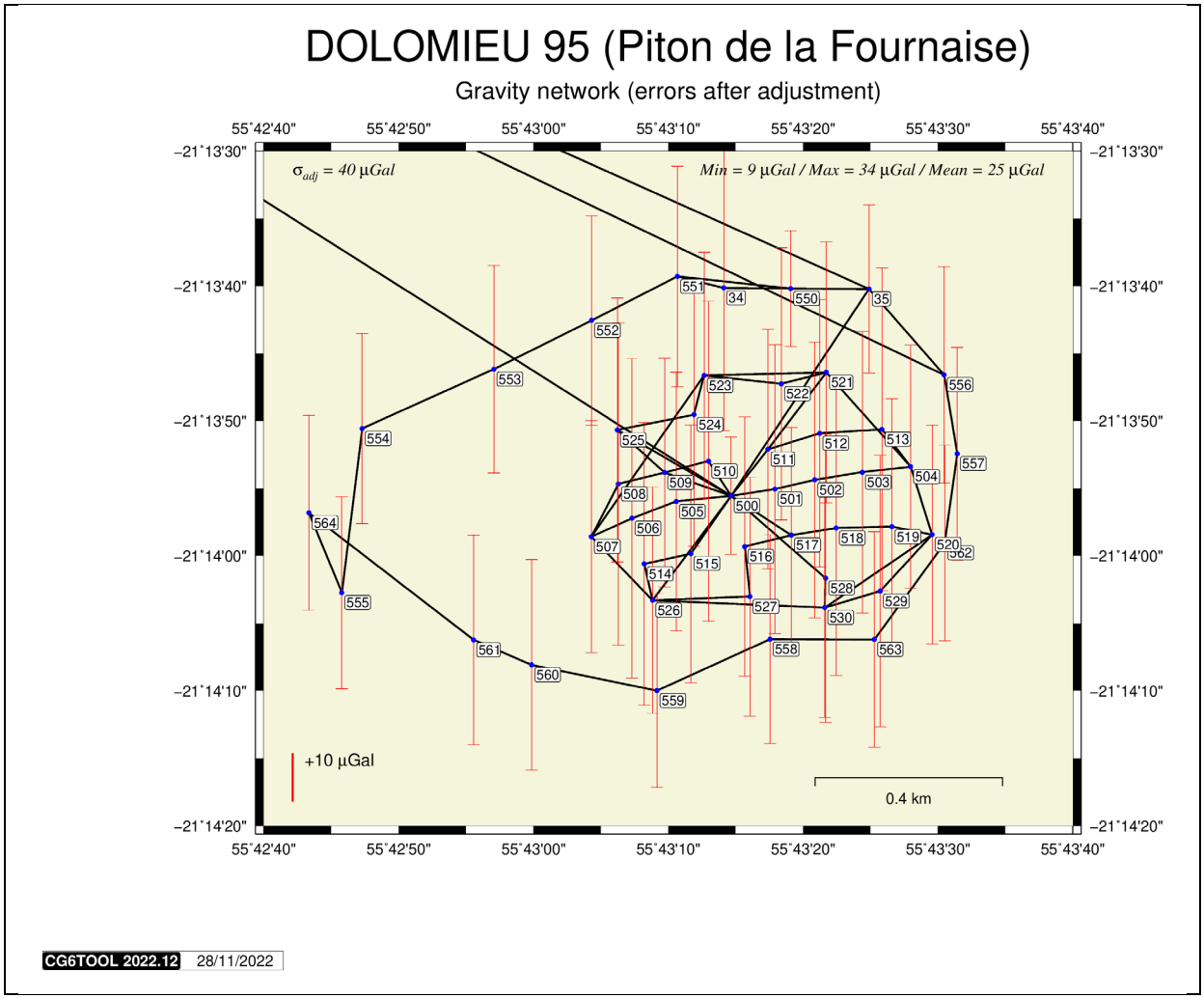


Figure 6.3: Network with errors bars (after adjustment)

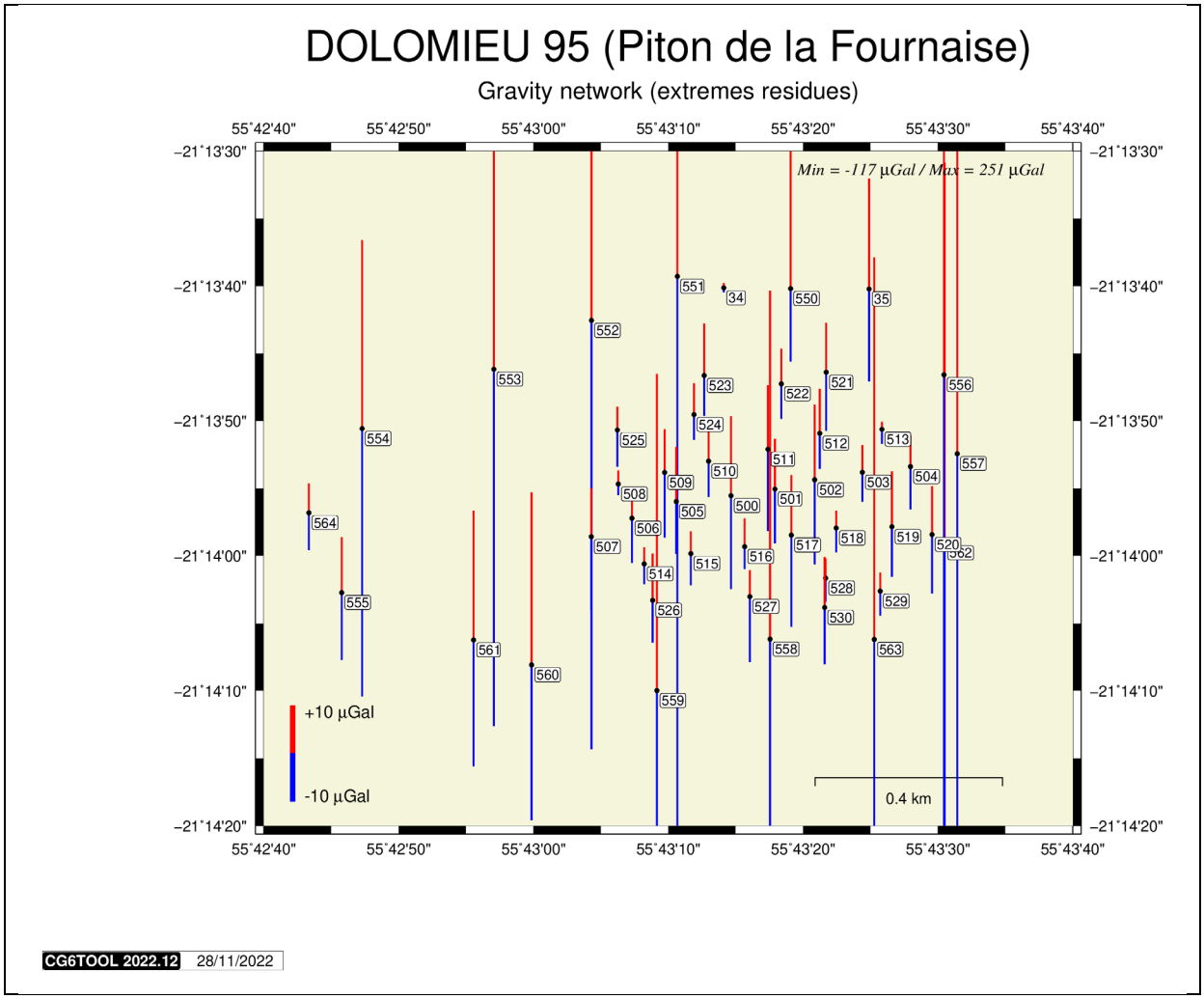


Figure 6.4: Network with residues extremes

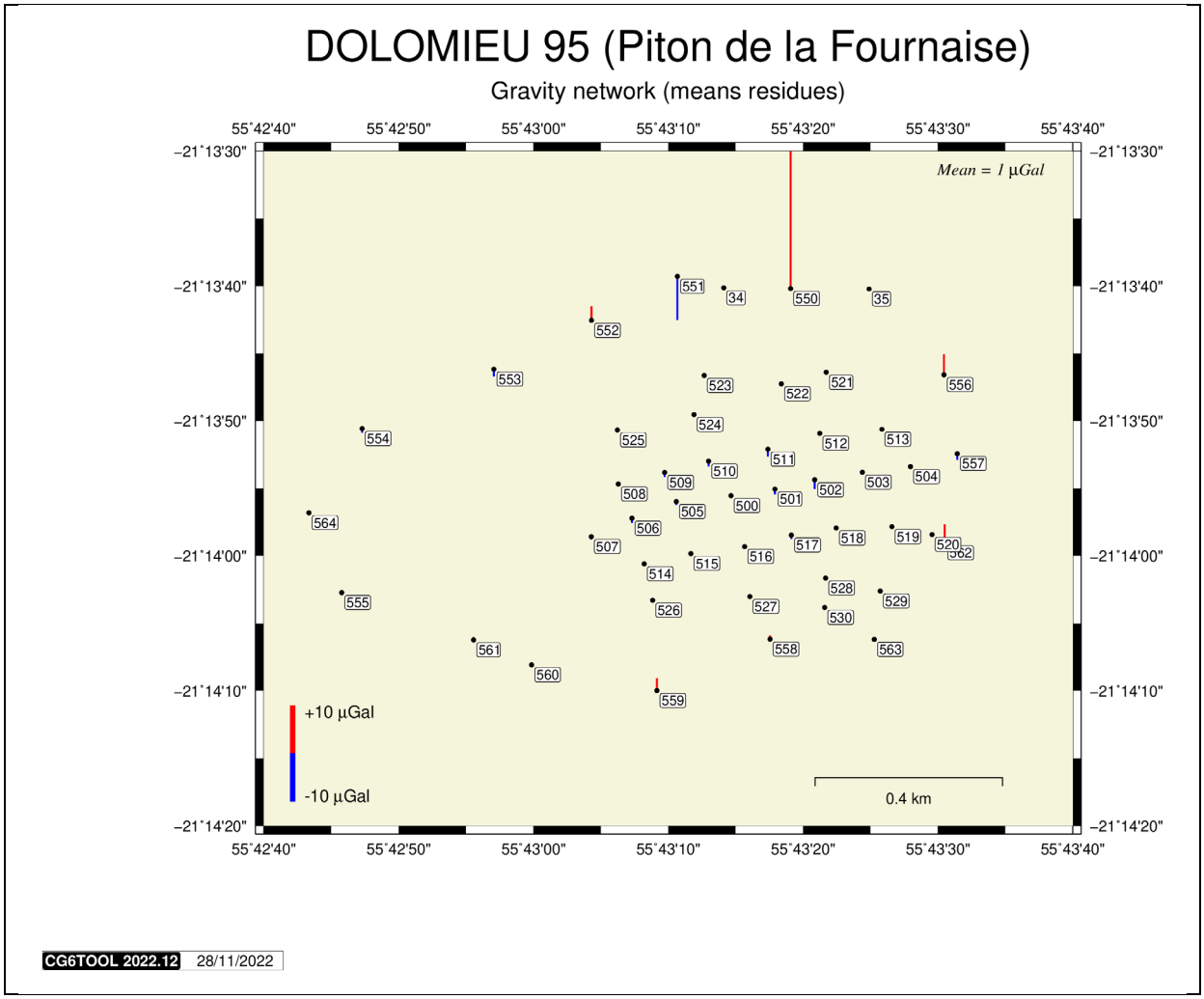


Figure 6.5: Network with residues means

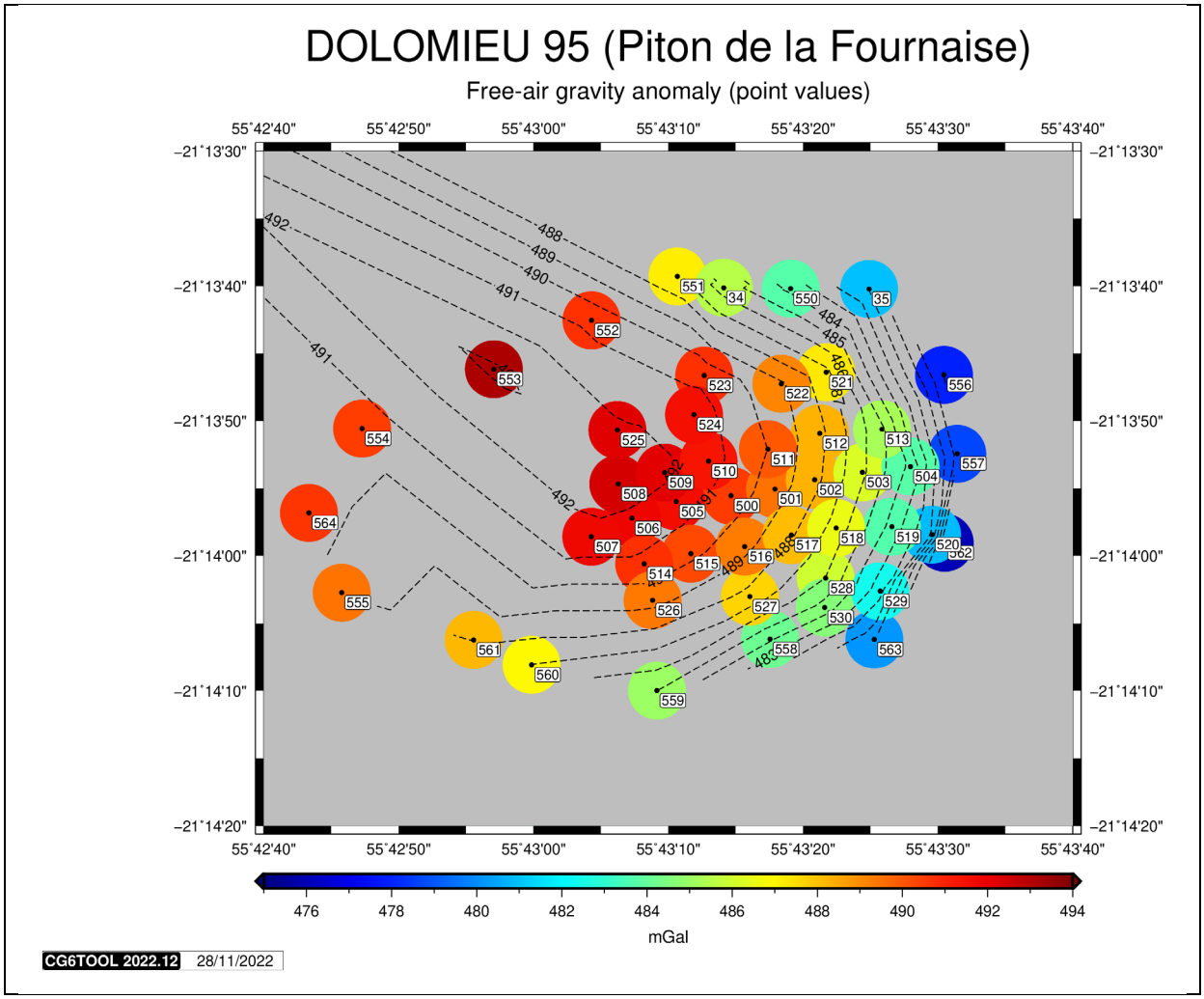


Figure 6.6: Network with free-air gravity anomaly (point values)

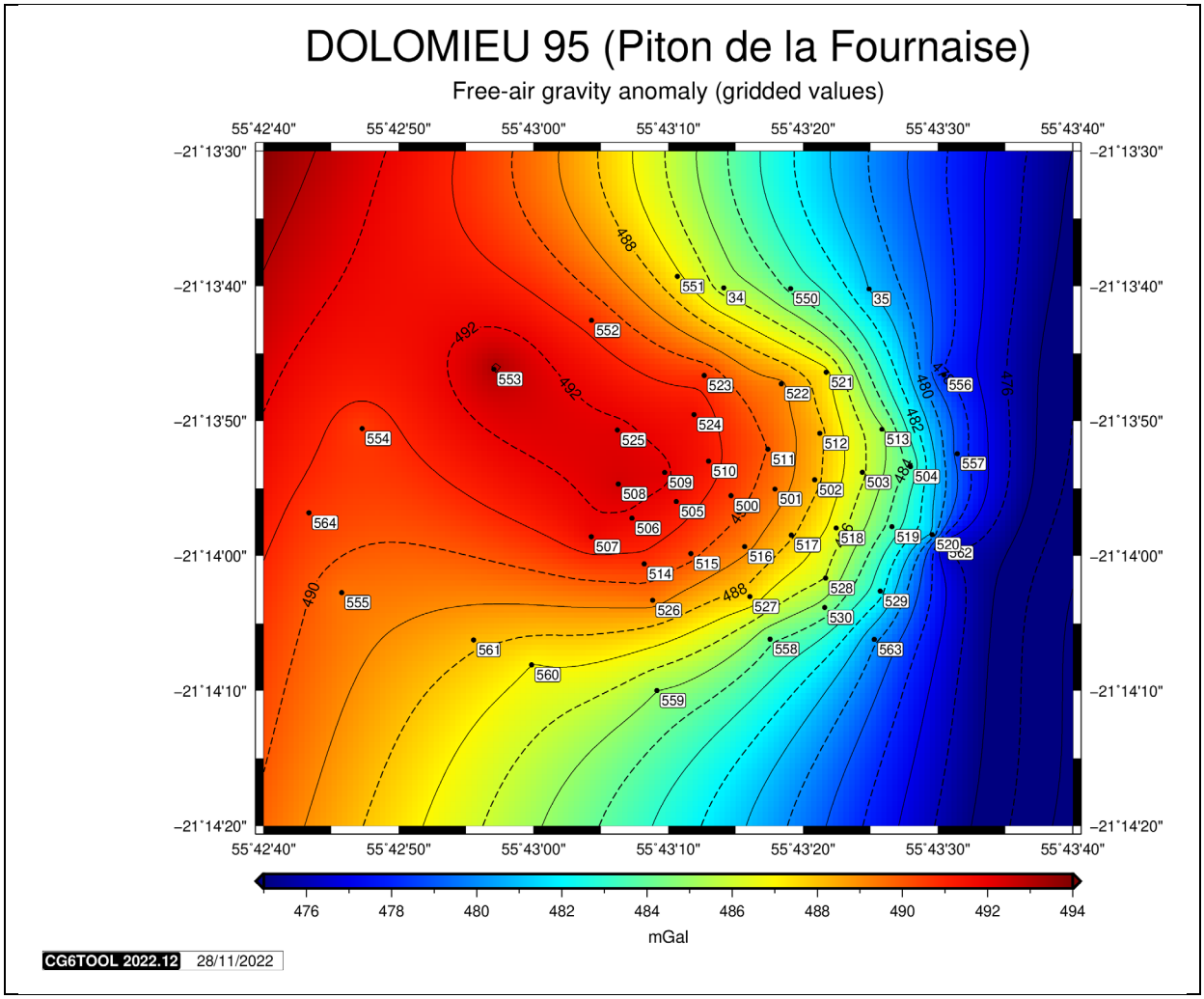


Figure 6.7: Network with free-air gravity anomaly (gridded values)

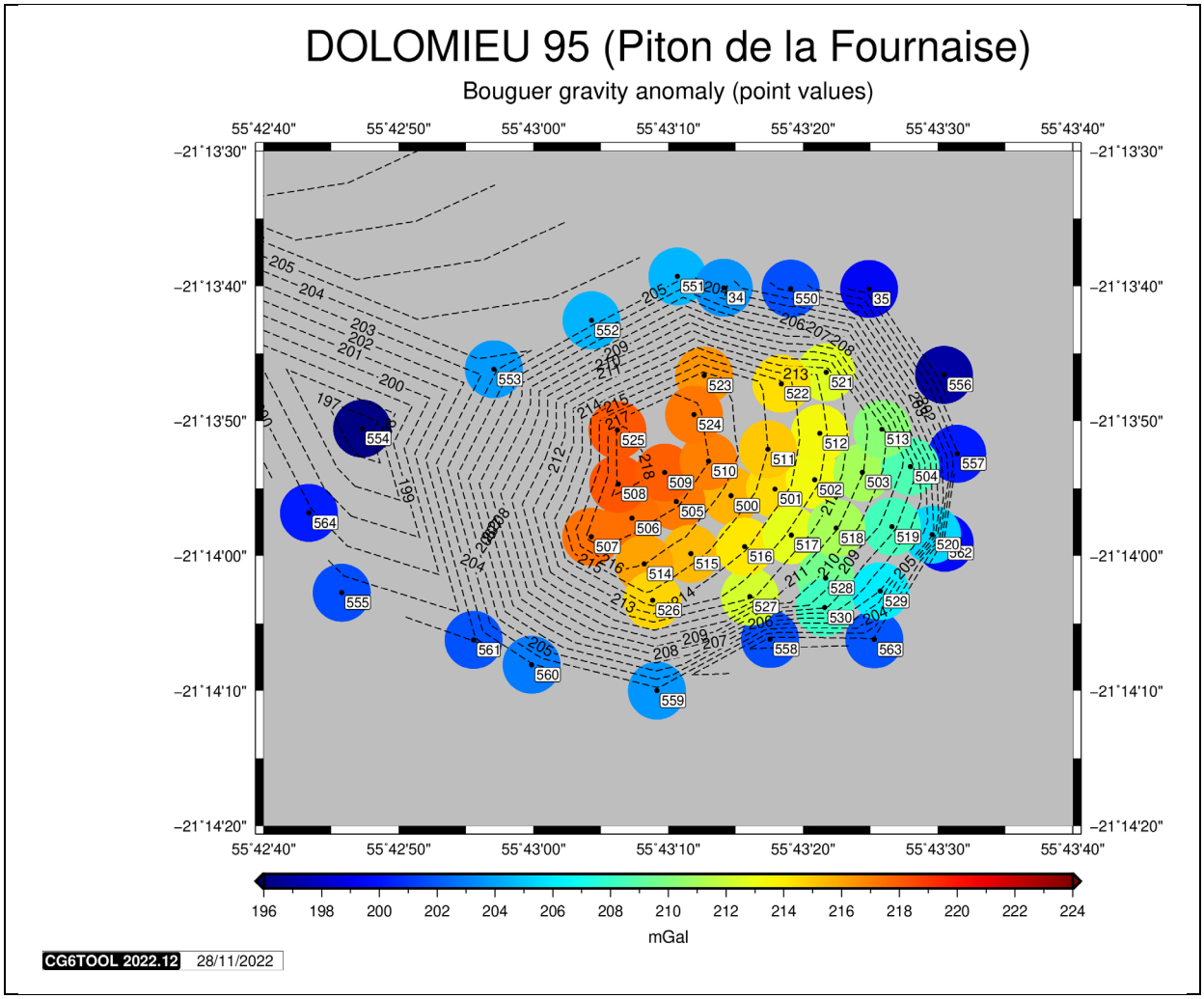


Figure 6.8: Network with Bouguer gravity anomaly (point values)

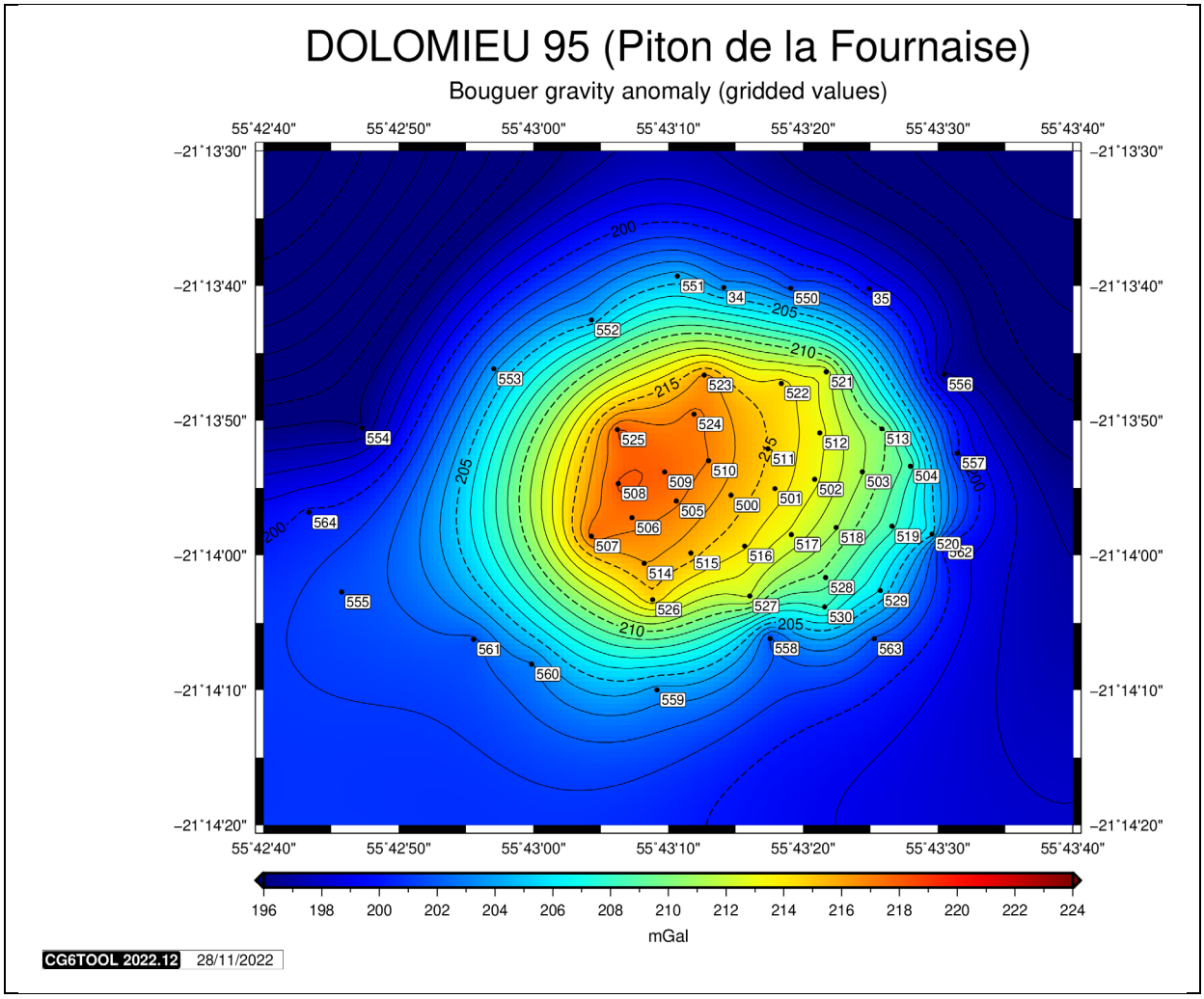


Figure 6.9: Network with Bouguer gravity anomaly (gridded values)

7. Adjustment report

Adjustment report in **PDF format** can be automatically generated when the user closes the adjustment windows by clicking the **X** icon on the tab (*figure 7.1*) or when he want to begin a new adjustment by clicking the **LOAD** button (*figure 7.2*).

Figure 7.1: The confirmation dialog after clicking the **X** icon

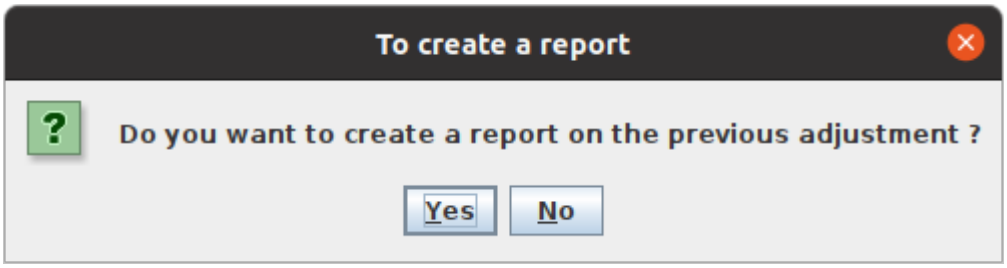


Figure 7.2: The confirmation dialog before a new adjustment (**LOAD** button)

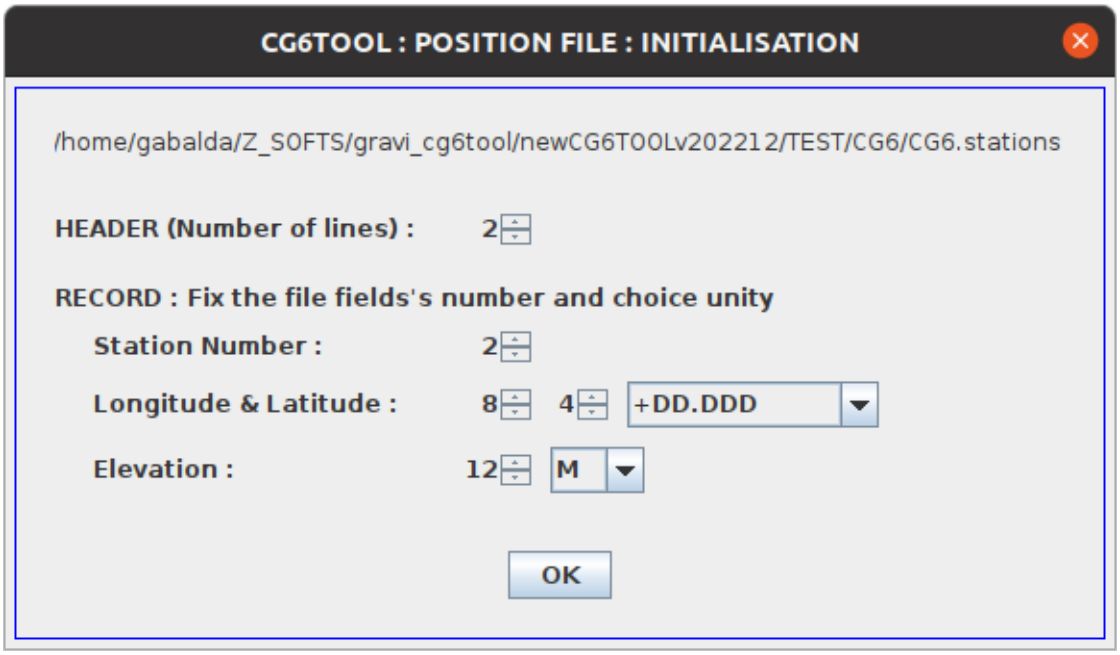
By checking Yes, CG6TOOL produces a report with the generic name is ***reportfile***_report.pdf where ***reportfile*** is **REPORT** value (or ***gna*** by default).

The report contains the following information:

- User, date and time of the adjustment
- Title (COMMENT) if exist
- Log file name
- Configuration file
- Adjustment information (input, output, absolute station, …)
- Adjusted values (station, gravity, error, coordinates, faa, simple Bouguer)
- All the graphics

In some case, the user needs precise coordinates for each station. They are imported in a file named "**Position file**" in CG6TOOL with a format defined by the user:

- with a dialog box in ***Field Survey*** (Position file : **Load** button):



- with keywords in ***Adjustment Tool*** (**IPOSFILE** and **IPOSFMT** in ***config-file***). **IPOSFMT** can accept 7 or 9 parameters depending on whether or not the position file contains a column with ***Terrain Correction*** (necessary for the calculation of the complete Bouguer anomaly).

IPOSFMT 2 2 8 4 12 16 DD M MGAL

The two cases require the following information:

- ✓ header's lines number (0 if no header)
- ✓ position of the fields (station, longitude, latitude, elevation, [terrain correction])
- ✓ longitudes and latitudes format:

Field Survey	Adjustment	01°26'37.15" East
DD.DDD	DD	1.4436528
DD.MMSSSS	D.MS	1.263715
DDMMSS.SS	DMS	012637.15
0.00001D	EOL	144365.28

- ✓ elevation unit:

Field Survey	Adjustment	150 m
CM	EOL	15000
M	M	150
KM	KM	0.15

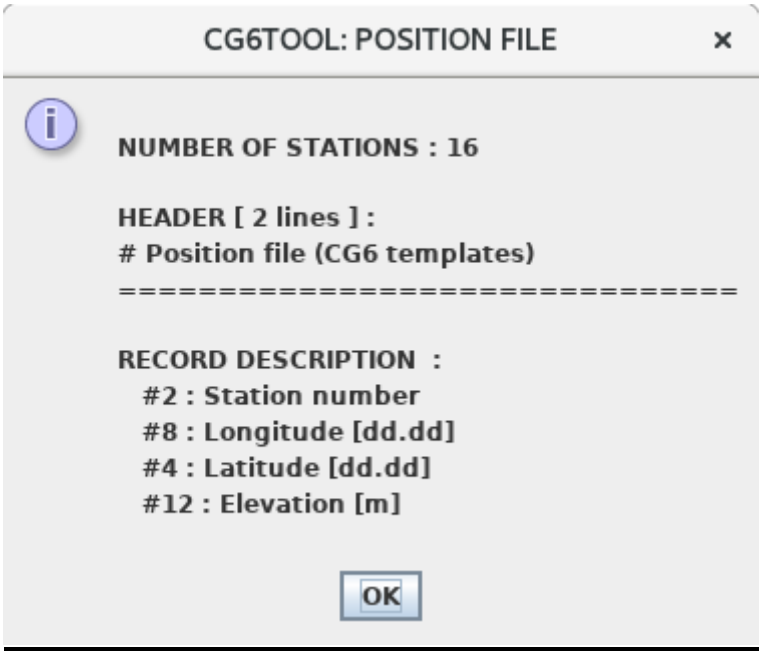
✓ terrain correction unit:

Field Survey	Adjustment	40.88 mGal
Non disponible	MGAL	40.88
Non disponible	EOL	4088

Above the two formats (graphic interface and command line) are almost identical :

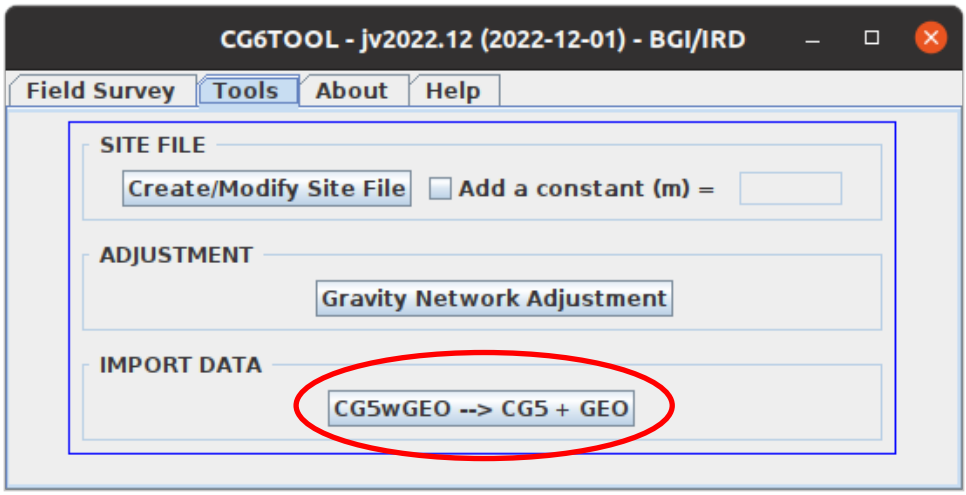
- Position file with a header of two lines (**2**)
- Station (field **2**), longitude (field **8**), latitude (field **4**) and elevation (field **12**)
- Longitude and latitude in Decimal Degrees (**DD.DDD** / **DDD**)
- Elevation in meters (**M**)
- Terrain Correction (field **16**) in **mGal** (only IPOSFMT)

While a <***Field Survey***> this information are available with the <**Infos**> button:



En this example we have the following informations :

- ✓ The coordinates file contains 16 stations
- ✓ With 2 header lines
- ✓ In first the station number (field 2 in the origin file)
- ✓ Field 2 : longitud in decimal degrees (field 8 in the origin file)
- ✓ Field 3 : latitud in decimal degrees (field 4 in the origin file)
- ✓ Field 4 : altitud in meters (field 12 in the origin file)



"**CG5wGEO → CG5 + GEO**" available from <**Tools**> can import the gravity observations acquired using Scintrex CG-5 gravimeter with the GEXT option GEXT which contains geographic coordinates (*see example below*).

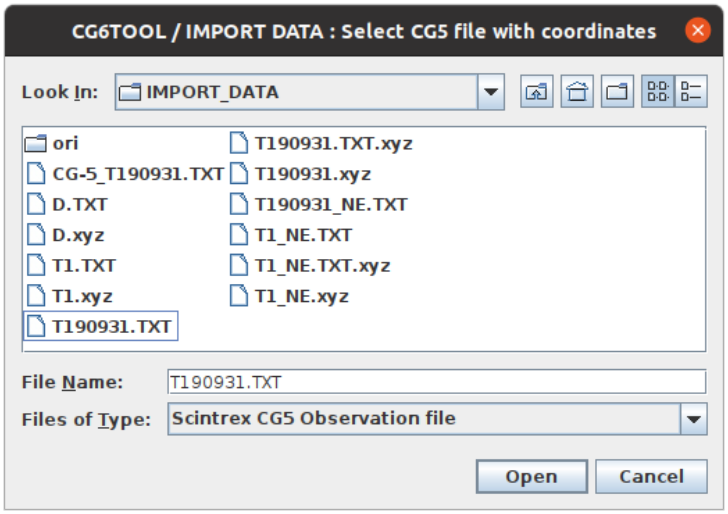
```
/           CG-5 SURVEY
/           Survey name:        LAT LONG
/           Instrument S/N:     40005
/           Client:
/           Operator:           RL
/           Date:               2015/ 8/ 14
/           Time:               19:04:43
/           LONG:               79.5035248 W
/           LAT:                43.7902756 N
/           ZONE:               0
/           GMT DIFF.:          0.0

/           CG-5 SETUP PARAMETERS
/           Gref:               0.000
/           Gcal1:              8757.598
/           TiltxS:             665.577
/           TiltyS:             708.322
/           TiltxO:             -1.292
/           TiltyO:             15.236
/           Tempco:             -0.127
/           Drift:              -0.008
/           DriftTime Start:    19:04:46
/           DriftDate Start:    2015/08/14

/           CG-5 OPTIONS
/           Tide Correction:    YES
/           Cont. Tilt:         YES
/           Auto Rejection:     YES
/           Terrain Corr.:      NO
/           Seismic Filter:     YES
/           Raw Data:           NO
Line        1.000
/----------LAT-------------LON-------ALT.-------GRAV.---SD.--TILTX--TILTY---TEMP---TIDE---DUR-REJ-----TIME----DEC.TIME+DATE--TERRAIN---DAT
43.7902410 -79.5035400 160.000  5491.907 0.034  -25.4  -24.4    17.38   -0.001  30   3   19:04:54   42198.79380  0.0000 2015/08/14
43.7902408 -79.5035400 170.000  5491.910 0.033  -25.3  -24.6    17.38   -0.001  30   0   19:05:29   42198.79420  0.0000 2015/08/14
43.7902418 -79.5035400 165.000  5491.906 0.026  -25.1  -24.7    17.38   -0.002  30   1   19:06:04   42198.79461  0.0000 2015/08/14
Line        2.000
/----------LAT-------------LON-------ALT.-------GRAV.---SD.--TILTX--TILTY---TEMP---TIDE---DUR-REJ-----TIME----DEC.TIME+DATE--TERRAIN---DAT
43.7905119 -79.5034710 255.000  5491.628 0.046  -15.4  -14.4    17.58   -0.005  30   2   19:07:30   42198.79560  0.0000 2015/08/14
43.7905121 -79.5034714 257.000  5491.632 0.030  -15.0  -10.6    17.59   -0.006  30   0   19:08:05 42198.796000  0.0000 2015/08/14
```

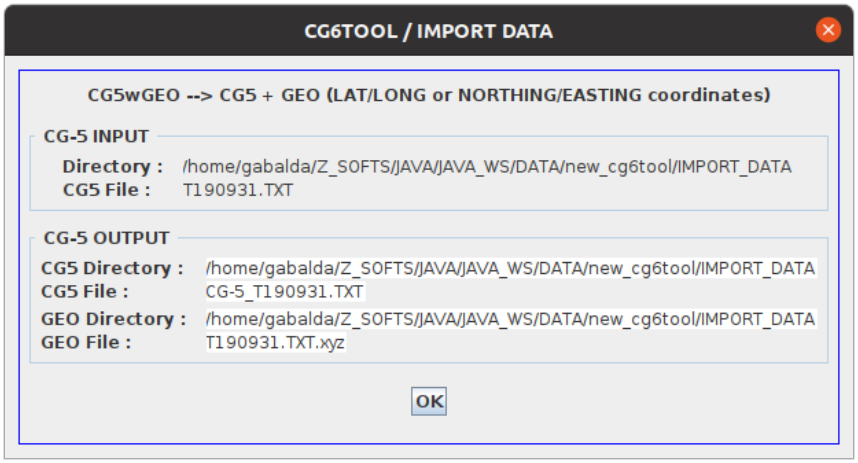
Warning, only this format above is recognized by CG6TOOL:

- ✓ *Only one header with « CG-5 SURVEY », « CG-5 SETUP » and « CG-5 OPTIONS »*
- ✓ *the **Line** parameter is used as an indicator of the station number*
- ✓ *the first fields of the time series are **LAT** and **LONG** or **NORTHING** and **EASTING***

Two output files are created, one containing the gravity observations in a usable format for **CG6TOOL** and another containing the geographic coordinates.

Click the <**CG5wGEO → CG5 + GEO**> button and select one Scintrex CG-5 data file.

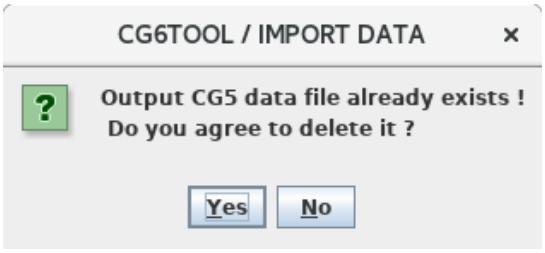


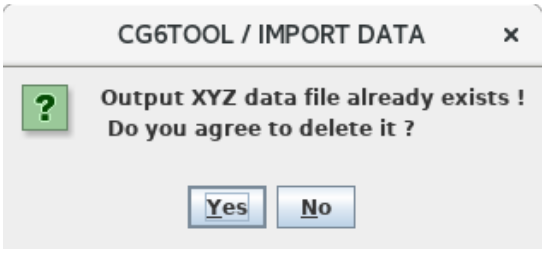


- ✓ The user has the possibility to choose the output directory. By default the output directory is identical to the input directory. Names of the output files are also editable.
- ✓ Click « **OK** » button to verify the parameters and continue the processing.
- ✓ The coordinates are averaged per station

CG6TOOL can display windows information (or dialog) . See examples below :

- ✓ If an output file exist the user has the choice between interrupting the process (to change his choice) or continue (and destroy the existing file).





- ✓ An error has prevented the process to unfold properly until its completion. In this case it is also desirable to take knowledge of the more explicit information displayed in "**CG6TOOL messages**".

As long as the main GUI is displayed, **the user can exit the program by right-clicking the program's icon ☒**, and choose **Yes** to exit or **No** to continue :

The "**CG6TOOL messages**" window allows you to monitor the operations and especially contains explicit information in the event of errors.

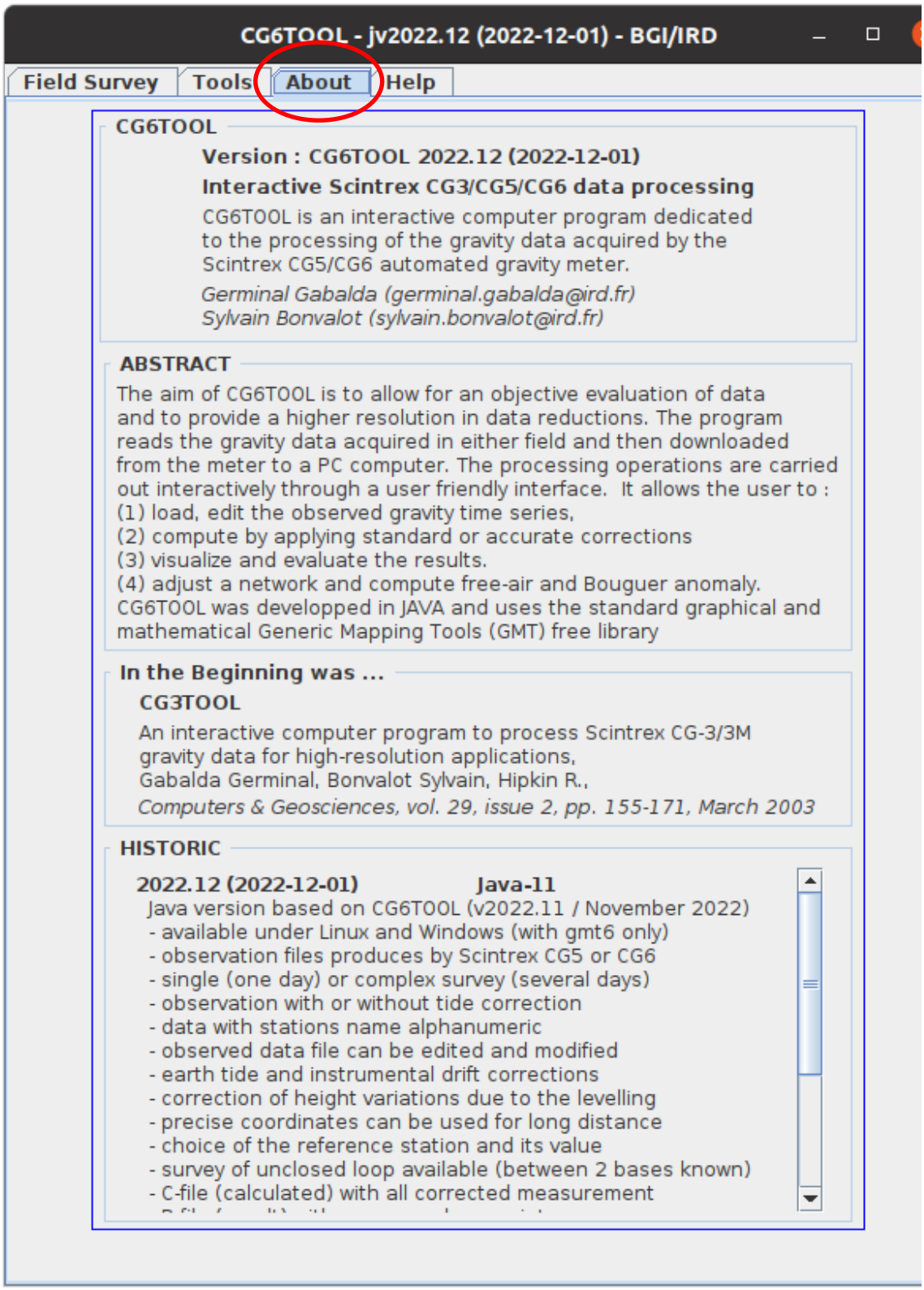
Example of CG5 File

```
/              CG-5 SURVEY
/
/ CG6TOOL - IMPORT DATA - CG5wGEO --> CG5 + GEO - Proccessing by gabalda (28/11/2022)
/
/ CG5 INPUT  : /home/gabalda/Z_SOFTS/JAVA/JAVA_WS/DATA/new_cg6tool/IMPORT_DATA/T190931.TXT
/
/ CG5 OUTPUT : /home/gabalda/Z_SOFTS/JAVA/JAVA_WS/DATA/new_cg6tool/IMPORT_DATA/CG-5_T190931.TXT
/ XYZ OUTPUT : /home/gabalda/Z_SOFTS/JAVA/JAVA_WS/DATA/new_cg6tool/IMPORT_DATA/T190931.TXT.xyz
/
/              CG-5 SOFTWARE VER.:  4.2
/              CG-5 SURVEY
/              Survey name:          LAT LONG
/              Instrument S/N:       9601323
/              Client:
/              Operator:             RL
/              Date:                 2015/ 8/14
/              Time:                 19:04:43
/              LONG:                 79.5035248 W
/              LAT:          43.7902756 N
/              ZONE:         0
/              GMT DIFF.:            0.0
/              CG-5 SETUP PARAMETERS
/              Gref:                 0.000
/              Gcal1:                8757.598
/              TiltxS:               665.577
/              TiltyS:               708.322
/              TiltxO:               -1.292
/              TiltyO:               15.236
/              Tempco:               -0.127
/              Drift:                -0.008
/              DriftTime Start:      19:04:46
/              DriftDate Start:      2015/08/14
/              CG-5 OPTIONS
/              Tide Correction:    YES
/              Cont. Tilt:         YES
/              Auto Rejection:     YES
/              Terrain Corr.:      NO
/              Seismic Filter:     YES
/              Raw Data:           NO
/------LINE-----STATION-----ALT.------GRAV.---SD.--TILTX--TILTY-TEMP---TIDE---DUR-REJ-----TIME----DEC.TIME+DATE--TERRAIN---DATE
1              1             160.0000 5491.609 0.030 -0.3 3.5  -0.05 0.070 30 0 19:04:54 42198.79380 0.0000 2015/08/14
1              1             170.0000 5491.610  0.033 -0.4 4.1  -0.05 0.070 30 0 19:05:29 42198.79420 0.0000 2015/08/14
1              1             165.0000 491.610  0.026 -0.5 4.3 -0.05 0.069 30 6 19:06:04 42198.79461  0.0000 2015/08/14
1              2             255.0000 5491.628 0.046 -0.8 4.9 -0.04 0.069 30 0 19:06:55 42198.79520 0.0000 2015/08/14
1              2             257.0000 5491.609 0.032  -1.3 4.7 -0.04 0.069 30 0 19:07:30 42198.79560  0.0000 2015/08/14
```

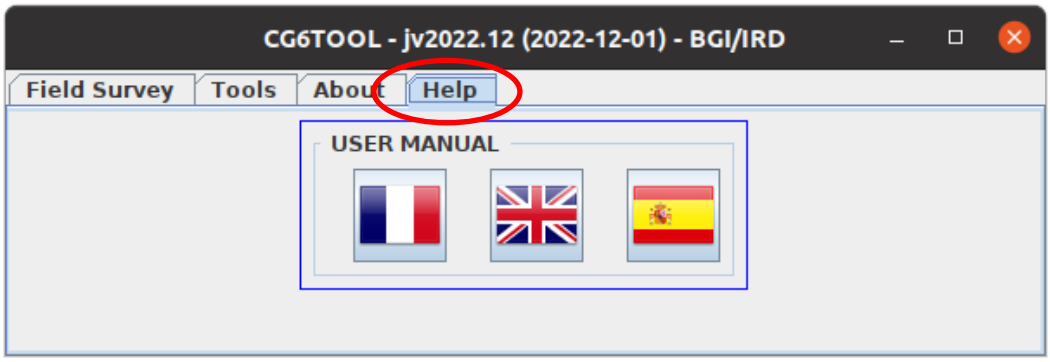
Example of “coordinates” File

```
# CG6TOOL - IMPORT DATA - CG5wGEO --> CG5 + GEO - Proccessing by gabalda (28/11/2022)
#
# CG5 INPUT  : /home/gabalda/Z_SOFTS/JAVA/JAVA_WS/DATA/new_cg6tool/IMPORT_DATA/T190931.TXT
#
# CG5 OUTPUT : /home/gabalda/Z_SOFTS/JAVA/JAVA_WS/DATA/new_cg6tool/IMPORT_DATA/CG-5_T190931.TXT
# XYZ OUTPUT : /home/gabalda/Z_SOFTS/JAVA/JAVA_WS/DATA/new_cg6tool/IMPORT_DATA/T190931.TXT.xyz
#
# STATION---------------LATITUDE----LONGITUDE----ALTITUDE
1               43.7902412  -79.5035400  165.0000
2               43.7905120 -79.5034712   256.0000
```

The ***'About'*** tab contains some general information on **CG6TOOL** (current version, summary,...) as well as a history on the main contributions of each version.



The ***'Help'*** tab allows access to the documentation in french, English and Spanish..



- Documentation ***("pdf" files)*** must be present in the directory ***$CG6TOOL/pdf***.
- Under ***Linux***, if the **$CG6READER** (PDF Reader) environment variable is not set then **'evince'** is used by default.

1. Field survey processing

1.1. Gravity raw data with error (g_m, e)

- $\mathbf{g_m}$ is computed from **GRAV** (measured in **DUR-REJ**) and **TIDE** (respectively **Grav**, **Dur - #Rej** and **E.T.C.** for a CG3 gravimeter).
- **e** is **SD** or estimated from **SD** and **DUR-REJ**.

$\mathbf{g_m}$ = GRAV – TIDE	**e** = SD or $SD\frac{SD}{\sqrt{DUR-REJ}}$

1.2. Earth tide correction (ΔG*etc*)

- By default (**CG6** option) CG6TOOL uses the *Earth Tide Correction* generated via the Longman formula and the header coordinates. With "**Common Longman**" or "**Precise Longman"** options, CG6TOOL computes new values. This is interesting if the header coordinates are false or if you want a different value per station.

1.3. Site correction (ΔG*height*)

- To remove the height variations in the instrument leveling

ΔG*height* (mGal) = *Hgrad* . ΔH (m)	*Hgrad* = **-0.3086** mGal/m (*default*)
	ΔH = height to benchmark

1.4. Drift correction (ΔG*drift*)

- $\mathbf{R_{ij}}$ is the **i** repetition at the station **j**

$\mathbf{t_{1j}}$ ($\mathbf{t_{ij}}$) the time at the **first** (**i**) measure at the station **j**

$\mathbf{g_{1j}}$ ($\mathbf{g_{ij}}$) corrected gravity (etc,site) computed at time $\mathbf{t_{1j}}$ ($\mathbf{t_{ij}}$)

$\mathbf{e_{1j}}$ ($\mathbf{e_{ij}}$) the error associated to $\mathbf{g_{1j}}$ ($\mathbf{g_{ij}}$)

$\mathbf{R_{ij}}\left\{\Delta T_{ij} = t_{ij} - t_{1j},\ \Delta G_{ij} = g_{ij} - g_{1j},\ E_{ij} = \sqrt{e_{ij}^2 + e_{1j}^2}\right\}$

- The drift rate is defined by a least-squares fitting with all weighted gravity observations $\mathbf{R_{ij}}$ at reoccupied sites.

$$\sum_{\substack{1\le i\le iterations \\ 1\le j\le stations}} \left(\frac{\Delta G_{ij} - B - K.\Delta T_{ij}}{Er_{ij}}\right)^2 = \chi^2_{(K,B)}\ \boldsymbol{minimal}$$

$$S = \sum\frac{1}{E_{ij}^2} \quad S_x = \sum\frac{\Delta T_{ij}}{E_{ij}^2} \quad S_y = \sum\frac{\Delta G_{ij}}{E_{ij}^2} \quad S_{xx} = \sum\frac{\Delta T_{ij}^2}{E_{ij}^2} \quad S_{xy} = \sum\frac{\Delta T_{ij}\Delta G_{ij}}{E_{ij}^2}$$

$$\nabla = S.S_{xx} - S_x^2 \quad K = \frac{S.S_{xy} - S_x.S_y}{\nabla} \quad B = \frac{S_{xx}.S_y - S_x.S_{xy}}{\nabla}$$

$$SD\ (Standard\ deviation\ weighted) = \sqrt{\frac{\chi^2_{(K,B)}}{S}} \quad \sigma_K^2 = \frac{S}{\nabla} \quad \sigma_B^2 = \frac{S_{xx}}{\nabla}$$

- Drift correction

ΔG*drift* = *K* . ΔT + B	Δ*T* = Time with the first measure

1.6. Corrected gravity values (ΔG*cal*)

- The last column of the « c-file » (calculated file) contains for each measures the corrected gravity value **ΔG*cal***.

> **ΔG*cal*** = G*m* + ΔG*etc* + ΔG*height* + ΔG*drift* - ΔGcal_0
>
> with **ΔGcal_0** the first corrected value of the field survey

1.7. Averaged values of gravity (G*res*)

- The « r-file » (result file) contains for each station a unique value averaged over all repetitions (**ΔGcal_i** , **e_i**).

> $\boldsymbol{Gres_j} = \frac{\sum_1^N w_i \Delta Gcal_i}{\sum_1^N w_i} + \mathbf{G_0}$ $\quad with\ \boldsymbol{w_i} = \frac{1}{e_i^2}\ and\ \boldsymbol{G_0} = Gravity\ Base$
>
> $\boldsymbol{EP_j} = \sqrt{\frac{\sum_1^N w_i \Delta Gcal_i^2}{\sum_1^N w_i} - \boldsymbol{Gres_j^2}}$ = weighted error
>
> No reiteration of the station j : $\boldsymbol{Eres_j} = \sqrt{e_i^2 + \boldsymbol{SD^2}}$
>
> Reitered station j but no reoccupied : $\boldsymbol{Eres_j} = \sqrt{\boldsymbol{EP_j^2} + \boldsymbol{SD^2}}$
>
> Reoccupied station j (∃ **ΔTi >REOCDT**) : $\boldsymbol{Eres_j} = \sqrt{\boldsymbol{EP_j^2}}$

2. Gravity Network Adjustment

1.1. Scaling factors computing

- Absolute data read in « *config-file* »
- Relative data read in « *c-file* » or « *r-file* »
- Gravity variation between stations are computed for each file.
- The segments (ΔG_i, ΔE_i) reoccupied are averaged (by gravimeter)

$$\overline{\Delta G_j} = \frac{\sum_1^N w_i \Delta G_i}{\sum_1^N w_i} \quad avec\ w_i = \frac{1}{\Delta E_i^2} \qquad for\ N\ identicals\ segments$$

$$\overline{\Delta E_j} = \sqrt{\frac{\sum_1^N w_i \Delta G_i^2}{\sum_1^N w_i} - \overline{\Delta G_j^2}}$$

- **STEP 1** : The set of common segments to two gravimeters allows to compute by least-squares method the scaling factors : **Gr** (*reference*) = **b** + **k . Gc** (*calibrated*).

We calculate $\mathbf{X} = \begin{bmatrix} \mathbf{k} \\ \mathbf{b} \end{bmatrix} = \left(\mathbf{Gc^T W Gr}\right)^{-1} \mathbf{Gc^T\ W\ Gr}$

$$\mathbf{W} = \begin{bmatrix} \frac{1}{\Delta \mathbf{Er}_1^2 + \Delta \mathbf{Ec}_1^2} & \cdots & \mathbf{0} \\ \vdots & \ddots & \vdots \\ \mathbf{0} & \cdots & \frac{1}{\Delta \mathbf{Er}_n^2 + \Delta \mathbf{Ec}_n^2} \end{bmatrix} = weight\ matrix$$

$$\mathbf{Gc} = \begin{bmatrix} \overline{\Delta Gc}_1 & \mathbf{1} \\ \overline{\Delta Gc}_2 & \mathbf{1} \\ \vdots & \vdots \\ \overline{\Delta Gc}_n & \mathbf{1} \end{bmatrix} \qquad \mathbf{Gr} = \begin{bmatrix} \overline{\Delta Gr}_1 \\ \overline{\Delta Gr}_2 \\ \vdots \\ \overline{\Delta Gr}_n \end{bmatrix} \qquad \mathbf{R = Gc\,.X - Gr} = residues$$

$\widehat{\sigma}_0^2$ the variance estimation **:** $\widehat{\sigma}_0^2 = \frac{R^T W R}{n-2}$

$\overline{W}$ the "**normalized**" weight matrix $\overline{W} = \frac{W}{\widehat{\sigma}_0^2}$

$$\mathbf{C} = \begin{bmatrix} \sigma_k^2 & \mathbf{0} \\ \mathbf{0} & \sigma_b^2 \end{bmatrix} = \left(\mathbf{Gc^T} \overline{W} \mathbf{Gc}\right)^{-1} = Normalized\ covariance\ matrix$$

$$\sigma = \sqrt{\frac{R^T R}{n-2}} = Standard\ deviation$$

- **STEP 2** : To eliminate the "outliers" observations

Step 1: Scaling factors $\mathbf{k_1}$, $\mathbf{b_1}$ and the standard deviation $\boldsymbol{\sigma_1}$

Step 2: 19 repetition of « Step 1 » to eliminate the observations ($\overline{\mathbf{\Delta Gr}}, \overline{\mathbf{\Delta Gc}}$)
if $\boldsymbol{Residues_{i+1} = \overline{\Delta \mathbf{Gr}} - k_i \overline{\Delta \mathbf{Gc}} - b_i \geq 3\,\sigma_i}$

- **STEP 3** : Student test to evaluate the hypothesis $\mathbf{b_{20}=0}$ (greater than 95%)

- **STEP 4** : To compute the scaling factor **k** only with observations selected in the Step 2 and **b=0** : **Gr** (*reference*) = **k . Gc** (*calibrated*).

$$\mathbf{K} = [\mathbf{k}] = \left(\mathbf{Gc^T W Gc}\right)^{-1} \mathbf{Gc^T\, W\, Gr}$$

$$\mathbf{W} = \begin{bmatrix} \frac{1}{\Delta Er_1^2 + \Delta Ec_1^2} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \frac{1}{\Delta Er_n^2 + \Delta Ec_n^2} \end{bmatrix} = weight\ matrix$$

$$\mathbf{Gc} = \begin{bmatrix} \overline{\Delta Gc}_1 \\ \overline{\Delta Gc}_2 \\ \vdots \\ \overline{\Delta Gc}_n \end{bmatrix} \quad \mathbf{Gr} = \begin{bmatrix} \overline{\Delta Gr}_1 \\ \overline{\Delta Gr}_2 \\ \vdots \\ \overline{\Delta Gr}_n \end{bmatrix} \qquad \mathbf{R = Gc\,.K - Gr} = residues\ matrix$$

$\hat{\sigma}_0^2$ the variance estimation **:** $\hat{\sigma}_0^2 = \frac{R^T W R}{n-1}$

$\overline{W}$ the "**normalized**" weight matrix $\overline{W} = \frac{W}{\hat{\sigma}_0^2}$

$$\sigma_k^2 = \left(\mathbf{Gc^T}\overline{W}\mathbf{Gc}\right)^{-1} \qquad \sigma = \sqrt{\frac{R^T R}{n-1}}$$

1.2. Network adjustment

The gravity network contains $\mathbf{n_{sta}}$ stations. We have $\mathbf{n_{seg}}$ relative observations and $\mathbf{n_{abs}}$ absolute stations known :

- **STEP 1** : Calculate a value for the base (first station) of each file (or traverse). Only are used the absolutes measures $\mathbf{a_i}$ and the traverses which base is an **absolute stations** (read in *config_file*).

To compute $[\mathbf{S_k}]$ with $[\mathbf{W_{ii}}]\,[\mathbf{C_{ik}}]\,[\mathbf{S_k}] = [\mathbf{W_{ii}}][\mathbf{G_i}]$

S_k absolute station : $\mathbf{G_i} = (\mathbf{a_i}, \mathbf{e_i})$ with ($\mathbf{a_i}$, $\mathbf{e_i}$) read in *config_file*

$\mathbf{C_{ik}} = \mathbf{1}$ and $\mathbf{C_{ij}} = \mathbf{0}$ (j ≠ k) $\quad \mathbf{W_{kk}} = \frac{\mathbf{1}}{e_i^2}$ and $\mathbf{W_{ii}} = \mathbf{0}$ (i ≠ k)

Segment $\mathbf{S_b}(\mathbf{g_{i1}}, \mathbf{e_{i1}}) \equiv \mathbf{S_k}(\mathbf{g_{i2}}, \mathbf{e_{i2}})$: $\mathbf{W_{ii}} = \frac{\mathbf{1}}{e_{i1}^2 + e_{i2}^2}$ and $\mathbf{W_{ij}} = \mathbf{0}$ (i ≠ j)

$\mathbf{S_b}$ an **absolute station** ($\mathbf{a_b}$, $\mathbf{e_b}$) read in *config_file*

$\mathbf{S_k} = \mathbf{S_b}$(Reocupation) : $\mathbf{G_i} = \mathbf{S_b}(\mathbf{a_b}, \mathbf{e_b}) + \Delta\mathbf{g_{i1i2}} \times \mathbf{k}_g$

$\mathbf{C_{ib}} = \mathbf{1}$ and $\mathbf{C_{ij}} = \mathbf{0}$ (j ≠ b)

$\mathbf{S_b} \neq \mathbf{S_k}$: $\mathbf{G_i} = \Delta\mathbf{g_{i1i2}} \times \mathbf{k}_g$ with $\mathbf{k}_g$ scaling factor

$\mathbf{C_{ib}} = \mathbf{1}$, $\mathbf{C_{ib}} = -\mathbf{1}$ and $\mathbf{C_{ij}} = \mathbf{0}$ (j ≠ b ≠ k)

$$[\mathbf{R_i}] = [\mathbf{C_{ik}}]\,[\mathbf{S_k}] - [\mathbf{G_i}] \qquad \sigma = \sqrt{\frac{R^T R}{n_{seg} - n_{sta}}}$$

- **STEP 2** : Only if all stations have not been determined in step 1. All the network bases have a value (absolute or adjusted in step 1) and we use all the observations.

To compute $[\mathbf{S_k}]$ with $[\mathbf{W_{ii}}]\ [\mathbf{C_{ik}}]\ [\mathbf{S_k}] = [\mathbf{W_{ii}}][\mathbf{G_i}]$

$\mathbf{S_k}$ **absolute station** : $\mathbf{G_i} = (\mathbf{a_i}, \mathbf{e_i})$ with ($\mathbf{a_i}$, $\mathbf{e_i}$) read in *config_file*

$\mathbf{C_{ik}} = \mathbf{1}$ and $\mathbf{C_{ij}} = \mathbf{0}$ (j ≠ k) $\quad \mathbf{W_{kk}} = \frac{\mathbf{1}}{e_i^2}$ and $\mathbf{W_{ii}} = \mathbf{0}$ (i ≠ k)

Segment $\mathbf{S_b}(\mathbf{g_{i1}}, \mathbf{e_{i1}}) \equiv \mathbf{S_k}(\mathbf{g_{i2}}, \mathbf{e_{i2}})$:

$\mathbf{S_k} = \mathbf{S_b}$(reoccupation) and $\mathbf{S_b}$ **absolute station** ($\mathbf{a_b}, \mathbf{e_b}$):

$\mathbf{G_i} = \mathbf{S_b}(\mathbf{a_b}, \mathbf{e_b}) + \Delta\mathbf{g_{i1i2}} \times \mathbf{k}_g$ (scaling factor)

$\mathbf{C_{ib}} = \mathbf{1}$ and $\mathbf{C_{ij}} = \mathbf{0}$ (j ≠ b)

$\mathbf{W_{ii}} = \frac{\mathbf{1}}{e_{i1}^2 + e_{i2}^2}$ and $\mathbf{W_{ij}} = \mathbf{0}$ (i ≠ j)

$\mathbf{S_k} = \mathbf{S_b}$(reoccupation) and $\mathbf{S_b}$ **ajusted station** ($\mathbf{g_a}, \mathbf{e_a}$):

$\mathbf{G_i} = \mathbf{S_b}(\mathbf{g_a}, \mathbf{e_a}) + \Delta\mathbf{g_{i1i2}} \times \mathbf{k}_g$ (scaling factor)

$\mathbf{C_{ib}} = \mathbf{1}$ and $\mathbf{C_{ij}} = \mathbf{0}$ (j ≠ b)

$\mathbf{W_{ii}} = \frac{\mathbf{1}}{e_{i1}^2 + e_{i2}^2 + e_a^2}$ and $\mathbf{W_{ij}} = \mathbf{0}$ (i ≠ j)

$\mathbf{S_b} \neq \mathbf{S_k}$: $\mathbf{G_i} = \Delta\mathbf{g_{i1i2}} \times \mathbf{k}_g \quad \mathbf{W_{ii}} = \frac{\mathbf{1}}{e_{i1}^2 + e_{i2}^2}$ and $\mathbf{W_{ij}} = \mathbf{0}$ (i ≠ j)

$\mathbf{C_{ib}} = \mathbf{1}$, $\mathbf{C_{ib}} = -\mathbf{1}$ and $\mathbf{C_{ij}} = \mathbf{0}$ (j ≠ b ≠ k)

$[\mathbf{R_i}] = [\mathbf{C_{ik}}]\ [\mathbf{S_k}] - [\mathbf{G_i}] \qquad \boldsymbol{\sigma} = \sqrt{\frac{R^T R}{n_{seg} - n_{sta}}}$

- **STEP 3** : Another iteration can be realized only if the **ADJNSIG** keyword is initialized in the *config_file*.

Step 1 (and Step 2) : $\boldsymbol{\sigma} = \sqrt{\frac{R^T R}{n_{seg} - n_{sta}}}$

We compute $[\mathbf{S_k}]$: $[\mathbf{W_{ii}}]\ [\mathbf{C_{ik}}]\ [\mathbf{S_k}] = [\mathbf{W_{ii}}][\mathbf{G_i}]$

All the ***relative*** observations $\mathbf{G_i}$ with residue $[\mathbf{R_i}] = [\mathbf{C_{ik}}]\ [\mathbf{S_k}] - [\mathbf{G_i}]$

are eliminated if $\mathbf{R_i} >$ **ADJNSIG** * $\boldsymbol{\sigma}$

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