GRAVPROCESS 1.4

USER MANUAL

GRAVPROCESS is a user-friendly software to process relative gravity data and to evaluate the associated uncertainties. This user manual provides information that will help you to set up and to run GRAVPROCESS. It also includes information about the input-output files format.

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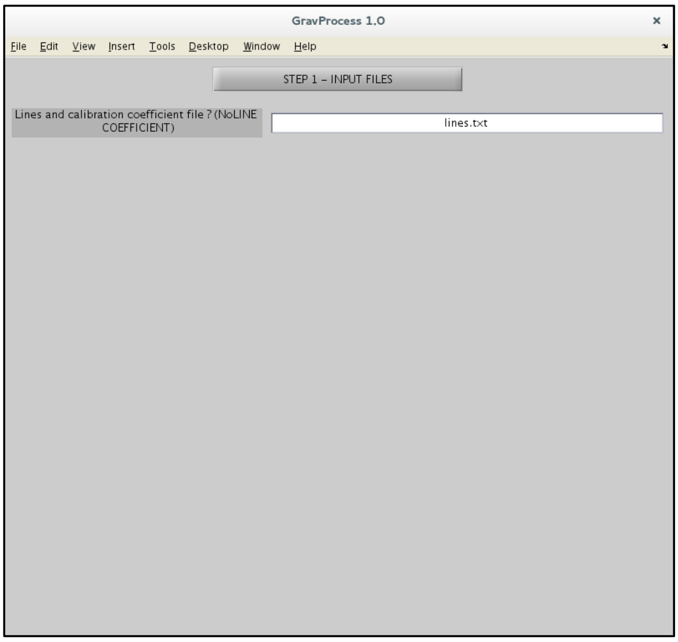
INSTALL GRAVPROCESS

This code is developed solely using the MATLAB™ language. This allows the user to perform all processing steps without the need for external programs. Taking advantage of the MATLAB™ graphics toolbox, GRAVPROCESS can be installed on most systems and platforms (so far tested on linux and MacOS X).
- Download the program code from the International Association for Mathematical Geosciences web site: http://www.iamg.org.
- Create a GRAVPROCESS directory.
- Move the downloaded file to this directory.
- Unzip the zip file.

LAUNCH GRAVPROCESS

After installing GRAVPROCESS, create a directory associated with your campaign gravity data-set. Next copy the startup.m file from the GRAVPROCESS directory to this working directory.
- Modify the startup.m file to give the appropriate path of the GRAVPROCESS directory on your computer.
- Launch MATLAB™ from the working directory.
- Type "gravprocess" in the MATLAB™ command windows. If it doesn't work, type "startup" before to launch "gravprocess".

A new window is created:



HOW TO REFERENCE GRAVPROCESS ?

Relative gravimeters are extensively used in numerous geosciences applications. GRAVPROCESS is a software dedicated to computing high-resolution data associated with complex gravity survey. This software is an open source code using the MATLAB™ language. It is designed to be easily accessible for users with no prior knowledge of MATLAB™.

A description of the algorithms and an example of processing can be found in Cattin, R., Mazzotti, S., Baratin, L.M, GravProcess : An easy-to-use MATLAB program to process campaign gravity data and evaluate the associated uncertainties, Computer & Geosciences, 81, 20-27, 2015.

This software is provided with no warranties and support. Please report any issues to rodolphe.cattin@umontpellier.fr

GIVE INPUT FILES AND INPUT PARAMETERS

GRAVPROCESS requires at least five input files:

1. A calibration file, with the gravimeter calibration factor for each line.
2. Raw gravity data files (one per line) in the Scintrex CG5 format. Please use the Matlab code **CG6toCG5.m** to convert data files in the Scintrex CG6 format into CG5 format.
3. A stations location file providing longitude, latitude, elevation and elevation uncertainty for each gravity station.
4. A network file that defines the strategy of network and line adjustments (i.e., sequence and steps of line combinations).
5. A base station file with locations and values of absolute gravity measurements for reference points.

Depending of the required accuracy, three additional files can be imported:

1. A digital elevation model (DEM) to calculate terrain correction. This DEM must be referenced to the same ellipsoid as the station locations. Commonly, GPS locations are referenced to the WGS 84 ellipsoid.
2. An ocean-tide correction file, with ocean-loading coefficients at chosen locations. This file can be obtained from the website http://holt.oso.chalmers.se/loading/ developed by M.S. Bos and H.-G. Scherneck,
3. A barometric measurement file that contains the location, date and time of pressure measurements.

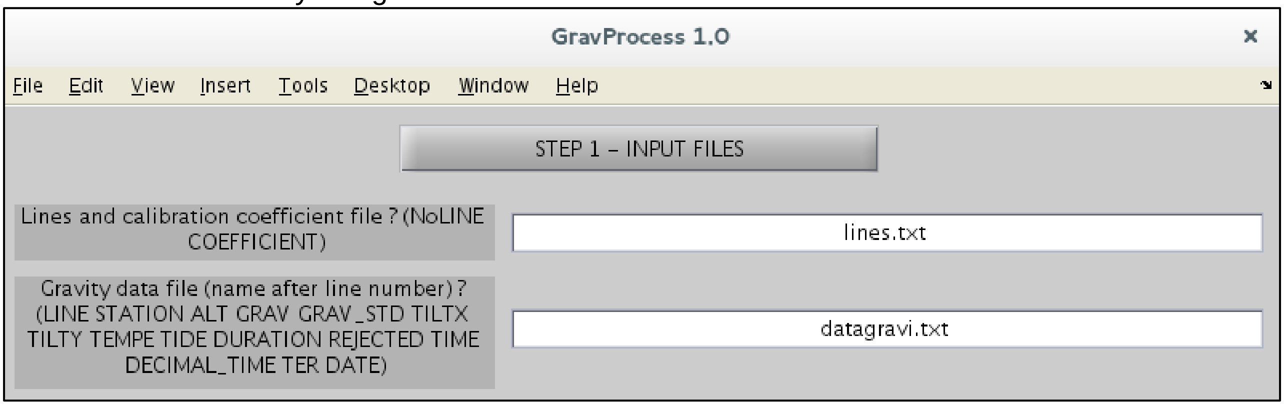
Lines number and calibration file

A line comprises measurements at stations associated with a unique gravimeter and drift estimate. The user must provide the path and name of the file defining the line numbers and calibration values. By default, the current directory is used. This file consists in two columns: (1) the line number and (2) the calibration factor associated with the gravimeter used:

11	0.998925
21	1.001124
22	1.001124
…	…

Import campaign gravity data file

Next, the user enters the generic name of raw gravity data files. The complete name consists in the line number followed by this generic name.



In this example, the raw gravity data file names are “11datagravi.txt”, “21datagravi.txt” and “22datagravi.txt”. These files must be in the Scintrex CG5 format, *i.e.* a text file with 15 columns including:

1. Line number, e.g. “11”.
2. Station number, *e.g.* “1101”.
3. Ambient temperature in degrees, *e.g.* “22.7891’.

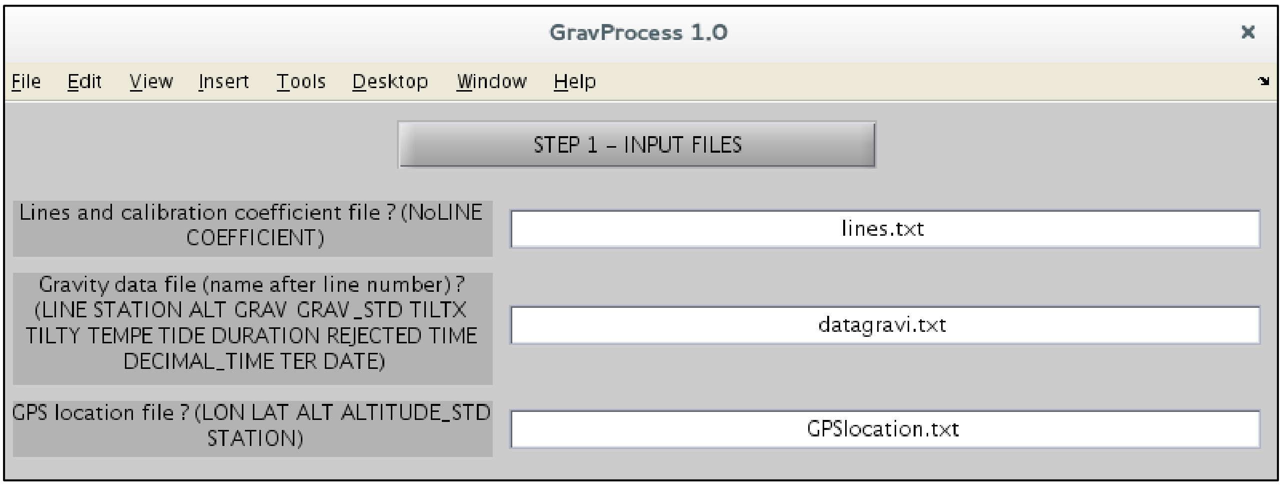
4. Gravity measurement in mGal, *e.g.* "5467.345".
5. Standard deviation of the mean of the five-second samples in mGal, *e.g.* "0.035".
6. Tilt about the X-axis in arcsecond, *e.g.* "1.8".
7. Tilt about the Y-axis in arcsecond, *e.g.* "-2.7".
8. Gravity sensor Temperature in mK, *e.g.* "-5.29".
9. Tidal correction in mGal, *e.g.* "0.012"
10. Duration of measurement in seconds, *e.g.* "90".
11. Number of rejected samples, *e.g.* "7".
12. Start time of measurements in hours:minutes:seconds, *e.g.* "10:32:55".
13. Decimal start time in decimal days, *e.g.* "41691.4296".
14. Terrain correction in mGal, *e.g.* "0.000".
15. Date in year/month/day, *e.g.* "2014/03/20".

⚠ A station measured several times must have the same station number.

Location file

Accurate locations of gravity measurement are needed to calculate corrections. The user must provide the path and the name of the location file. In the example we use "GPSlocation.txt" in the current directory. The location file consists in a 5 columns text file including:

1. Longitude in decimal degree, *e.g.* "6.4567".
2. Latitude in decimal degree, *e.g.* "34.9356".
3. Elevation in meter, *e.g.* "1052.87".
4. Standard deviation of the elevation in meter, *e.g.* "0.3".
5. Station number, *e.g.* "1101".



Network adjustment

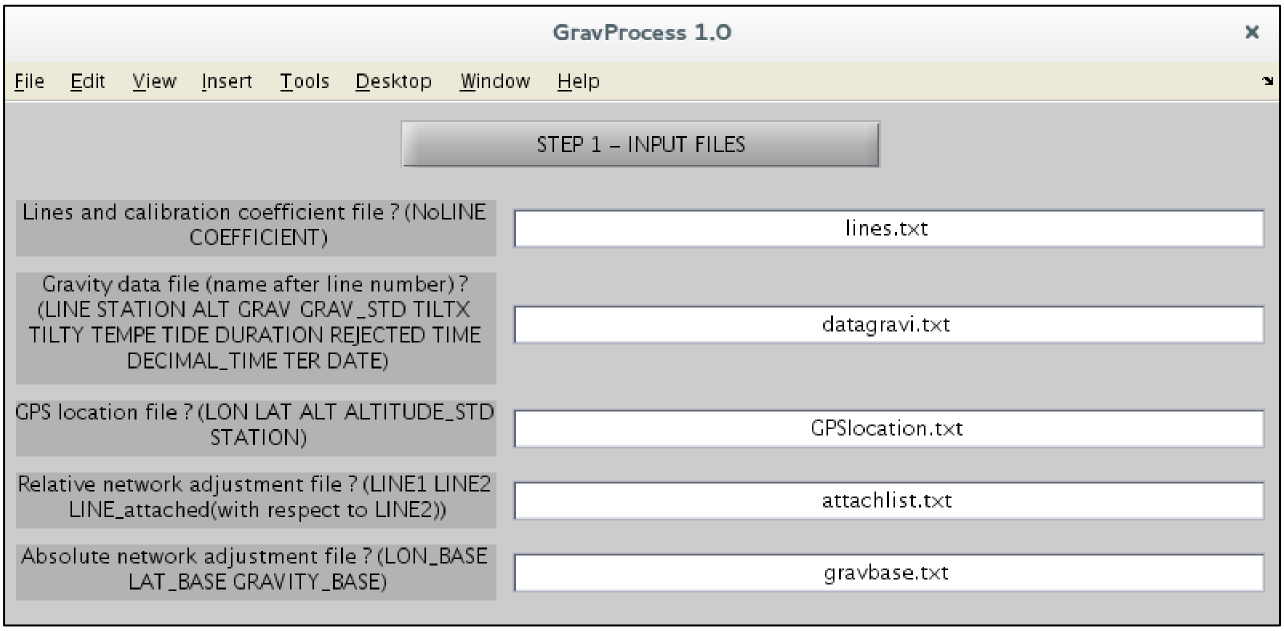
The user enters the paths and names for two files used for the network adjustment. The first one (attachlist.txt in the example) defines to successive adjustments of pairs of gravity lines. This file consists in 3 columns: (1) the first input line number, (2) the second input line number and (3) the number of the combined and adjusted output line:

1	2	12
3	4	34
5	12	512
6	34	634
512	634	0

In this example lines "1" and "2" are adjusted together in a new line "12", lines "3" and "4" in a new line "34", lines "5" and "12" in new line "512", … Line "0" corresponds to the final one, for which all relative gravity data are relative to a same reference.

The second file (gravbase.txt in the example) is used to adjust the relative data to a set of absolute base stations. This file is a 3 columns text file, with the location and value of absolute gravity bases in the study area:

1. Longitude in decimal degree, *e.g.* “6.4203”.
2. Latitude in decimal degree, *e.g.* “34.8456”.
3. Absolute gravity in mGal, *e.g.* “979588.32”.



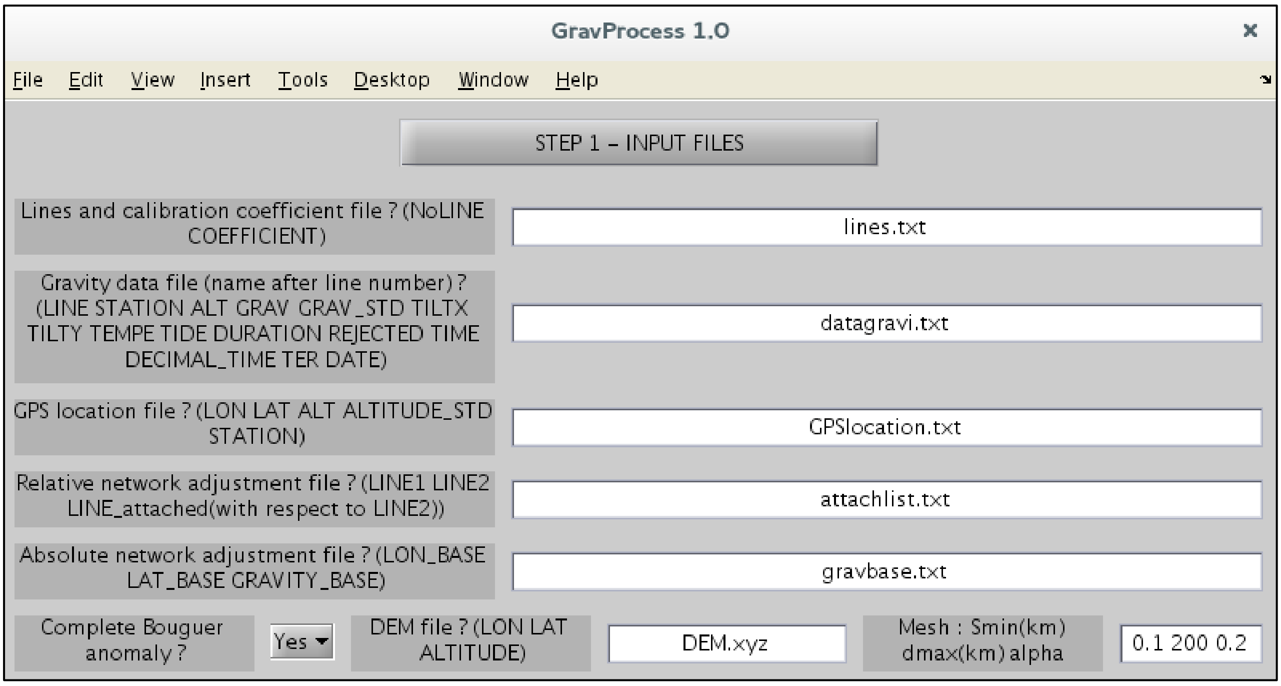
Terrain correction

A complete Bouguer correction is also proposed to account for local irregularities in topography around gravity stations. The Digital Elevation Model file (DEM.xyz here) must have 3 columns:

1. Longitude in decimal degree, *e.g.* “6.4529”.
2. Latitude in decimal degree, *e.g.* “34.7857”.
3. Elevation in meter, *e.g.* “132.4547”.

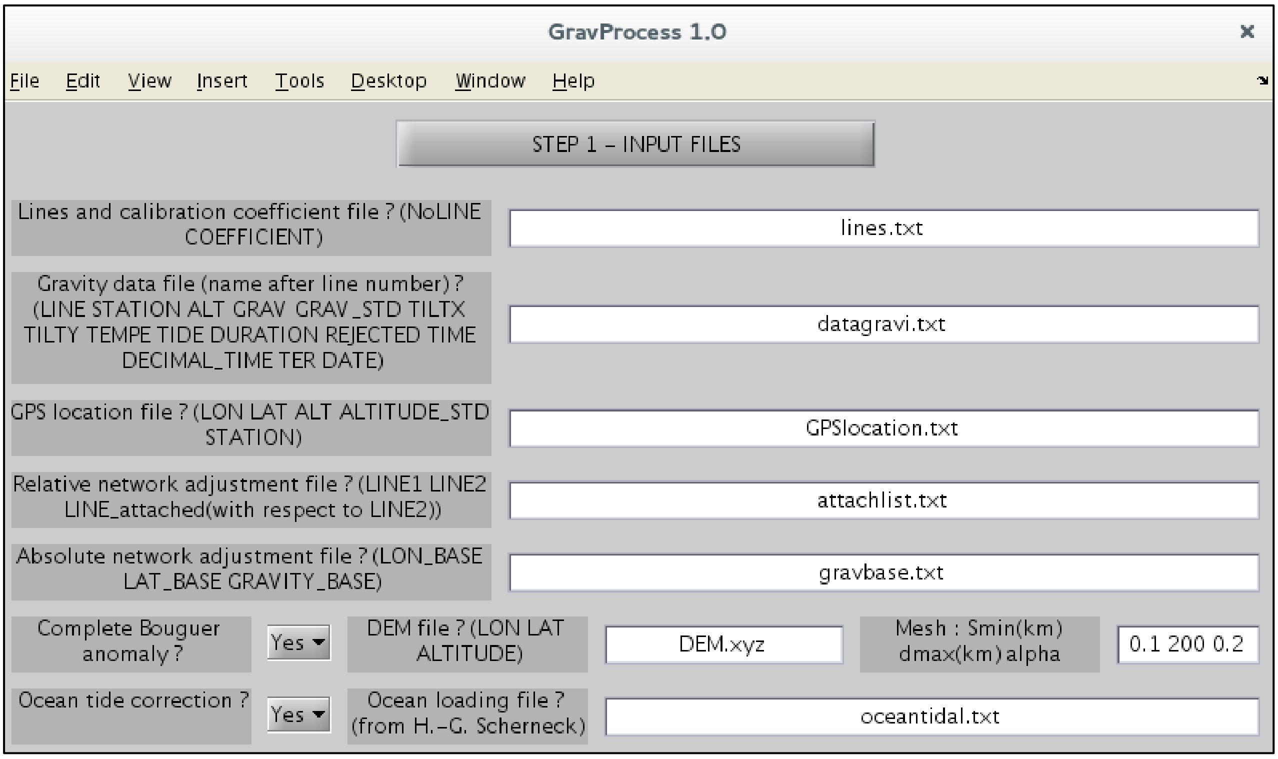
To improve processing speed performance, the elevation model is discretized with higher density near the gravity measurements. Three parameters are used to define the mesh refinement:

1. s_{min} is the mesh resolution at the measurement. It is expressed in km, *e.g.* “0.1”.
2. d_{max} is the radius of the circular area used for the correction. It is expressed in km, *e.g.* “200”.
3. α is a coefficient that controls the resolution relaxation with the distance from the measurement. α=0 means no mesh grid refinement.



Ocean tide correction

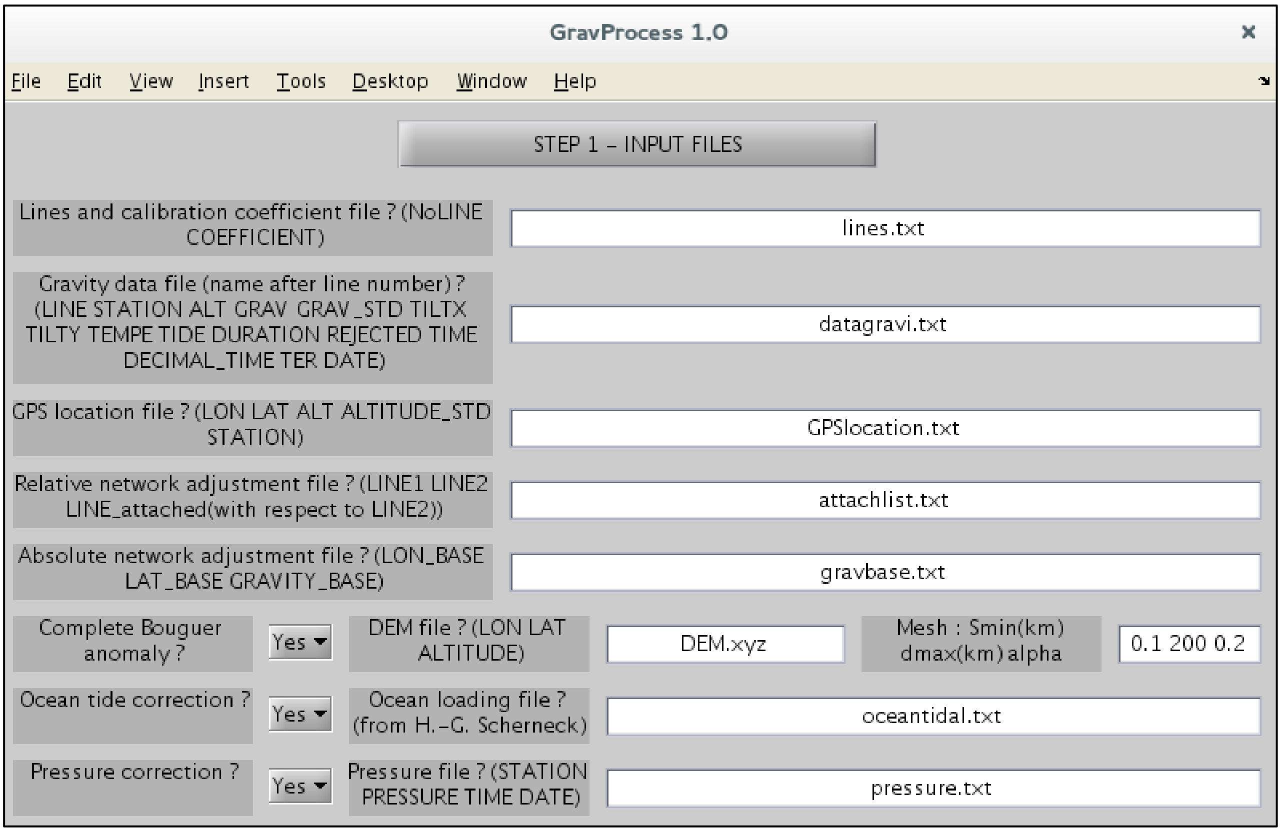
Ocean tide correction can be applied using the ocean-loading coefficients file provided by H.-G. Scherneck (http://holt.oso.chalmers.se/loading).



Pressure correction

Pressure correction is applied using the analytical formulation proposed by Torge (1989), which requires atmospheric pressure during gravity measurements. Input file consist in 4 columns:

1. Station number, *e.g.* “1101”.
2. Pressure in hPa, *e.g.* “1013.2”
3. Time of measurements in hours:minutes:seconds, e.g. “10:32:55”.
4. Date in year/month/day, *e.g.* “2014/03/20”.

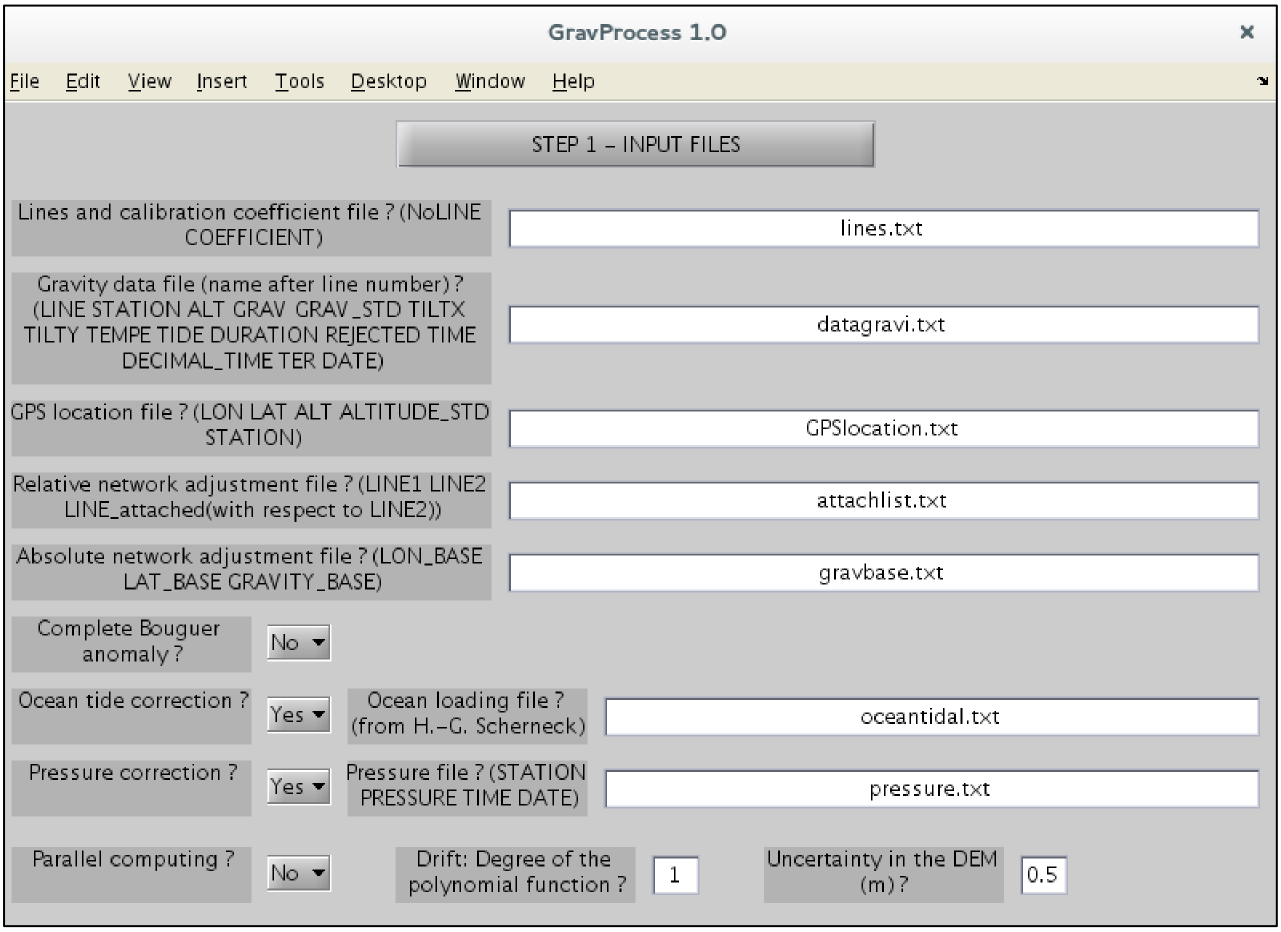


Others parameters

The user can perform parallel computation on multicore computers. This requires MATLAB^{TM} Parallel computing Toolbox.

Instrument drift is estimated by a least-square fit of the weighted time series at this station with an nth order polynom. The weighting factor used is the inverse of the standard deviation associated with each measurement. In many cases a first-order polynomial function is enough to remove short-term instrumental drift for lines with duration between hours and two days. For longer duration, a polynomial function of higher order can also be applied to remove non-linear instrumental drift. ⚠ Non-linear fit must be used with caution because it may remove signal.

Last, the user enters the elevation uncertainties in the DEM to assess the error in the calculated terrain corrections.



NB: Modification of specific parameters in the code subroutines

By default, raw measurements with a standard deviation greater than 0.2 mGal are discarded. This threshold can be modified into the subroutine loadgravi.m.

A standard density of 2670 kg/m^3 is used for terrain correction. This parameter can be easily changed in the subroutine graviterrain.m.

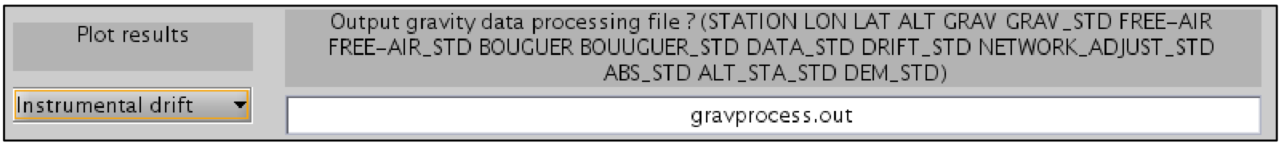
Absolute base station stations and relative measurements may not be at the same location. By default, absolute gravity measurements at a distance from campaign data greater than 100 m are discarded. This threshold can be modified into the subroutine gattachabs.m.

GRAVITY DATA PROCESSING

To process gravity data the user press the button “STEP2 – RUN GRAVITY DATA PROCESSING”. Depending of the total amount of data and resolution of the DEM, this step can take a few minutes to a few hours. Terrain correction is the most time consuming and can take 10 to 30 seconds per station. “Done” is written in red when processing is performed for all data.

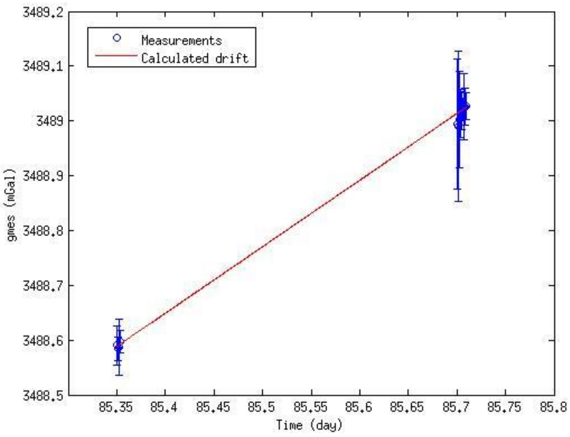
OUTPUT PLOTS AND OUTPUT FILES

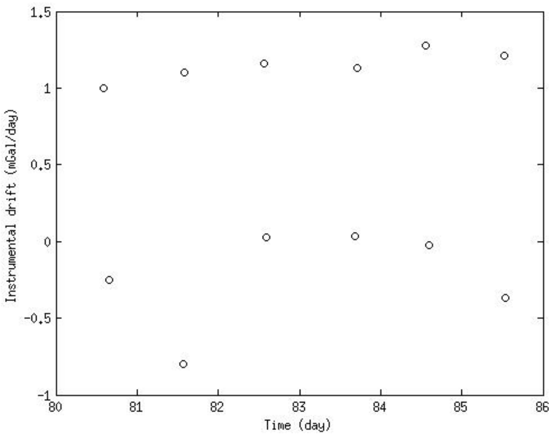
The post-processing tool provided in GRAVPROCESS consists in visualization of corrections, results and uncertainties using the MATLAB™ graphics tool box. All figures thus can be modified, saved or exported to other file format using figure toolbar.



Instrumental drift

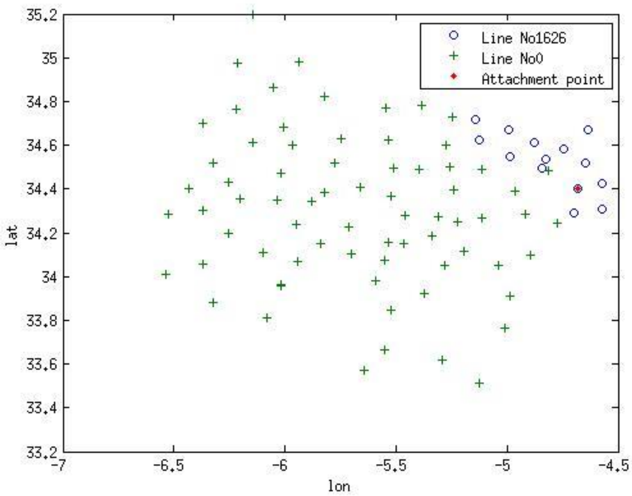
Drift is sampled at repeated base stations, which are defined as the stations with the longest time interval between repeated measurements. A first set of output plots shows for each line the repeated measurements and the associated drift. A second type of plot shows the drift variation estimated for the gravimeters used in the study.





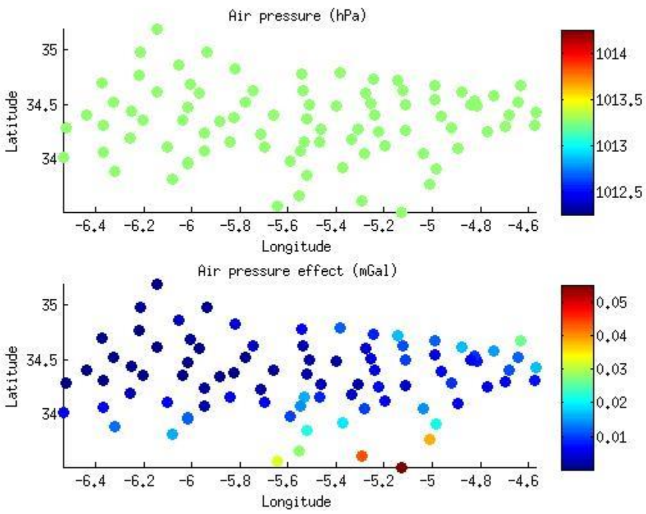
Network adjustment

Following the network adjustment file, GRAVPROCESS provides successive figures showing both pairs of gravity lines and common stations locations.



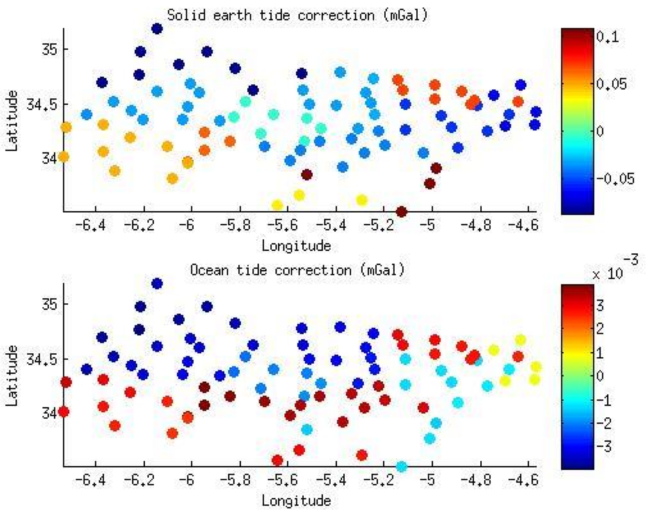
Air pressure effect

The pressure correction plot shows the air pressure measured nearby the campaign gravity measurements and the pressure correction.



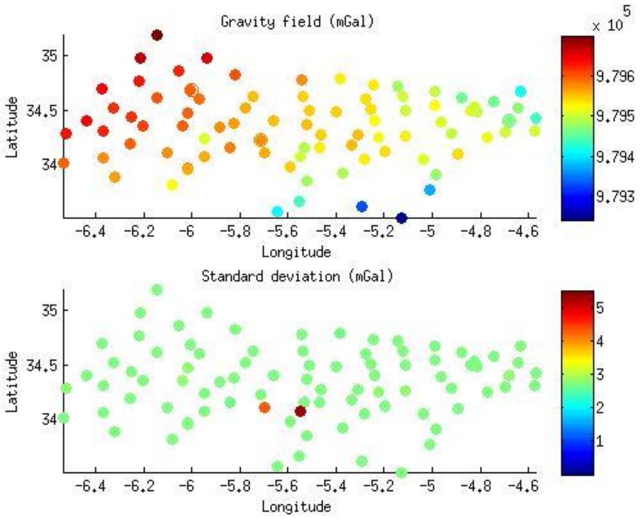
Earth and Ocean tides

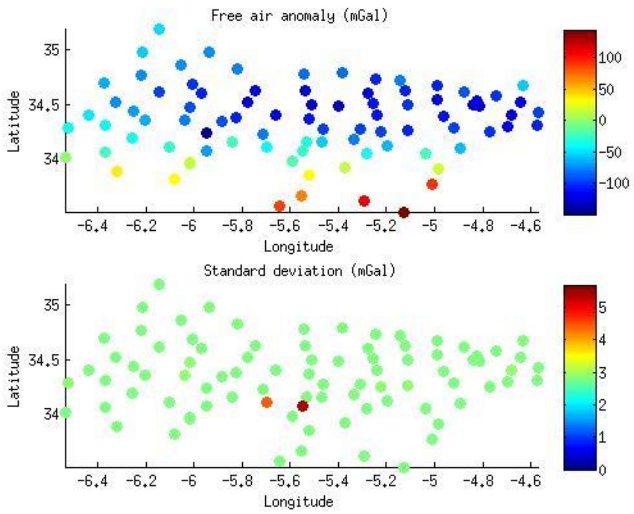
The tide plot shows the corrections for solid earth tide and ocean tide at the location of measurements.

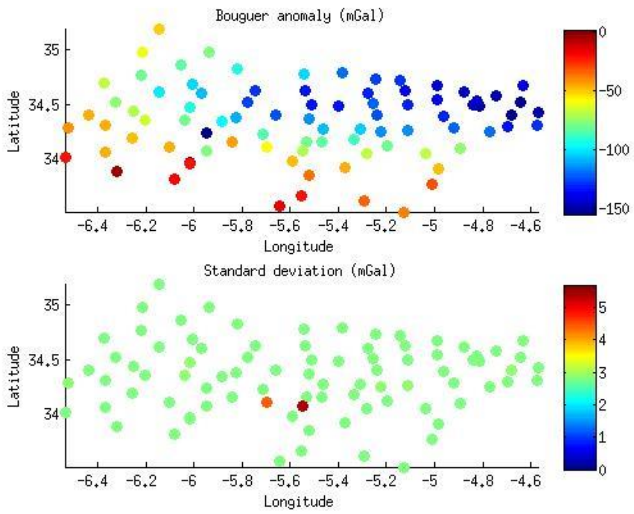


Gravity field – Free Air anomaly – Bouguer anomaly

Maps of the gravity field, free air, and Bouguer anomalies and their associated uncertainties can be plotted separately.

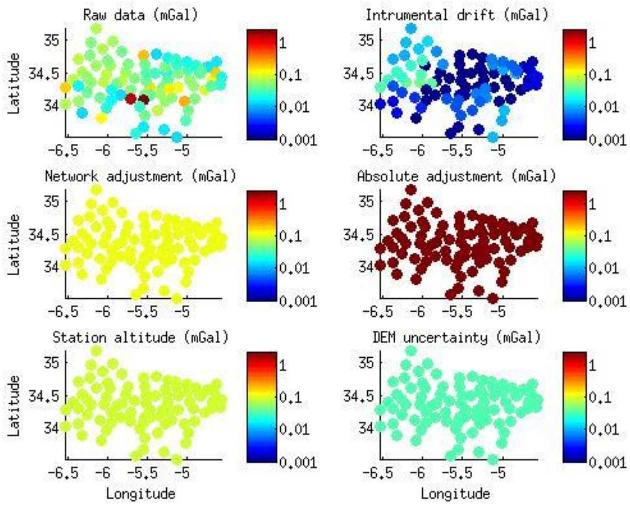






Uncertainties

The last figure shows the standard deviation associated with raw data, instrumental drift, network adjustment, measurements elevation and Digital Elevation Model uncertainties.



Output files

The user can save the processing results into an output file, which consists in a 16 columns file text:

1. Station number.
2. Longitude in decimal degree.
3. Latitude in decimal degree.
4. Elevation in meter.
5. Gravity field in mGal.
6. Total gravity field uncertainties in mGal.
7. Free air anomalies in mGal.
8. Total free air uncertainties in mGal.
9. Bouguer anomalies in mGal.
10. Total Bouguer uncertainties in mGal.
11. Raw data uncertainties in mGal.
12. Uncertainties associated with instrumental drift in mGal.
13. Uncertainties associated with relative network adjustment in mGal.
14. Uncertainties associated with absolute network adjustment in mGal.
15. Uncertainties associated with stations elevation in mGal.
16. Uncertainties associated with DEM in mGal.

This file can be used as input file in Geographic Information System softwares.

REFERENCE

Cattin, R., Mazzotti, S., Baratin, L.M, 2015. GravProcess : An easy-to-use MATLAB program to process campaign gravity data and evaluate the associated uncertainties, Computer & Geosciences, 81, 20-27.

Torge, W.T., 1989. Gravimetry. Walter de Gruyter, New York, Berlin, 465 pp.