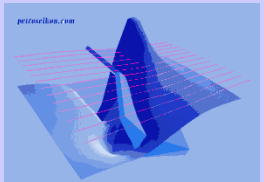
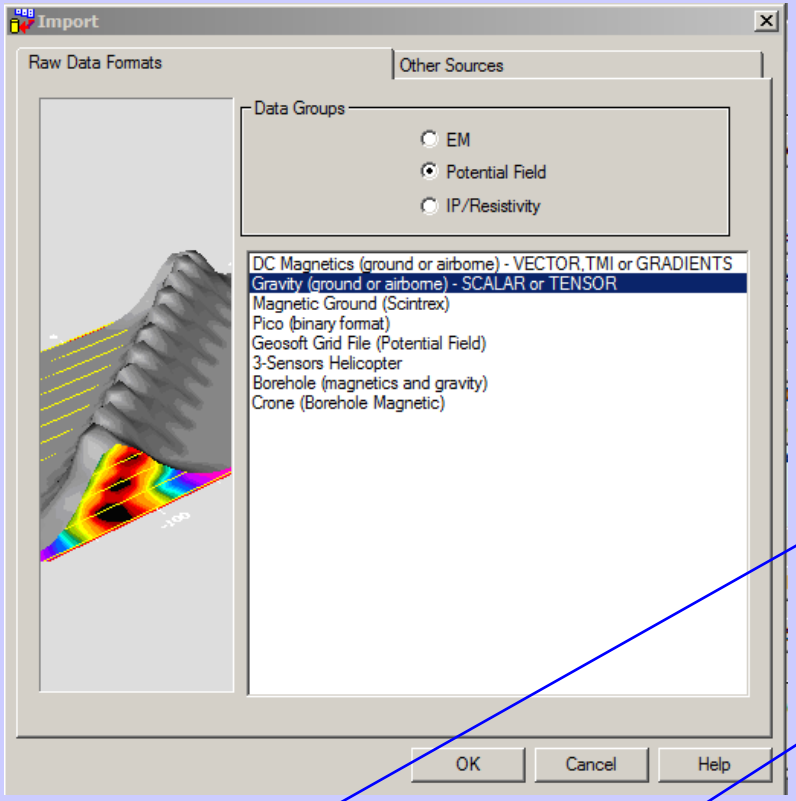
3D GRAVITY INVERSION TUTORIAL

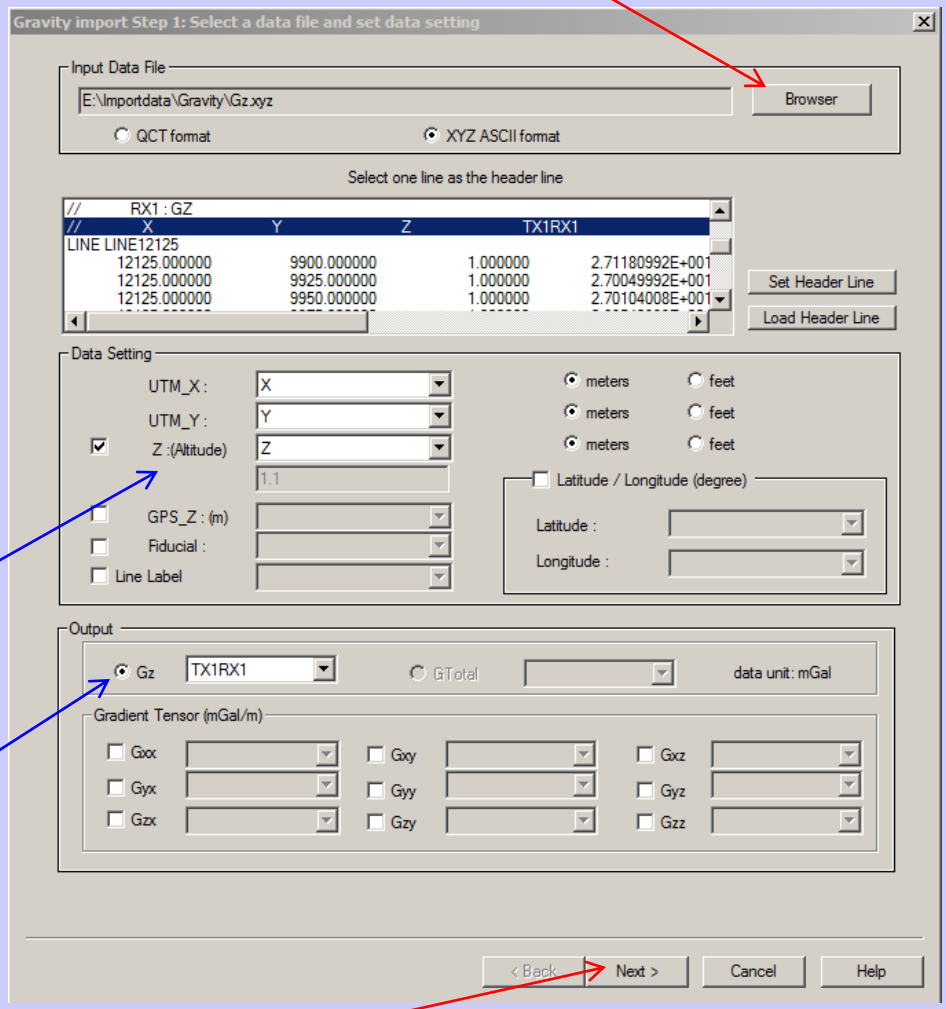
Steps: ***Page***



1. **Import data**
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. Check model and create plots

Browse and select .qct or .xyz data file for import



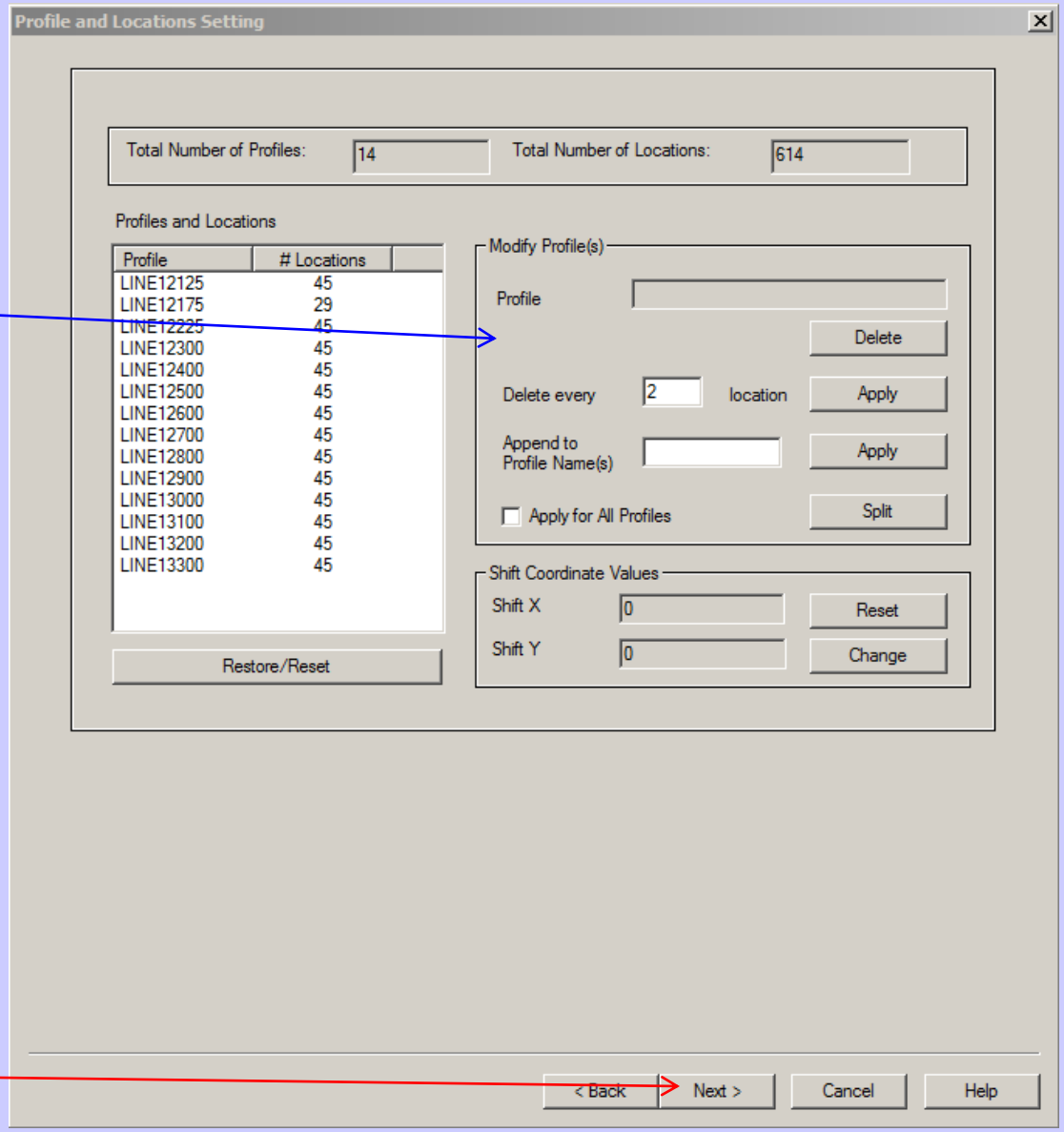


Set coordinate axis and output data column names

Click “Next “ button

1. **Import data**
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. Check model and create plots

Show profile information, and users can perform delete/reduction/shift operations on profiles in this dialog



Click “Next “ button

1. **Import data**
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. Check model and create plots

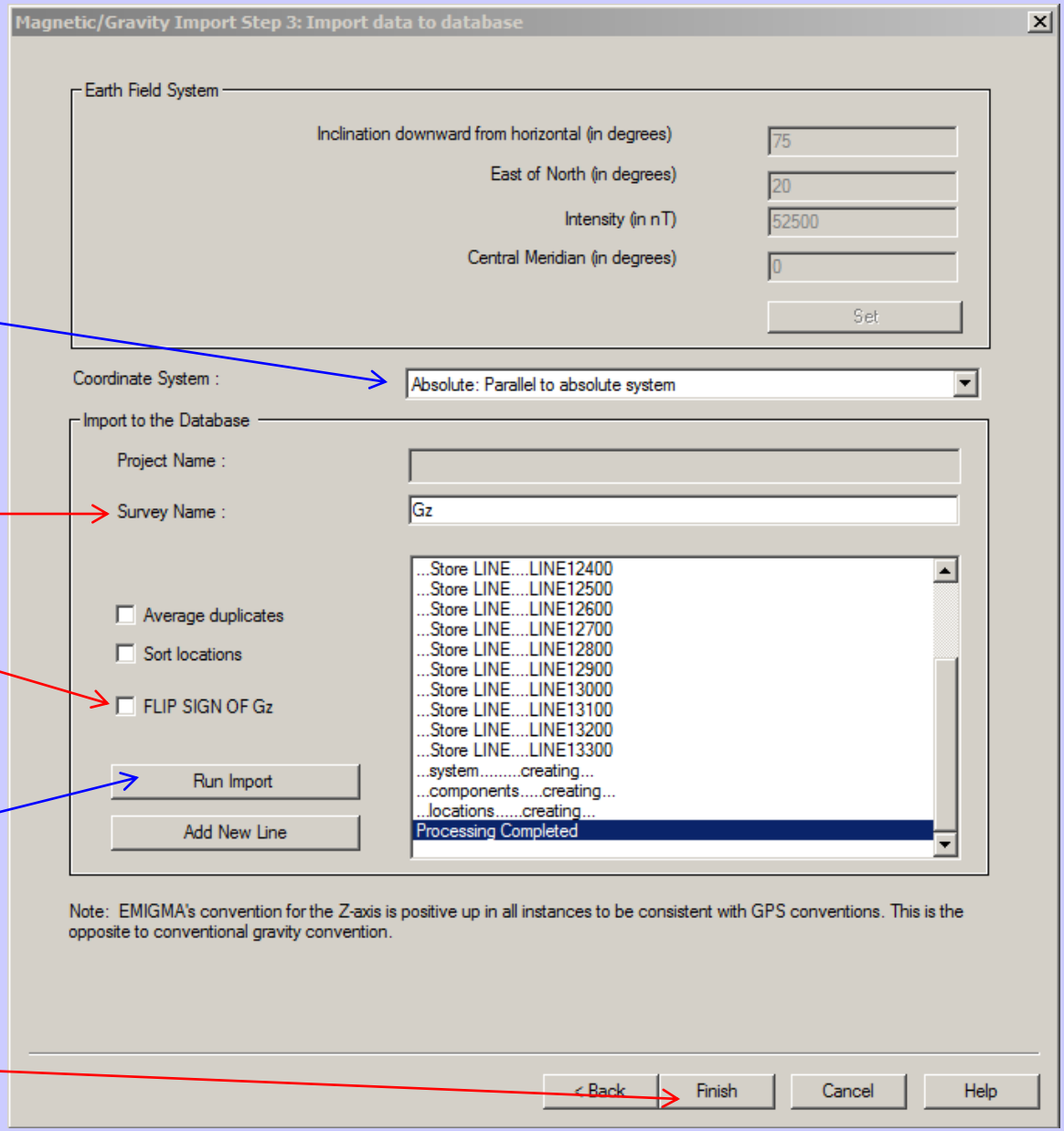
Select coordinate system

Set survey name

Flip sign of Gz data if it is not in accordance with the system

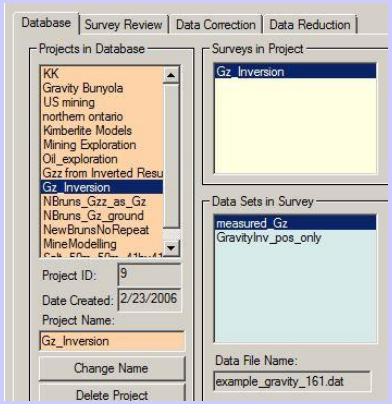
Click "Run Import" button to start importing data into database

After processing is done, click "Finish" button to complete this procedure

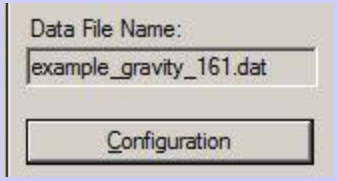


1. Import data
2. **Examine data**
3. Perform initial modeling
4. Perform 3D gravity inversions
5. Check model and create plots

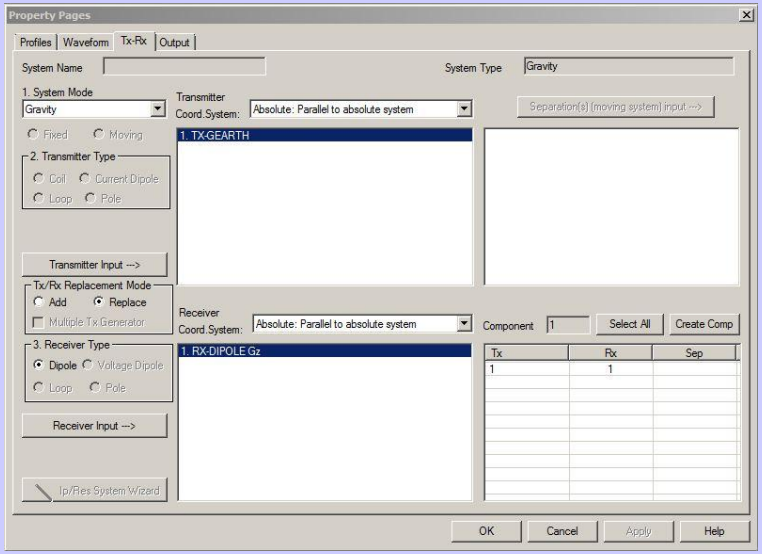
1. Check database for the survey



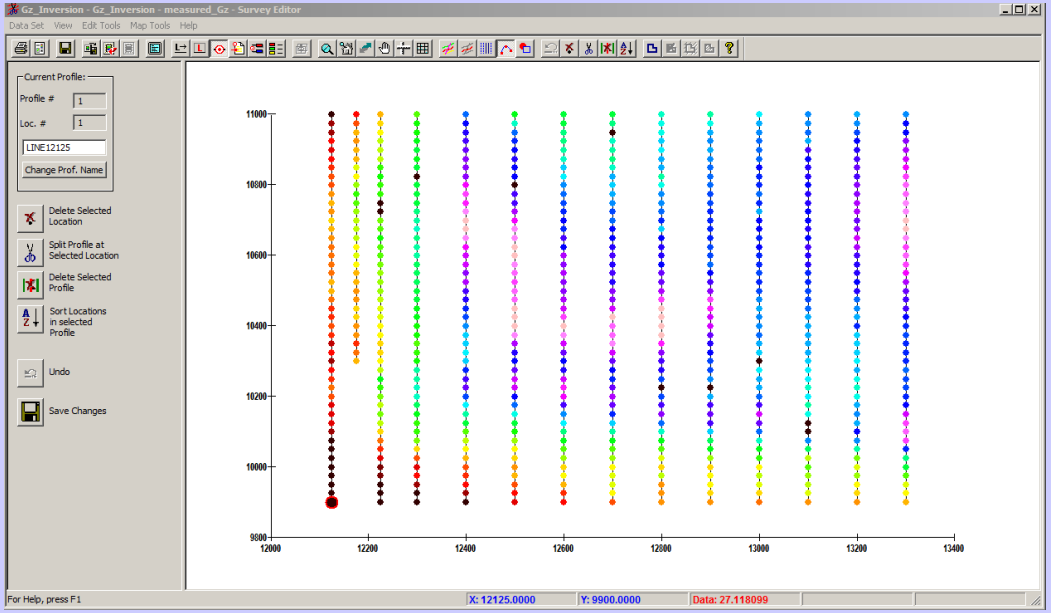
2. Click configuration



3. Check system configuration



4. Check lines and stations by clicking "Survey Editor" button 

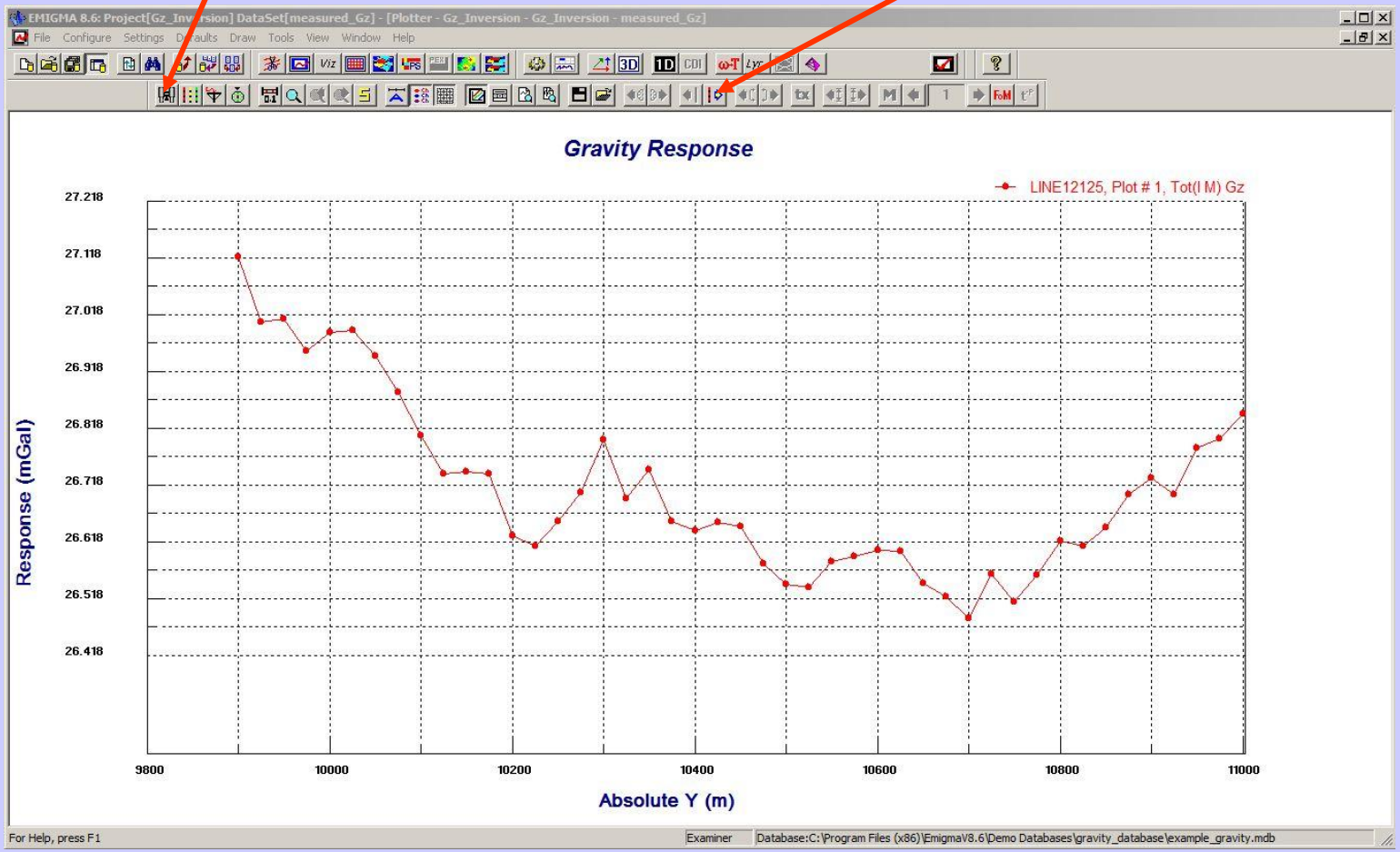


1. Import data
2. **Examine data**
3. Perform initial modeling
4. Perform 3D gravity inversions
5. Check model and create plots

Click “Plotter”…

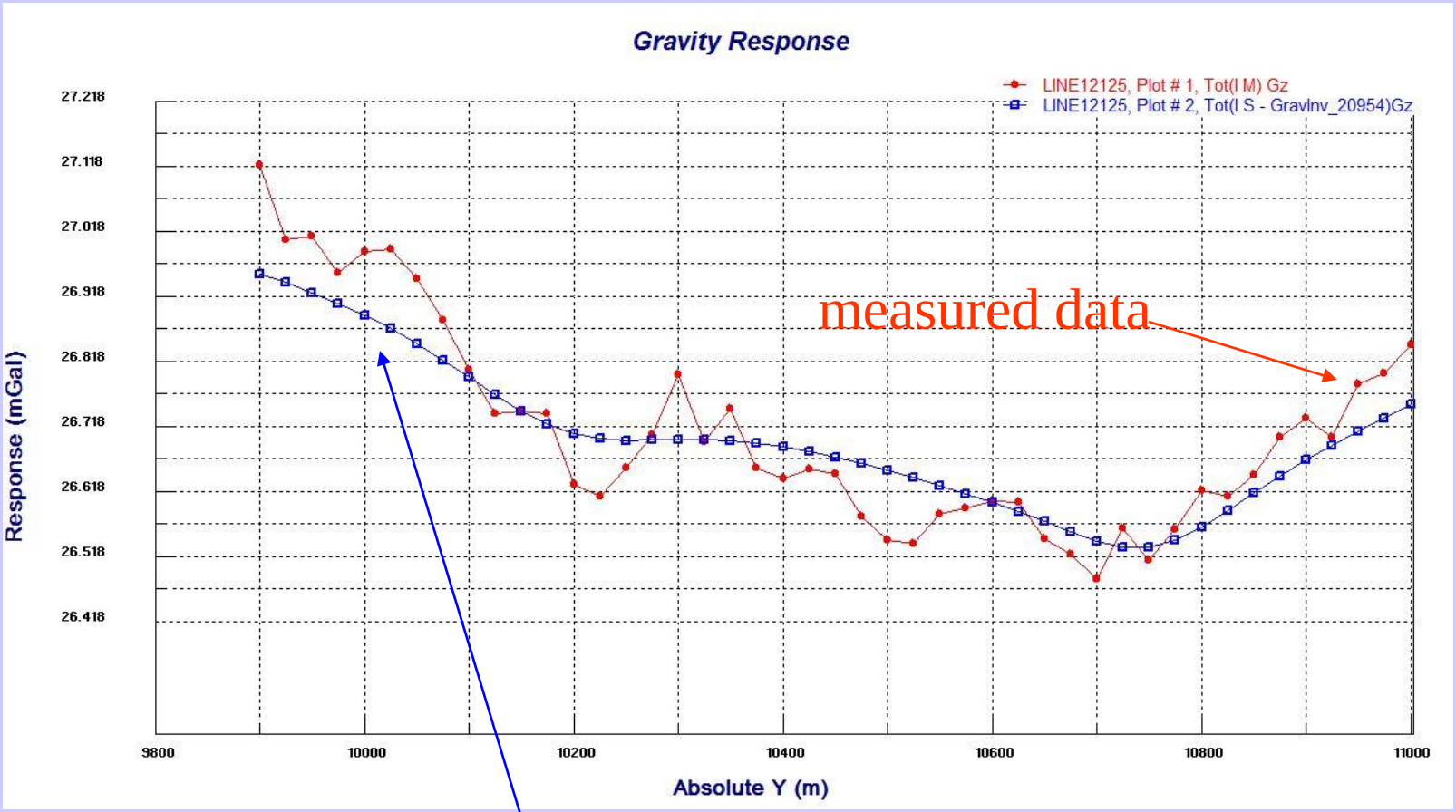
Load data set in plotter

Toggle between profiles

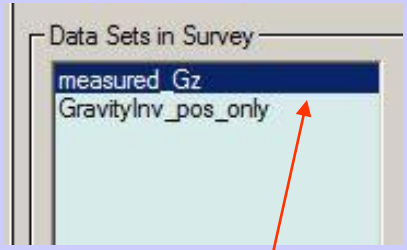


1. Import data
2. Examine data
3. **Perform initial modeling**
4. Perform 3D gravity inversions
5. Check model and create plots

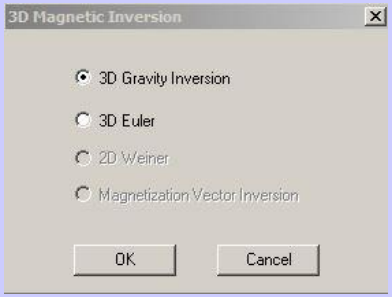
Note: *Performed some initial modeling to get a "feel" of the data and estimate parameters of initial model for inversion.*

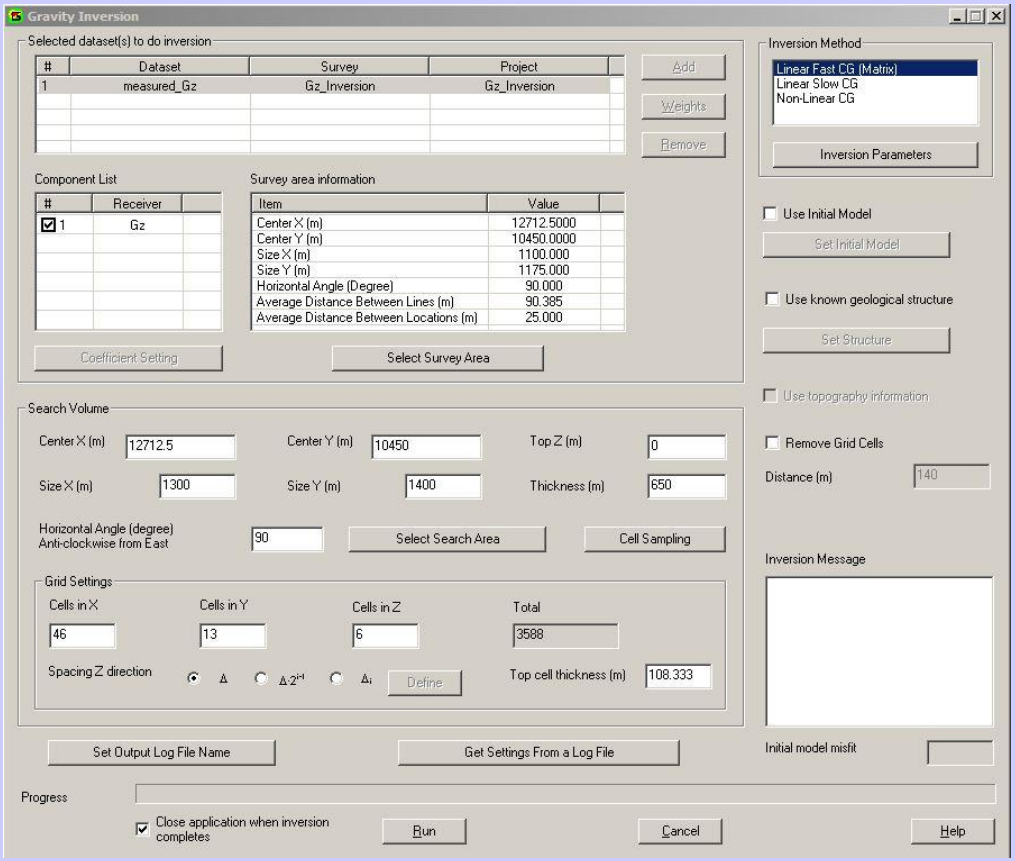


1. Import data
2. Examine data
3. Perform initial modeling
4. **Perform 3D gravity inversions**
5. Check model and create plots

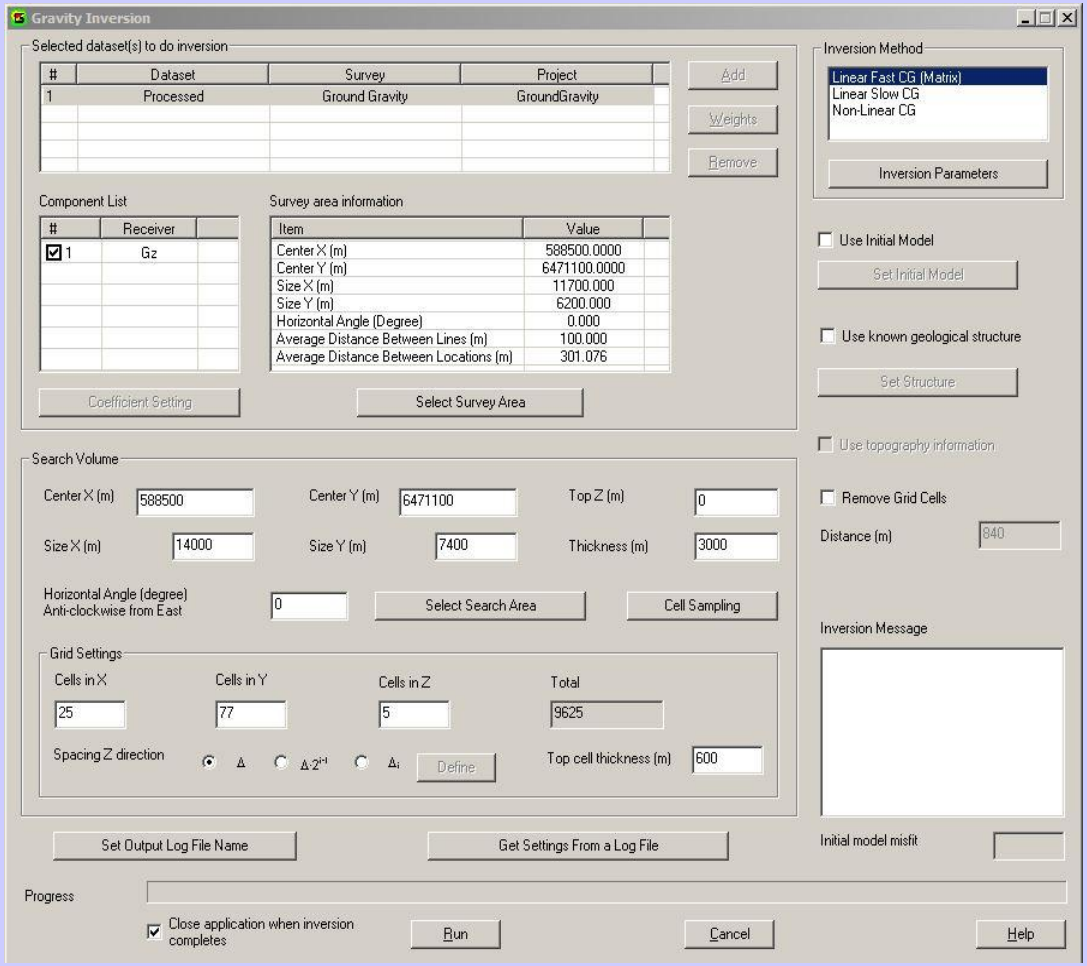


Select measured data





1. Import data
2. Examine data
3. Perform initial modeling
4. **Perform 3D gravity inversions**
5. Check model and create plots



Selected Data Sets

A dataset may be added for use in the inversion by clicking **Add**. Each dataset is given equal weight by default. This can be changed by clicking **Weights**.

Components

Components that will be used in the inversion are displayed here.

Log File

A log file is created each time an inversion is run. The name and location of the log file can be specified by clicking **Set Output Log File Name**. Click **Get Settings From a Log File** to use the settings from a previous inversion.

Use topography information

This option will be enabled if you imported your data with a gps z channel. Select this option and the gps z values will be used when performing the inversion. When loading inversion results to the visualizer, a window will appear asking to display the survey according to z or gps z. Select gps z to see the inversion results with topography.

Remove Grid Cells

Any cells that are beyond the specified **Distance** from the closest data point will be removed from the inversion result.

Geological Structure

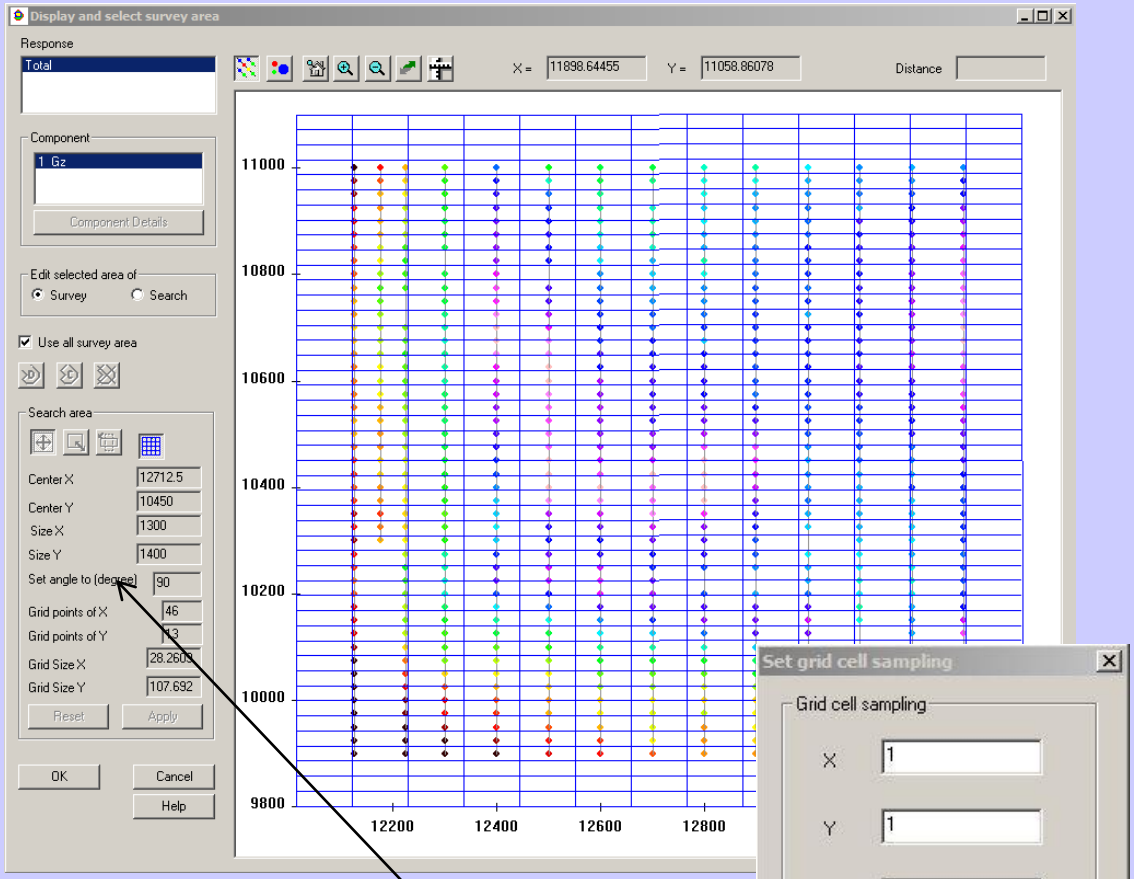
Click **Use known geological structure** to define a structure that will apply constraints to the inversion result.

Initial model misfit

Defines how close the initial model fits the data. The closer the value is to 0, the better the fit.

1. Import data
2. Examine data
3. Perform initial modeling
4. **Perform 3D gravity inversions**
5. Check model and create plots

Clicking either the **Select Search Area** or **Select Survey Area** buttons launches the same window. But search area means the area of data which the inversion algorithm works on, while survey area is the whole part of the imported survey data.



If change the value in "Set angle to (degree)" box, the angle between search area and survey area will be changed accordingly

Survey Area

Click the Select survey area button to launch the graphical tool which enables you to specify the data points that will be used in the inversion calculations.

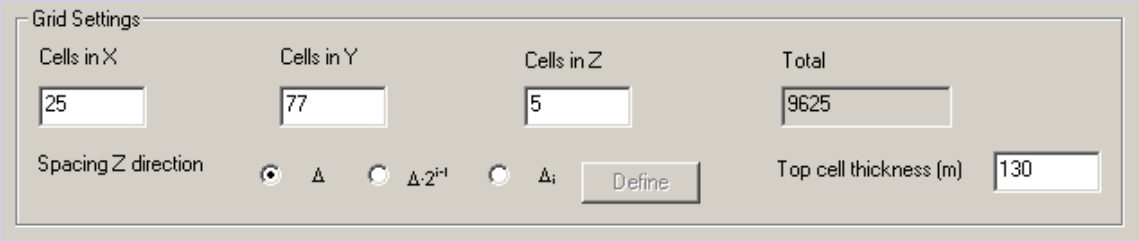
Search Volume

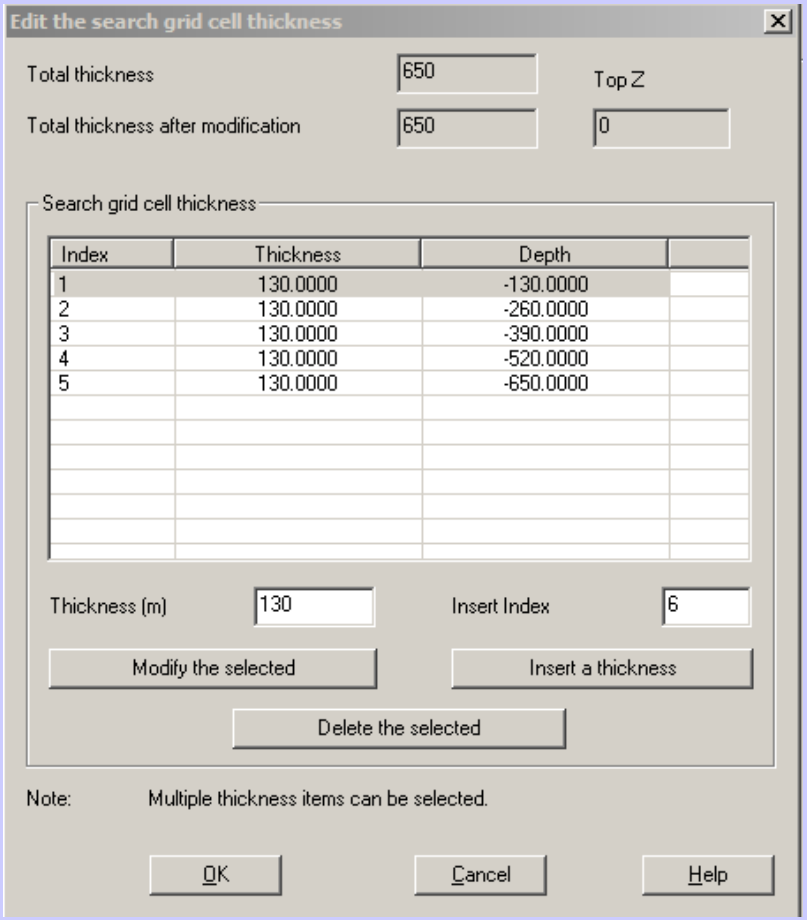
The default parameters in the **Search Volume** section will create a grid that covers the entire survey. You can modify the search area parameters by entering new values or by using the graphical tool

Cell Sampling

Grid cells defined in **Search Volume** can be divided into smaller units when calculate the simulated data by clicking **Cell Sampling.** Type your values in the **X**, **Y** and **Z** boxes to specify the number of samples in the X, Y and Z directions

1. Import data
2. Examine data
3. Perform initial modeling
4. **Perform 3D gravity inversions**
5. Check model and create plots





Grid Settings

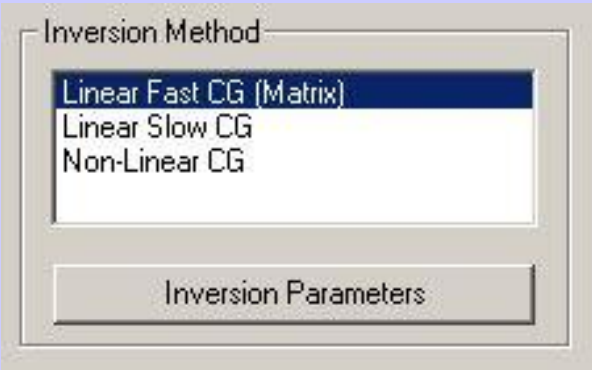
Confirm the number and layout of grid points to be used in the inversion in the **Grid Settings** area. The points will be evenly spaced in the x and y directions. Choose **Δ** for evenly spaced points in the z direction or $\Delta \cdot 2^{i-1}$ for exponentially spaced points. You may specify a custom spacing by selecting Δ_i. Your custom settings can be later modified by clicking **Define**.

Editing the Grid Cell Thickness

The interface displays the total thicknesses before and after editing as well as the topmost z value. The cell sizes are listed in the **Search grid cell thickness** section.

1. Import data
2. Examine data
3. Perform initial modeling
4. **Perform 3D gravity inversions**
5. Check model and create plots

Inversion Methods



There are three inversion methods to choose from. Set parameters for your chosen technique by clicking the Inversion Parameters button.

Linear Fast CG(Matrix) - Direct inversion technique that assumes that the forward function can be linearized. Quick technique but is bounded by solving for a small amount of parameters.

Linear Slow CG - Same as the fast technique but is necessary for cases when the number of data points or the number of grid cells is very large.

Non-Linear CG - General concept is to start with an initial guess and go looking for the best fitting model by minimizing a given function using an iteration process.

1. Import data
2. Examine data
3. Perform initial modeling
4. **Perform 3D gravity inversions**
5. Check model and create plots

Linear CG Technique

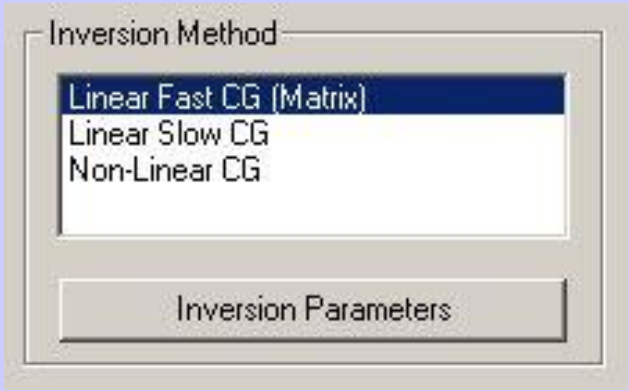
Assumes that the forward function can be linearized. Quick technique but is bounded by solving for a small amount of parameters.

$$\mathbf{d} = \mathbf{F}\,\mathbf{m}$$

$\mathbf{d} \rightarrow$ **vector of N – dimension**

$\mathbf{F} \rightarrow$ **Matrix of N × M – dimension**

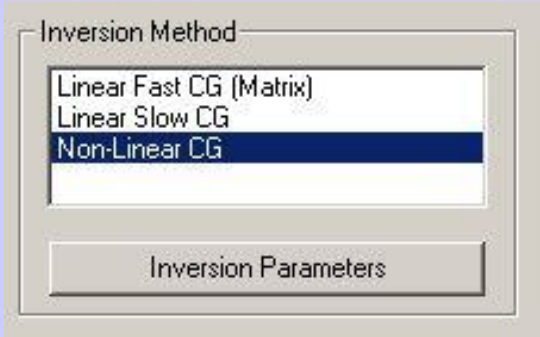
$\mathbf{m} \rightarrow$ **vector of M – dimension**



$$H_{ext}(r) = \int G(r,r')J(r')dr'$$

$$J(r') = (m(r') - m_0)H_{ins}(r') = \chi(r')H_{ins}(r')$$

1. Import data
2. Examine data
3. Perform initial modeling
4. **Perform 3D gravity inversions**
5. Check model and create plots



Non-Linear CG

General concept is to start with an initial guess and go looking for the best fitting model by minimizing a given function using an iteration process.

Unconstrained Conjugate Gradient Minimization

Uses the derivative information to construct two sequences of orthogonal vectors to define the search direction at a given iteration. Then by trial and error (line search) to move to the local minimum in that direction. The iteration stops when the gradient has achieved the required minimum value. This is an unconstrained minimization technique where the bounds on the parameters are imposed after the search is completed.

Critical factors to Optimization Results:

- Good forward simulation algorithm
- Good minimization technique
- Good starting model
- Good data

$$\phi(m) = \lambda \phi_d(m) + \phi_m(m)$$

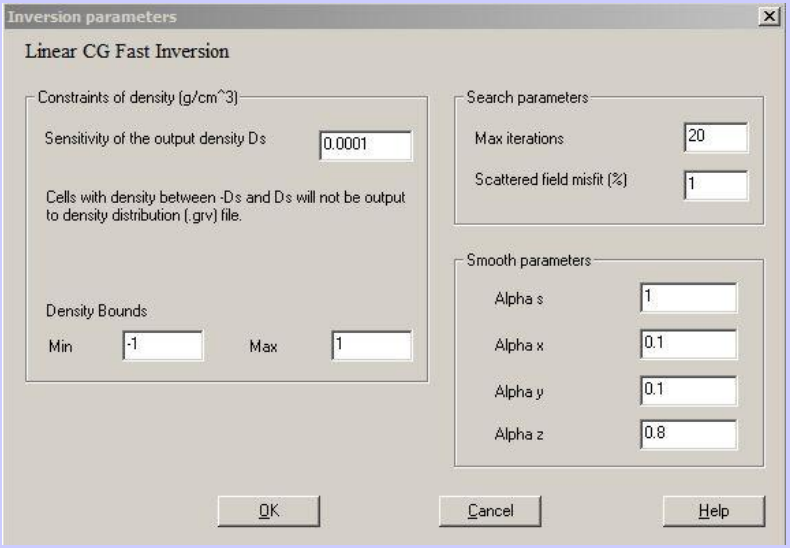
$\phi(m)$ - functional to be minimized
$\phi_d(m)$ - data misfit
$\phi_m(m)$ - model misfit
λ - Lagrangian multiplier - regularization weight

Occam style model misfit function

$$\phi_m(m) = \alpha_0 \int w^2(z) \, [\, m(r) - m^0(r) \,]^2 \, dv \; + \; \sum_{i=x,y,z} \alpha_i \int [\, w(z) \, \nabla_i \, (m(r) - m^0(r)) \,]^2 \, dv$$

α_I - weighting factors
w(z) - depth weighting

1. Import data
2. Examine data
3. Perform initial modeling
4. **Perform 3D gravity inversions**
5. Check model and create plots



Search Parameters

Maximum Iterations

User defines the number of iterations the program will run to generate the final solution. In general the default (25 for Linear Fast CG and about 15 for the others) is sufficient for the inversion.

Scattered field misfit

Defines the “stop” criteria for an iteration when the difference between the measured and simulated scattered field falls within a certain percentage of the measured value.

Smooth parameters

Larger values will increase the smoothness of the inversion result. **Alpha s** decreases the range of all the density values. **Alpha x, y and z** decreases the difference between the density of two neighboring cells in the x, y and z directions respectively.

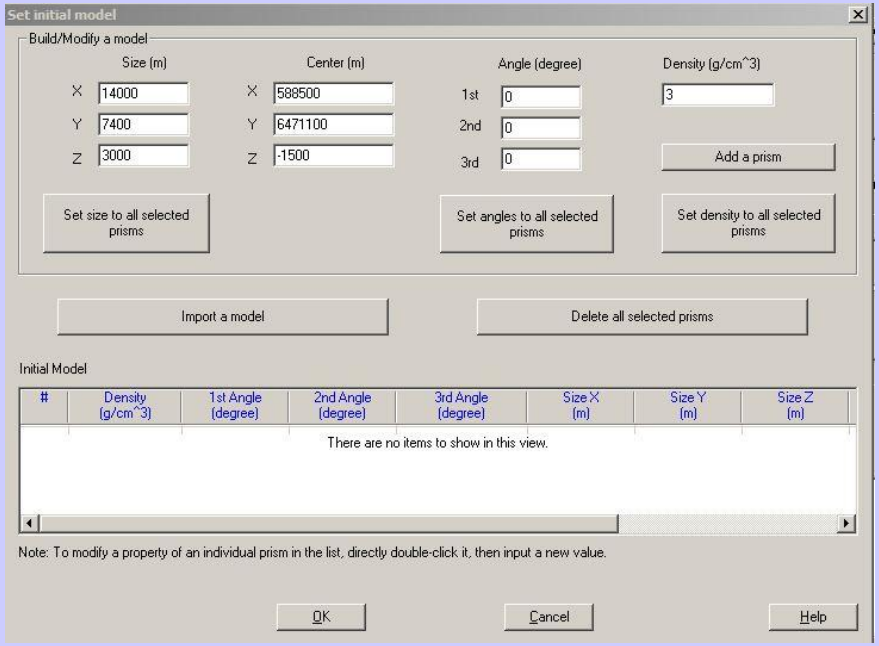
Constraint of Density

Output Sensitivity Cells with density |D| (close to 0 - where the user defines how close) are constrained or thrown out after each iteration. will not be output to the density distribution (.grv) files

Xmin Upon completion of iteration, X values less than Xmin will be set equal to Xmin

Xmax Upon completion of iteration, X values greater than Xmaz will be set equal to Xmax

1. Import data
2. Examine data
3. Perform initial modeling
4. **Perform 3D gravity inversions**
5. Check model and create plots



Initial Model

Click the checkbox labeled **Use Initial Model** to specify an initial model. Return to the initial model window by clicking the **Set Initial Model** button.

The starting model is described by a list of prisms with various properties in the box labeled **Initial Model**.

add a prism to the model list

Specify the density, size, position and orientation of the new prism in the **Build a model** section.
Click the **Add a prism** button.

modify an existing prism in the model list

Select the number of the prism to be modified in the anomaly list, and double-click the parameters to make modification directly.

delete prisms from the model list

Select the prisms to be deleted in the anomaly list.
Click **Delete all selected prisms**

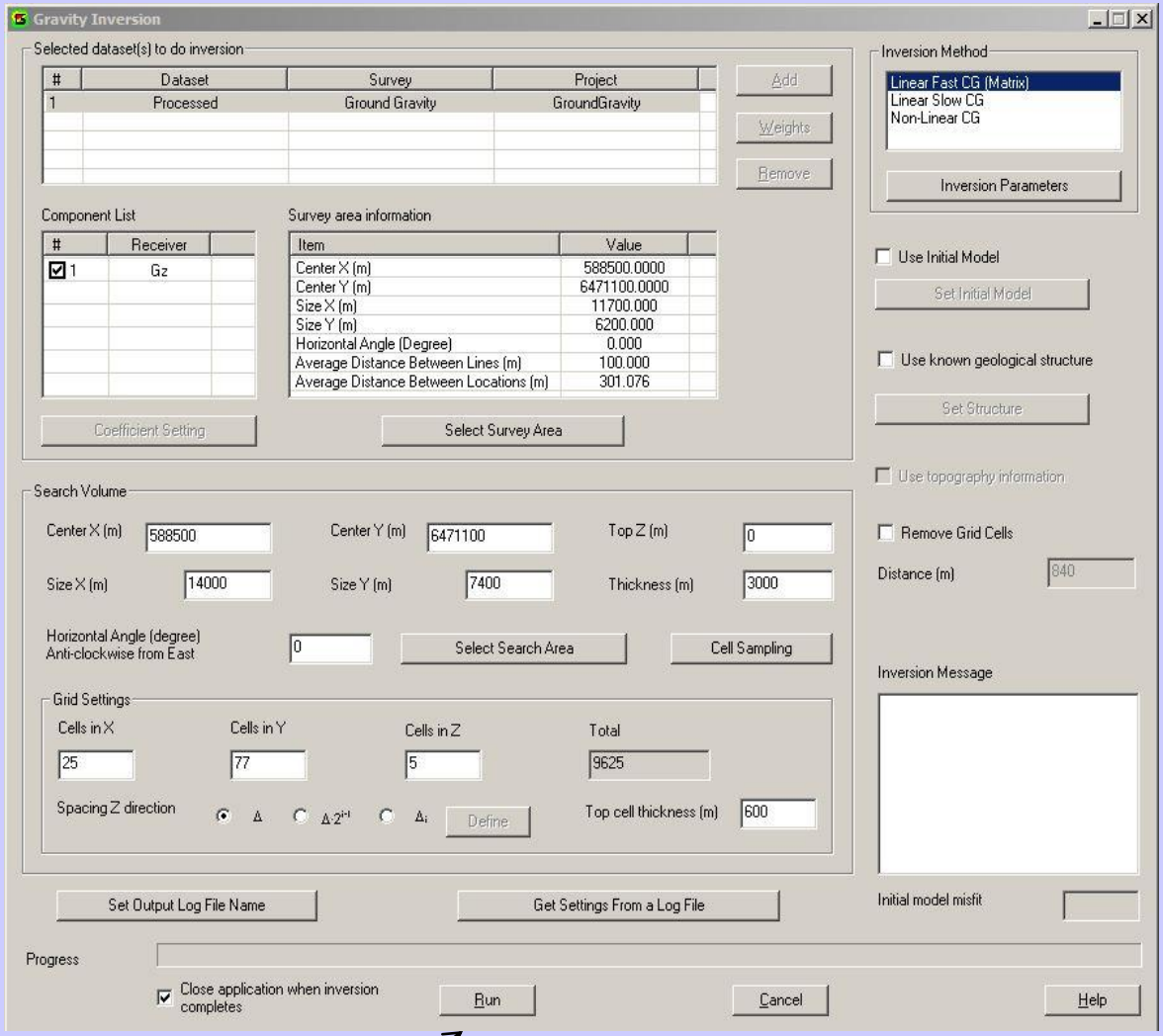
apply the same values for a group of selected prisms

Click the **Set density to all selected prisms** button to modify the density.
Click the **Set angles to all selected prisms** button to modify the angles.
Click the **Set size to all selected prisms** button to modify the size.

import a model from another data set in the current database

Click **Import a model**.
Select the project, survey, and data set with the desired model
Click **OK** and the model will appear in the **Initial Model**.

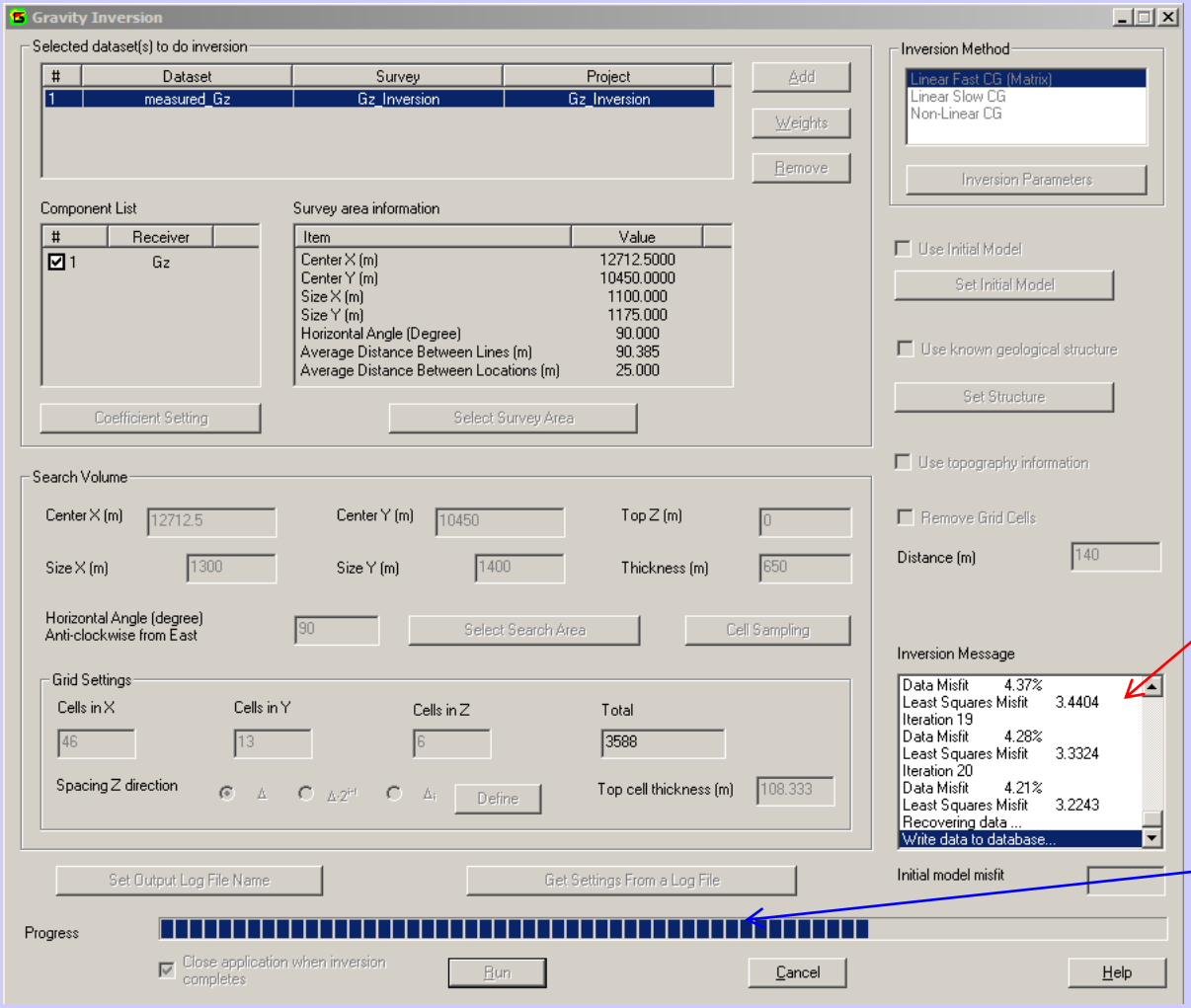
1. Import data
2. Examine data
3. Perform initial modeling
4. **Perform 3D gravity inversions**
5. Check model and create plots



- After settings are done, press **Run** button to start the inversion process.

1. Import data
2. Examine data
3. Perform initial modeling
4. **Perform 3D gravity inversions**
5. Check model and create plots

Executing the Inversion

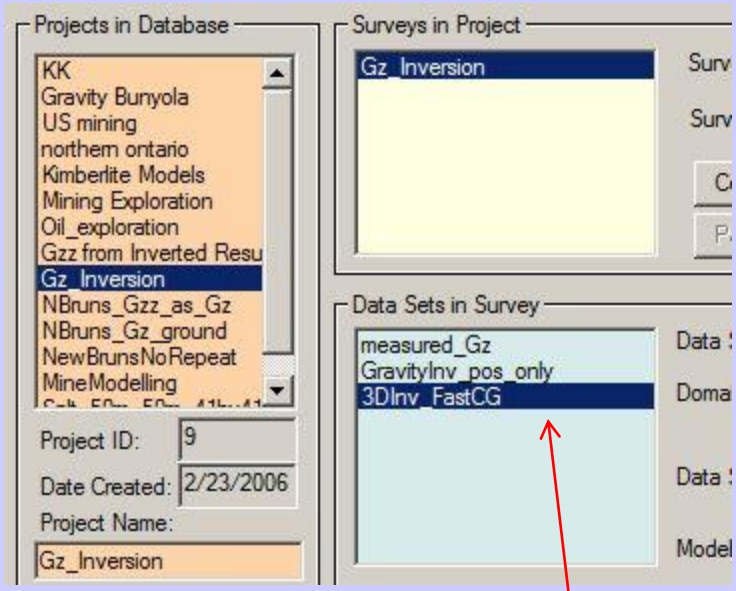


The right window (in white) shows each data point's progress.

The "Progress" bar shows the total progress of this inversion.

1. Import data
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. **Check model and create plots**

Inversion Evaluation

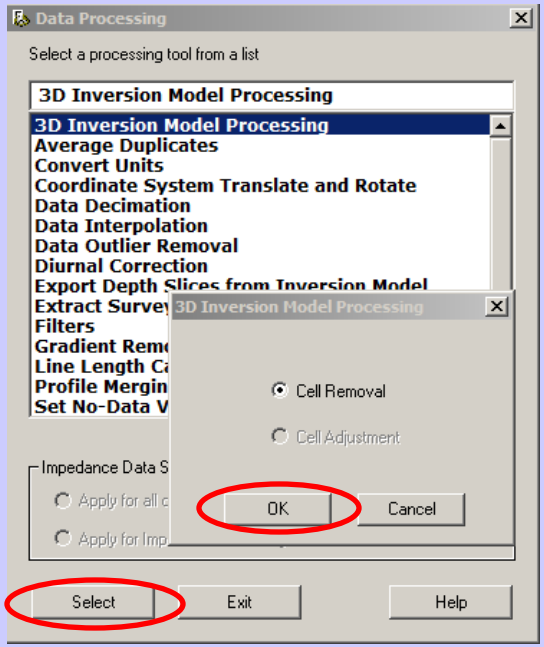


In each survey, there will be several data sets after modeling, inversion and processing. In this case, we have one forward model and one inversion model. The forward model has a new data set containing the simulated data under the model. Similarly, each inversion contains a new dataset containing the simulated data set under the inversion model (for each point) and attached to that data set is the inversion model.

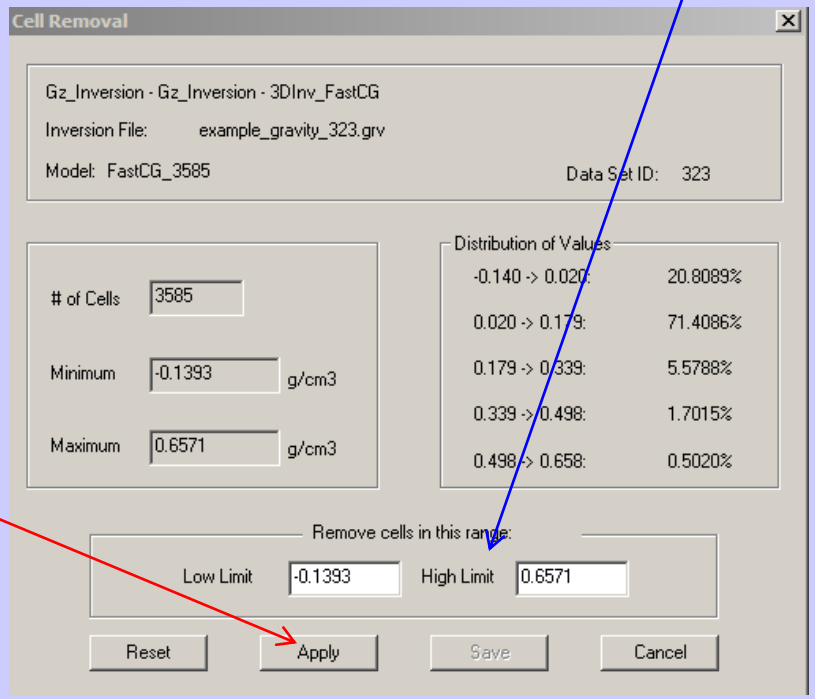
Our 3D gravity inversion model dataset

1. Import data
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. **Check model and create plots**

Inversion Evaluation



Users can use “3D Inversion Model Processing” tool to remove cells in inverted model. Follow the routine shown in this page and arrive “Cell Removal” dialog. Choose the removal range of cells: “Low Limit” and “High Limit” (any cell within this range will be removed)



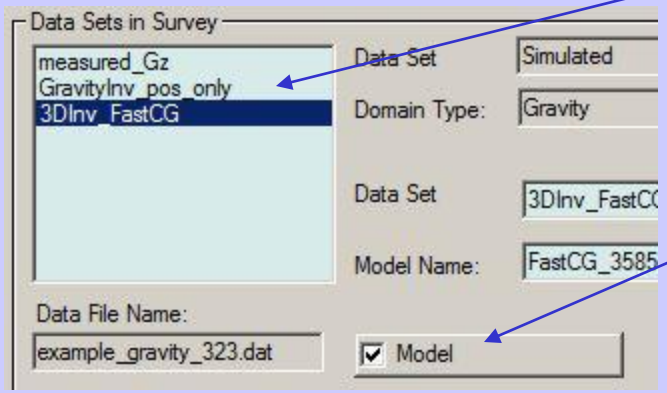
Click “Apply” button when it is done

Therefore, users can reduce the range of model either before inversion (by Select Search Area) or after inversion (by Cell Removal)

1. Import data
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. **Check model and create plots**

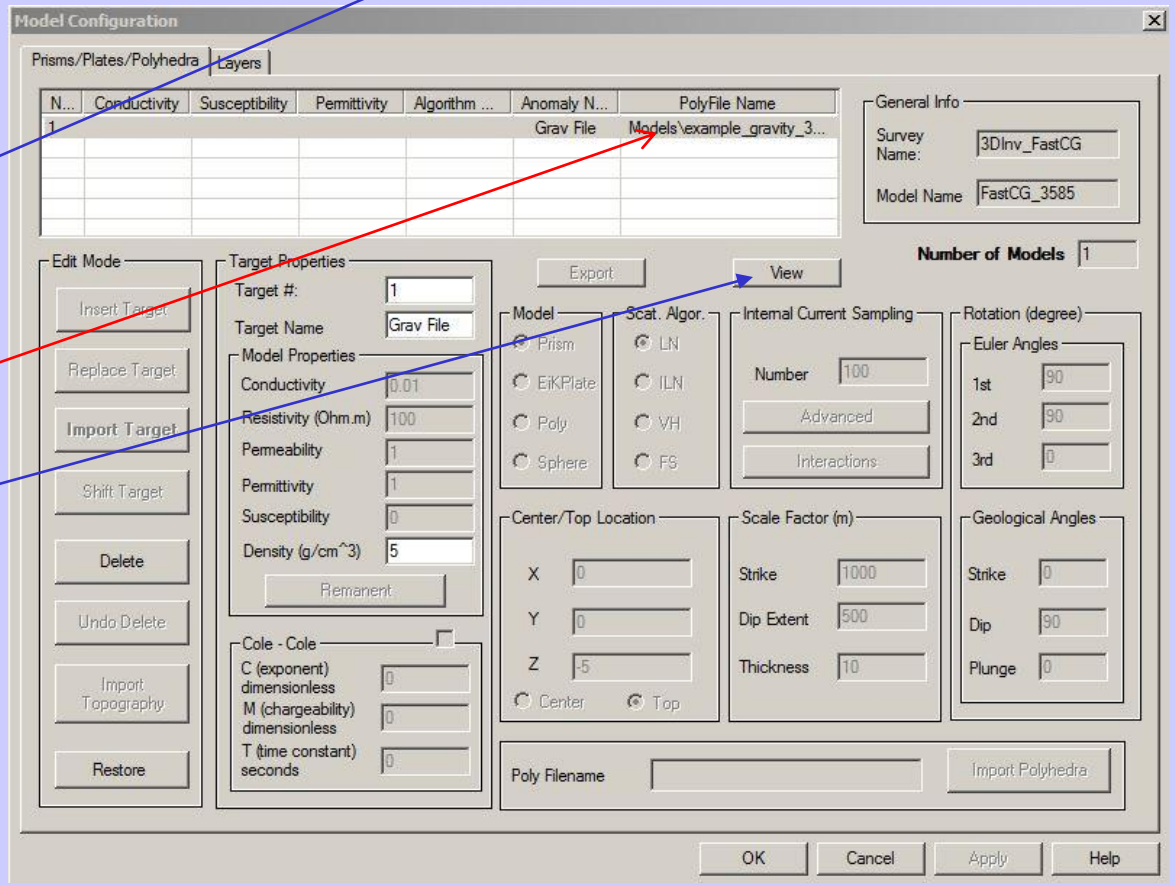
Inversion Evaluation

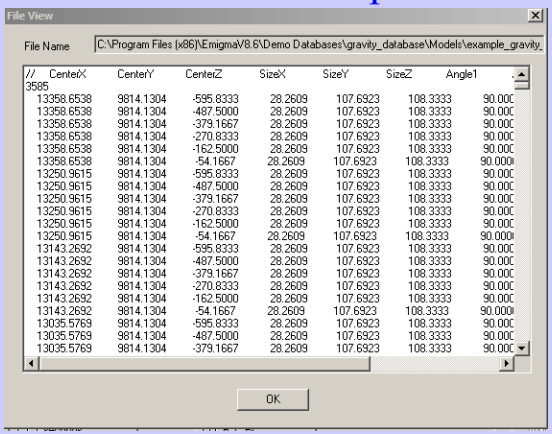
An inversion is selected. You will note the "Model" button is checked. If the "Model" button is clicked…



The model will be saved as a "Grav File" with its name and folder shown in the "PolyFile Name" column of the table

Click "View" button to open this file…

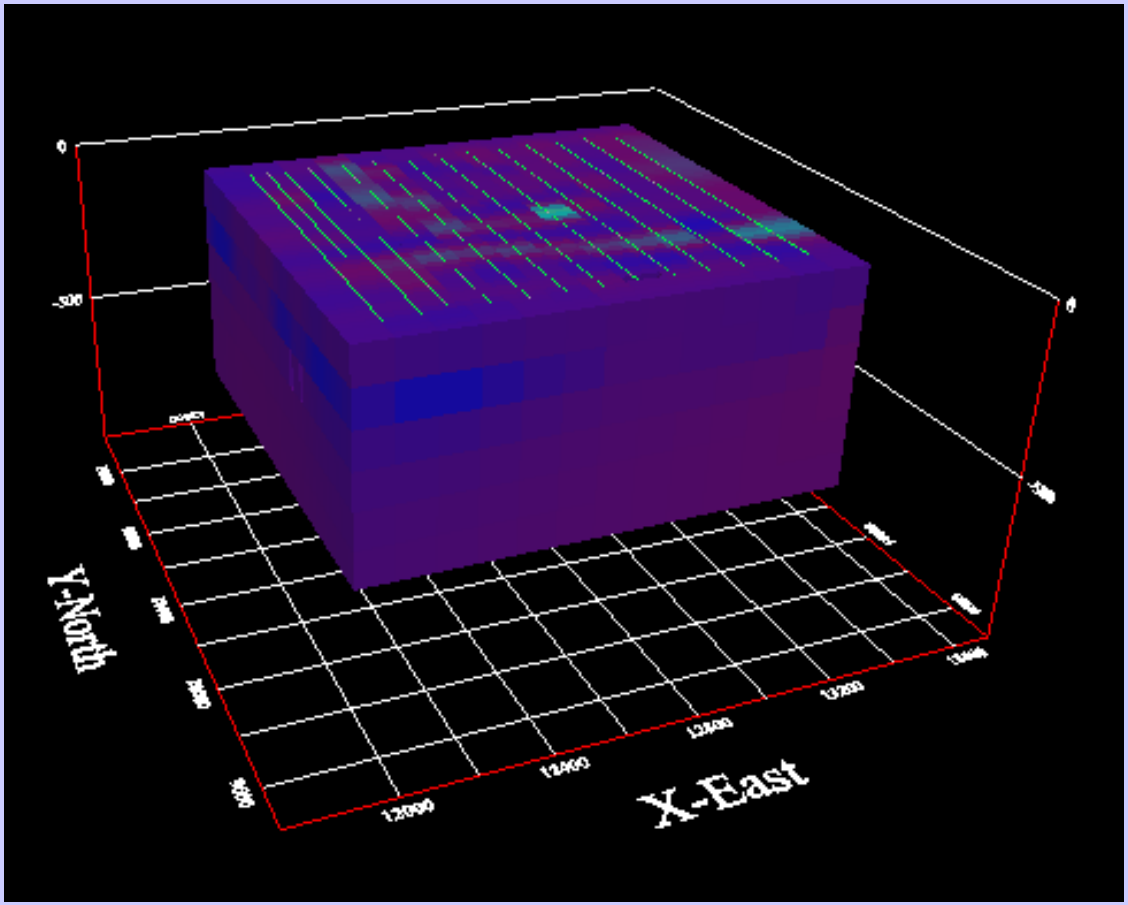




1. Import data
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. **Check model and create plots**

Inversion Evaluation

Click [Viz] button to open Visualizer tool to view the inverted 3D model…



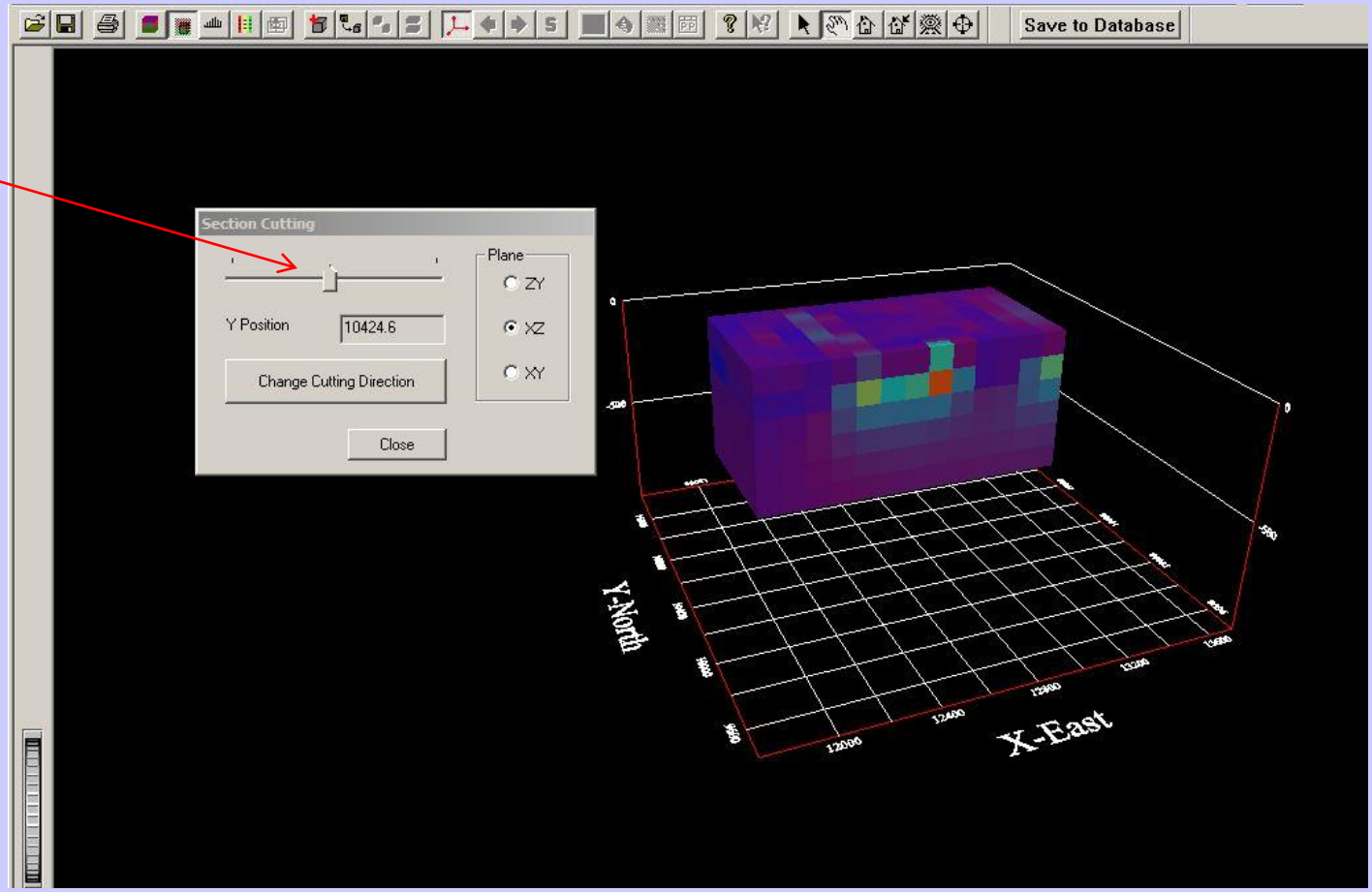
1. Import data
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. **Check model and create plots**

Inversion Evaluation

Select from menu “Model -> Mag/Grv/Res File -> mag/grv/res Cutting” to open the Section Cutting tool.

By adjusting the bar…

User can view sections of the 3D model from XY, XZ and ZY planes with any penetration depth



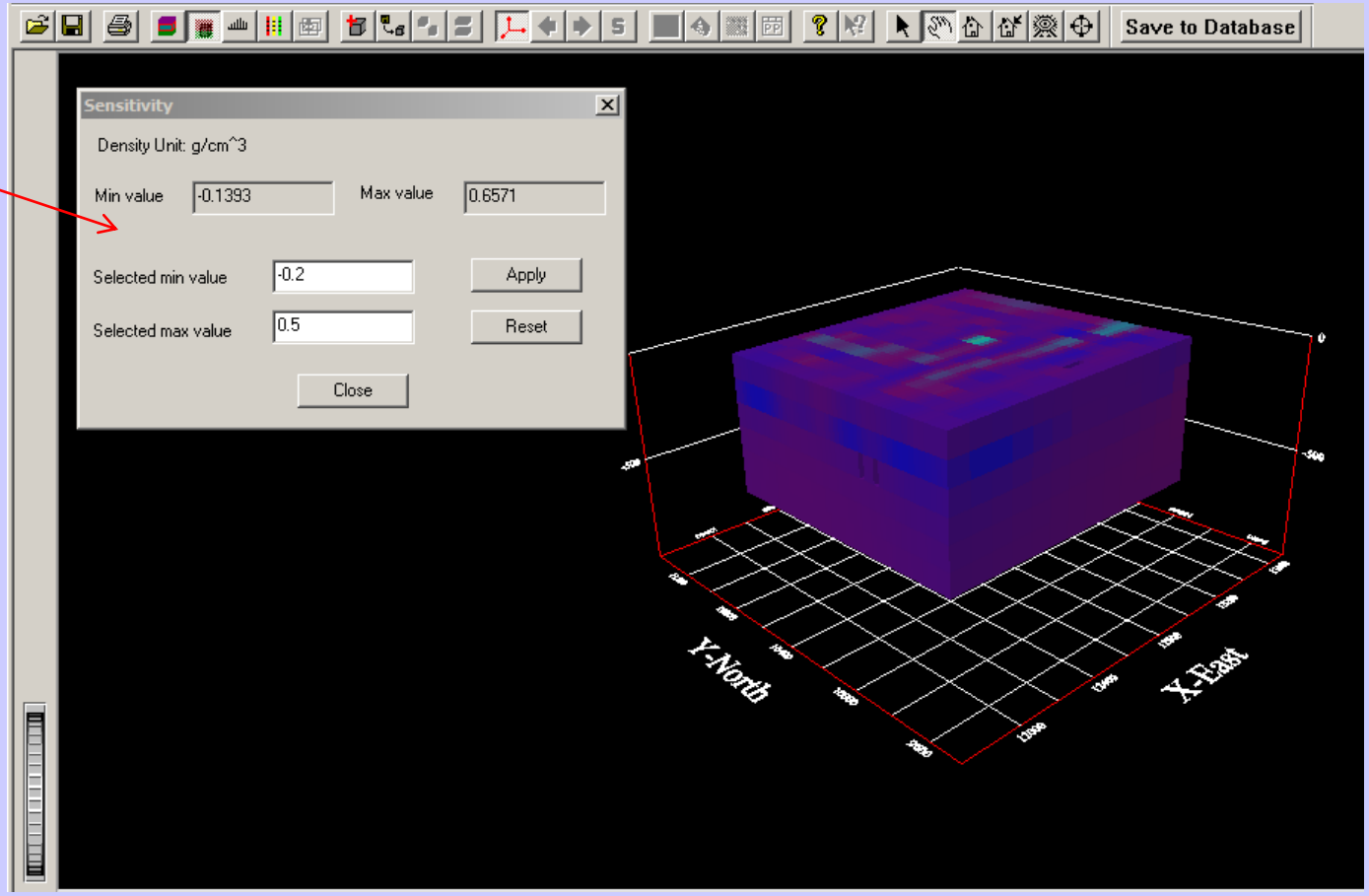
1. Import data
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. **Check model and create plots**

Inversion Evaluation

Select from menu “Model -> Mag/Grv/Res File -> Sensitivity” to open the Section Cutting tool.

By adjusting minimum value and maximum value shown in the figure…

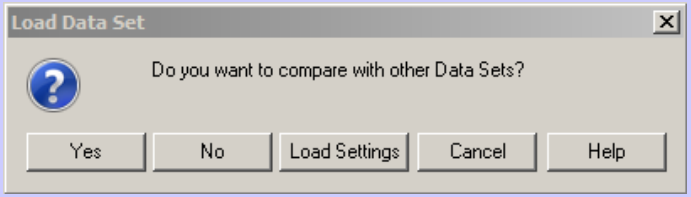
The model in this figure will only exhibit cells with values specified in this range



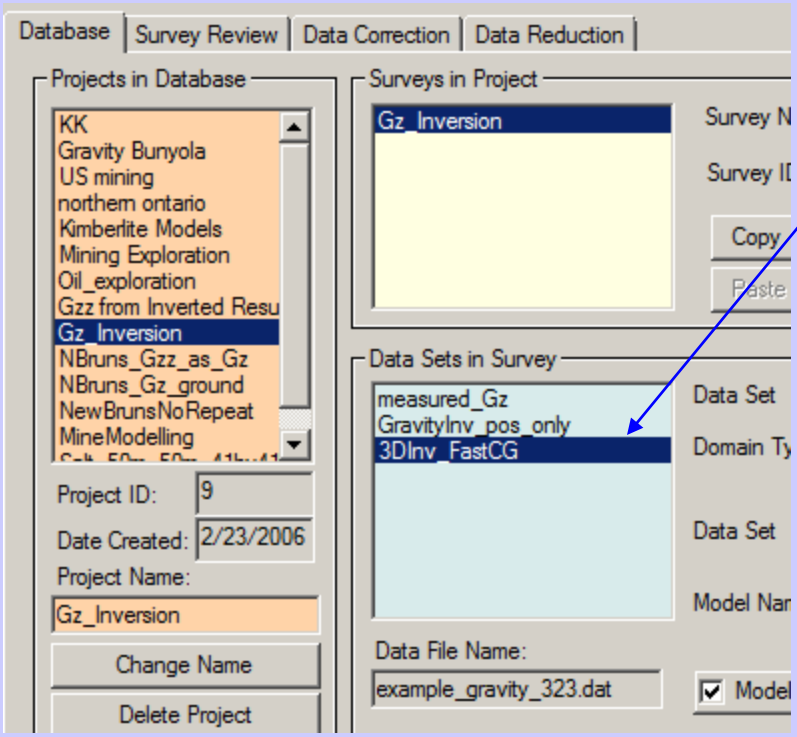
1. Import data
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. **Check model and create plots**

Inversion Evaluation

To assess how well the inversion model fits the data at each station, select the inversion data set and then select the plotter.



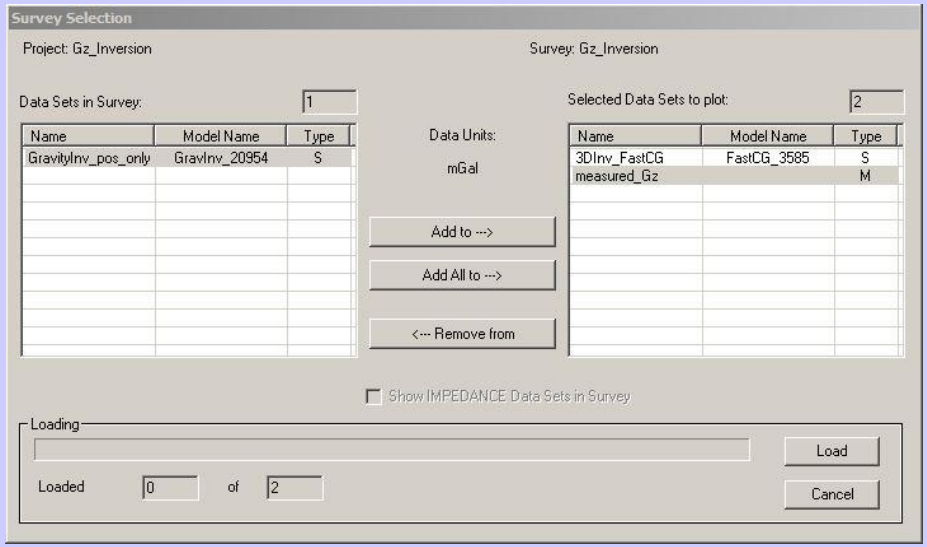
Select “Yes”, if this dialog is appeared



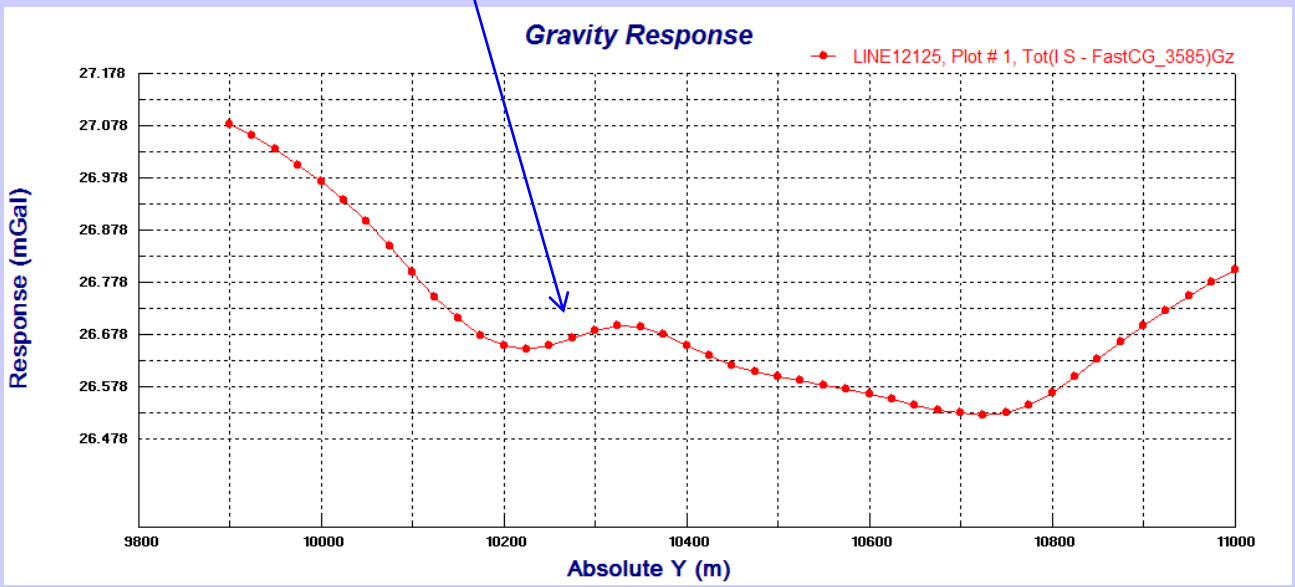
1. Import data
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. **Check model and create plots**

Inversion Evaluation

Select the data sets required for comparison and then click “Load”



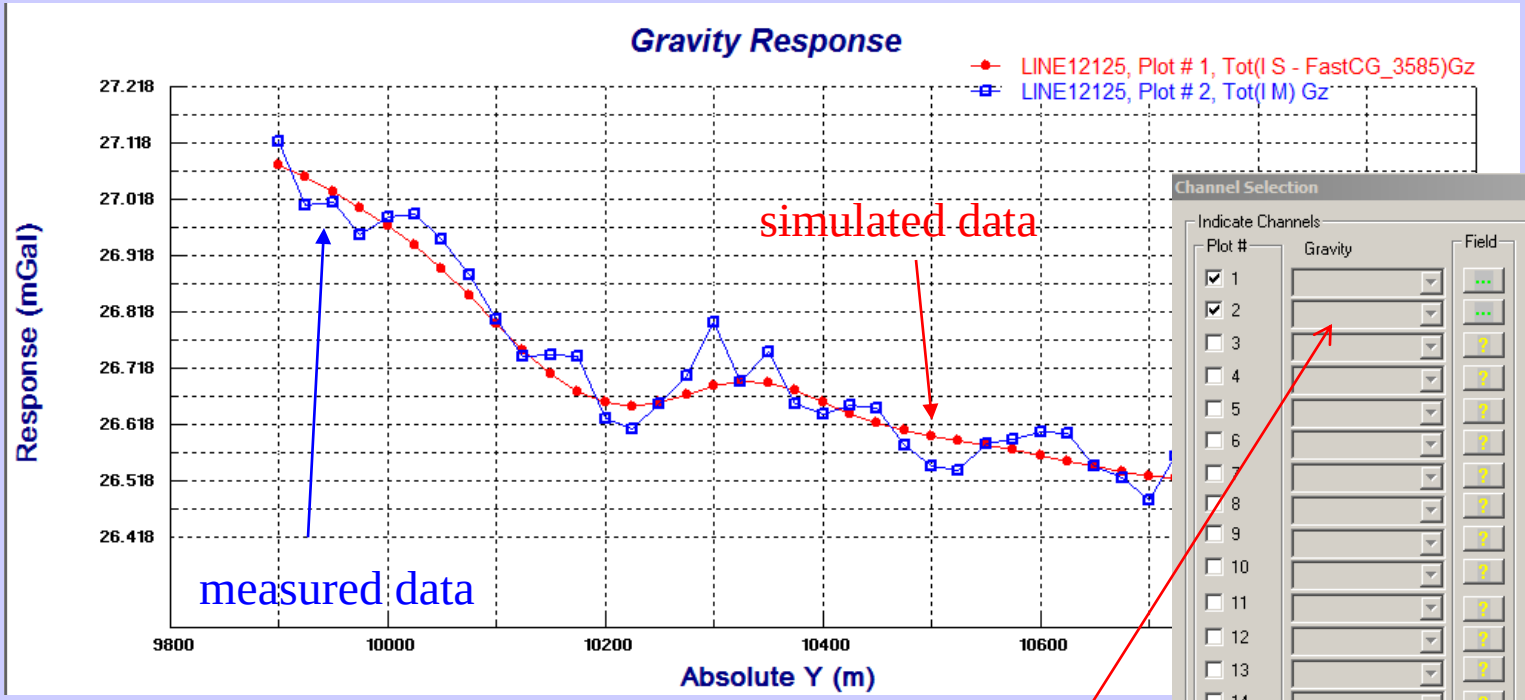
All selected data sets are then loaded to the Plotter application and the plot appears showing the simulated data of the first profile.

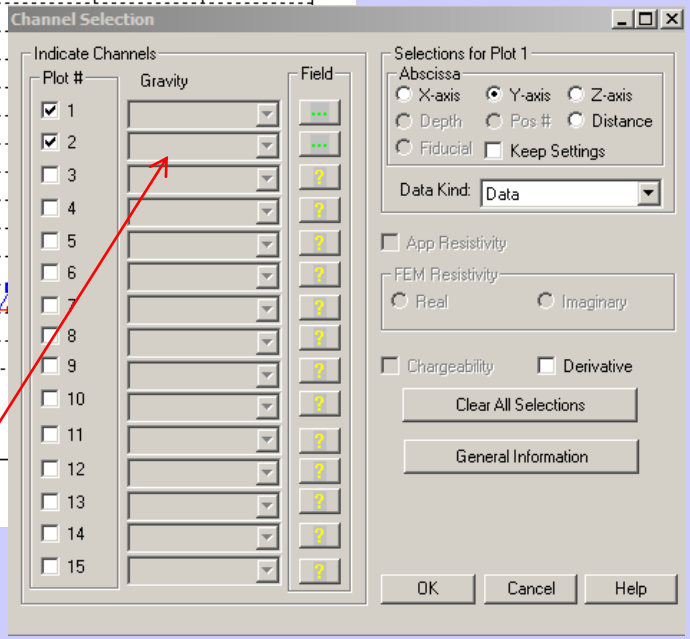


1. Import data
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. **Check model and create plots**

Inversion Evaluation

The user may select other data sets to plot by simply double clicking on the plot





Select for the 2nd plot on measured data

1. Import data
2. Examine data
3. Perform initial modeling
4. Perform 3D gravity inversions
5. Check model and create plots

Inversion Evaluation

Multiple plots can be shown for various inversions and models in “Static” mode. The user may step through different profiles by simply clicking the arrow.