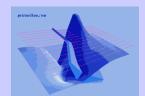
3D GRAVITY INVERSION TUTORIAL

Steps:	Page
1. Import data to new or existing database	2
2. Examine data	5
3. Perform initial forward modeling	7
4. Perform 3D gravity inversions	8
5. Check mode and create plots	19

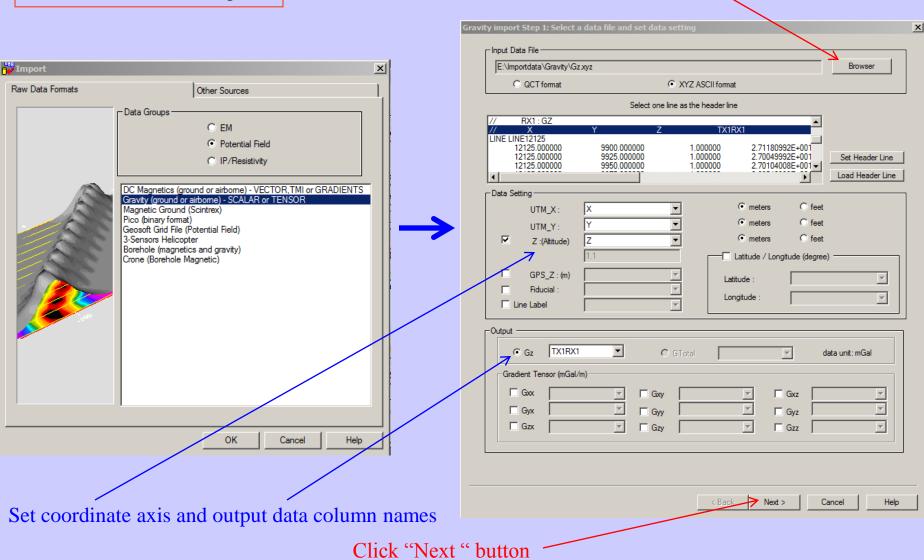


Gravity Inverse 1

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

Gravity Inverse 2

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



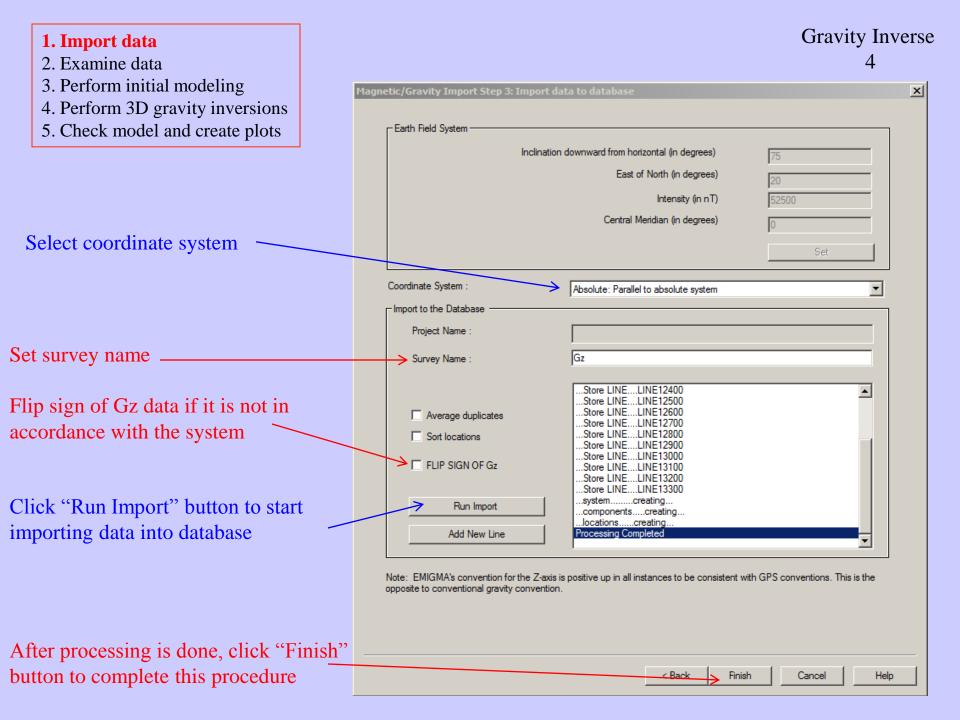
- 2. Examine data
- 3. Perform initial modeling
- 4. Perform 3D gravity inversions
- 5. Check model and create plots

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

Total Number of	Profiles: 14	Total Number of Locations: 614	
Profiles and Locat Profile LINE12125	ions # Locations 45	– Modify Profile(s) – – – – – – – – – – – – – – – – – – –	
LINE 12125 LINE 12175 LINE 12225 LINE 12300 LINE 12400	45 29 45 45 45	Profile Delete	
LINE12500 LINE12600 LINE12700 LINE12800	45 45 45 45	Delete every 2 location Apply Append to Profile Name(s) Apply	
LINE12900 LINE13000 LINE13100 LINE13200	45 45 45 45	Apply for All Profiles Split	
LINE13300	45	Shift Coordinate Values Shift X	
Re	store/Reset	Shift Y 0 Change	

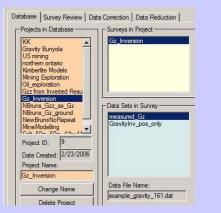
Click "Next " button

Gravity Inverse 3



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

1. Check database for the survey



Profiles Waveform Tx-Rx Output Gravity System Name System Type 1. System Mode Transmitter Coord System: Absolute: Parallel to absolute system -Gravity C Fixed C Moving -2. Transmitter Type -C Coll C Current Dipole C Loop C Pole Transmitter Input ---> - Tx/Rx Replacement Mode C Add C Replace Receiver Coord System: Absolute: Parallel to absolute system Multiple Tx Generator Component 1 Select All Create Comp - 3. Receiver Type --1. RX-DIPOLE G Sen ● Dipole ○ Voltage Dipol C Loop C Pole Receiver Input ---> > Ip/Res System Wizard OK Cancel Help

Gravity Inverse 5

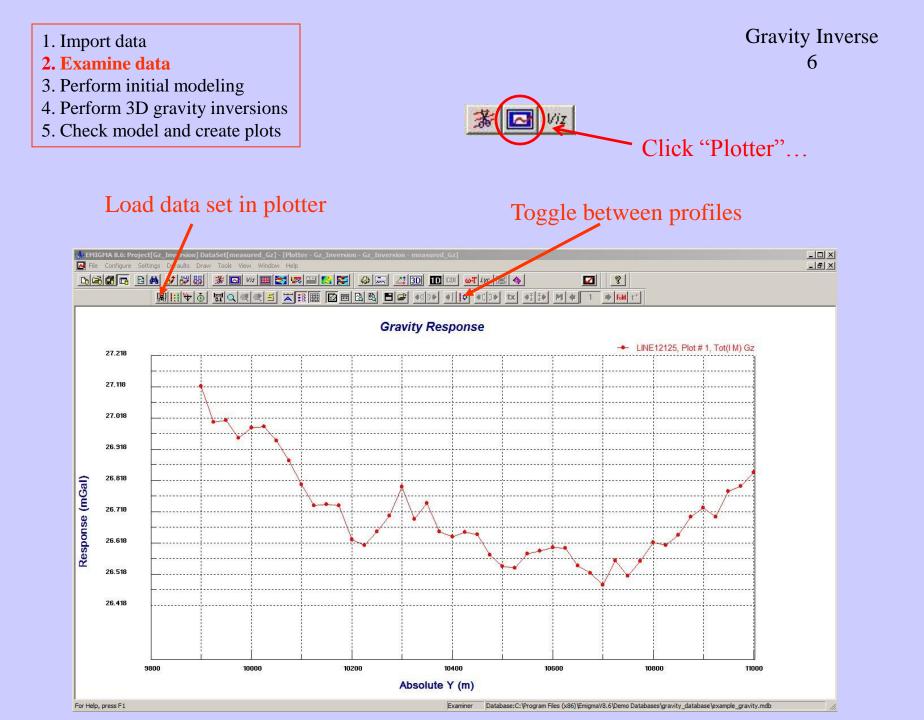
3. Check system configuration

GZ_Inversion - GZ_Inversion - mea	ielp							
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Spit Profile at Selected Location	10600							
Sort Locations in selected Profile	10400							
Lindo	16200							
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	9800- 12000	 12200	1 12400	12600	12800	13000	13200	13400
or Help, press F1	1		X: 12125.0000	Y: 9900.000	0 Data	: 27.118099		

2. Click configuration

Data File Name:	
example_gravity_161.dat	
	_,
<u>C</u> onfiguration	

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

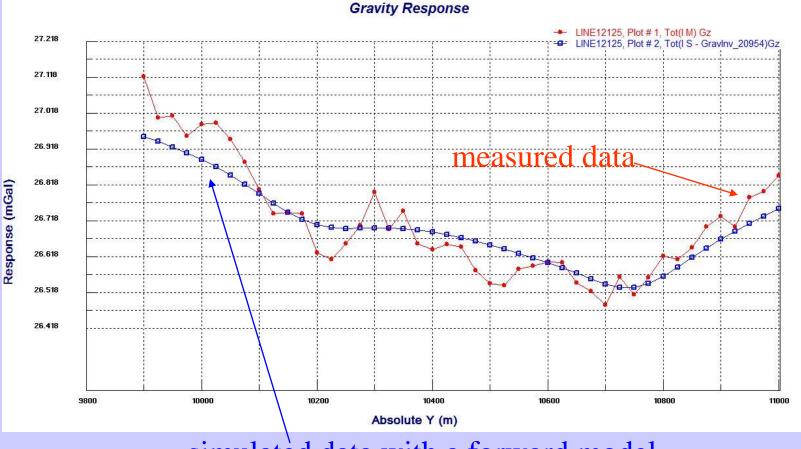


Import data
 Examine data

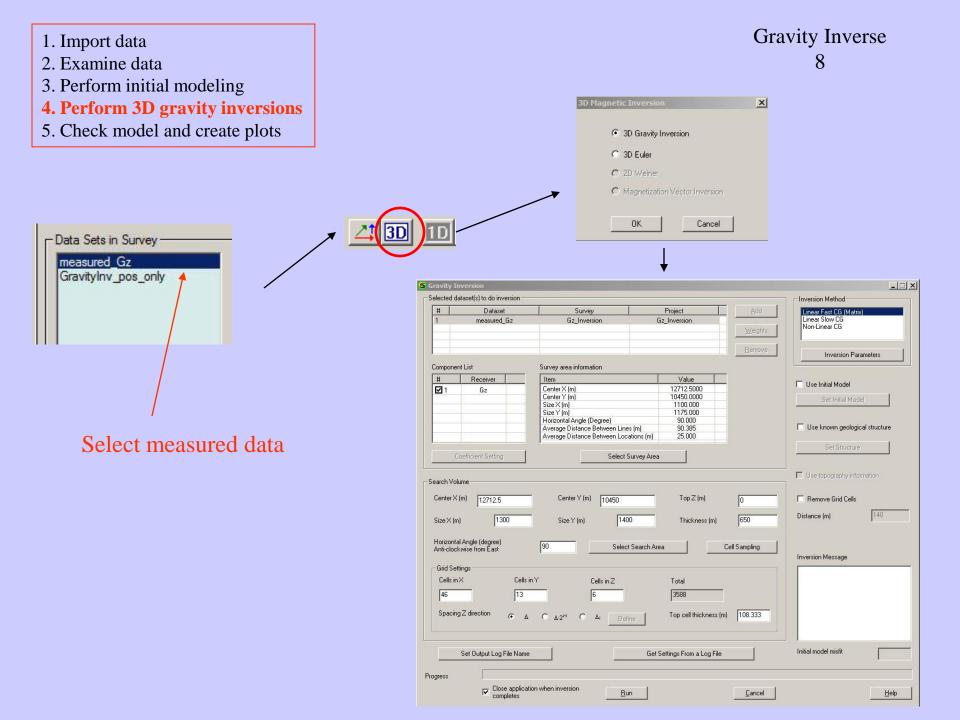
- 3. Perform initial modeling
- 4. Perform 3D gravity inversions
- 5. Check model and create plots

Gravity Inverse 7

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



simulated data with a forward model



1

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

Gravity Inverse 9

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.

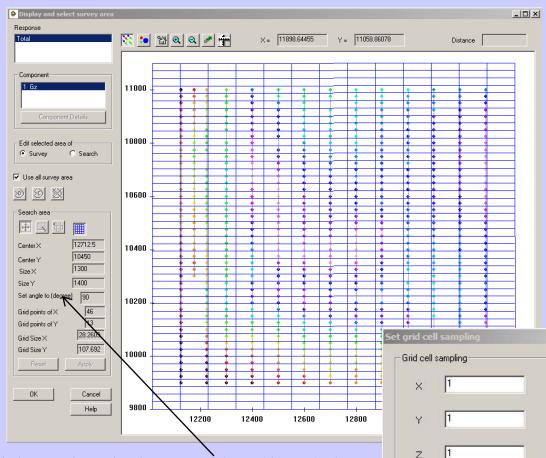
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Gravity Inverse 10

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

X

Cancel

OK

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

 Import data Examine data Perform initial modeling 				Gravity Inverse 11
4. Perform 3D gravity inversions5. Check model and create plots	Grid Settings Cells in X 25	Cells in Y 77	Cells in Z	Total 9625
	Spacing Z direction		Ο Δ; Define	Top cell thickness (m) 130

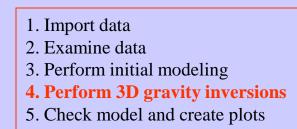
t the search g	rid cell thickness			2
otal thickness		650	Top Z	
otal thickness af	ter modification	650	0	
Search grid cell	thickness			
Index	Thickness	D	epth	
1	130.0000	-130	.0000	
2	130.0000	-260).0000	
3	130.0000).0000	
4	130.0000).0000	
5	130.0000	-650).0000	
Thickness (m)	130	Insert Inde	×	6
Modi	fy the selected	I	nsert a thicknes	s
	Delete the	eselected		
ote: Mu	Itiple thickness items can b	e selected.		

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.



Linea	ar Fast CG (Matrix)	
	ar Slow CG	
Non-	Linear CG	
	Inversion Parameters	

Inversion Methods

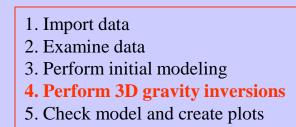
There are three inversion methods to choose from. Set parameters for your chosen technique by clicking the Inversion Parameters button.

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.

Gravity Inverse 12



	Fast CG (Matrix)	
	Slow CG	
Non-L	inear CG	
	Inversion Parameters	

Linear CG Technique

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

Gravity Inverse

13

d = F m

 $\label{eq:starses} \begin{array}{l} d \rightarrow \mbox{ vector of } N-\mbox{ dimension} \\ F \rightarrow \mbox{ Matrix of } N \times \mbox{ M- dimension} \\ m \rightarrow \mbox{ vector of } M-\mbox{ dimension} \end{array}$

 $H_{ext}(r) = \int G(r,r')J(r')dr'$ $J(r') = (m(r') - m_0)H_{ins}(r') = \chi(r')H_{ins}(r')$

Import data Examine data Perform initial modeling

- 4. Perform 3D gravity inversions
- 5. Check model and create plots

Linear Fa	st CG (Matrix)	
Linear Slo		
Non-Line	ar CG	
le le	nversion Parameters	

Gravity Inverse 14

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.

Critical factors to Optimization Results:

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

Occam style model misfit function

$$\phi_{\mathbf{m}}(\mathbf{m}) = \boldsymbol{\alpha}_0 \int \mathbf{w}^2(\mathbf{z}) \left[\mathbf{m}(\mathbf{r}) - \mathbf{m}^0(\mathbf{r}) \right]^2 d\mathbf{v} \quad +$$

 $\sum_{i=x.v.z} \alpha_i \int [w(z) \nabla_i (m(r)-m^0(r))]^2 dv$

 $\alpha_{I}\,$ - weighting factors w(z) - depth weighting

Unconstrained Conjugate Gradient Minimization

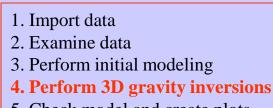
Uses the derivative information to construct two sequences of orthogonal vectors to define the search direction at a given iteration. Then by trial and error (line search) to move to the local minimum in that direction. The iteration stops when the gradient has achieved the required minimum value. This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

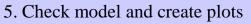
$$\phi(m) = \lambda \phi_d(m) + \phi_m(m)$$

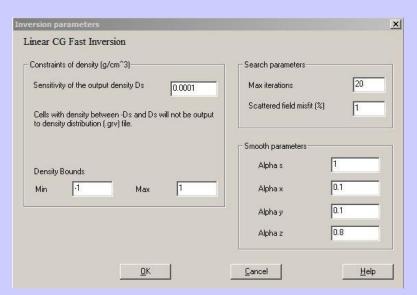
 $\phi(m)$ - functional to be minimized $\phi_d(m)$ - data misfit

 $\phi_m(m)$ - model misfit

 λ - Lagrangian multiplier - regularization weight







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

Gravity Inverse 15

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.

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

/Modify a model Size (m)		Center (m)	Ana	le (degree)	Density (g/cm	<u>^3</u> 1
× 14000	× 58	8500	1st 0		3	
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Z 3000	Z .15	500	3rd 0		Add	a prism
Set size to all selected prisms]			o all selected sms		to all selected isms
Imp	ort a model			Delete all	selected prisms	
Density (g/cm^3)	1st Angle (degree)	2nd Angle (degree)	3rd Angle (degree)	Size× (m)	Size Y (m)	Size Z (m)
		There are no	items to show in this v	view.		

Gravity Inverse

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.

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.

delete prisms from the model list

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

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**.

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

1	Dataset	Survey	Project	Add	Linear Fast CG (Matrix)
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				<u>R</u> emove	Inversion Parameters
	at ta	Contract and information			
oner	nt List	Survey area information			
	Receiver	Item	Value		Use Initial Model
	Gz	Center X (m)	588500.0000		Cise Initial Model
		Center Y (m)	6471100.0000		Set Initial Model
		Size X (m)	11700.000		00001110000
		Size Y (m)	6200.000		
		Horizontal Angle (Degree)	0.000		
		Average Distance Between Lines (m) 100.000		Use known geological structure
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	antis				
er X	(m) 588500	Center Y (m) 6471100	Top Z (m)	0	Remove Grid Cells
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	Close applica completes	tion when inversion <u>R</u> un		Cancel	<u>H</u> el
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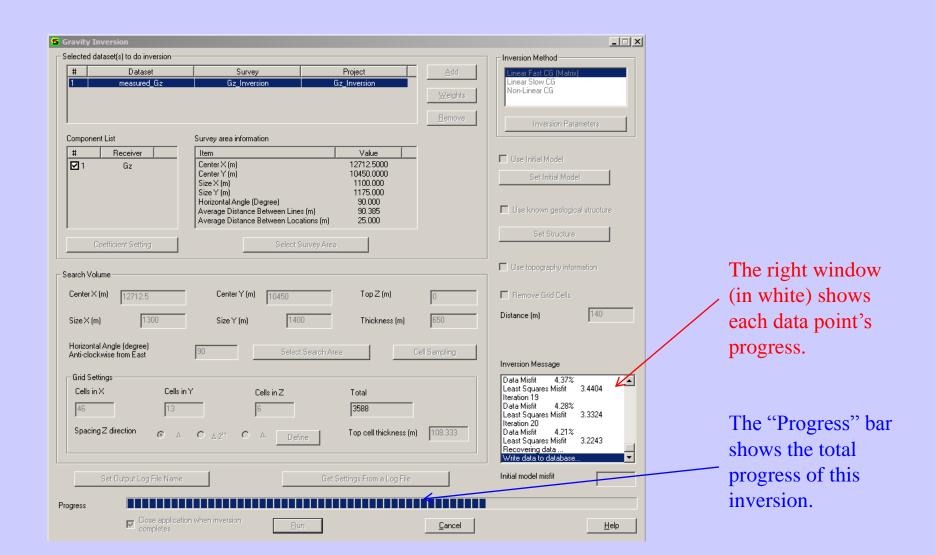
After settings are done, press **<u>R</u>un** button to start the inversion process. •

Gravity Inverse 17

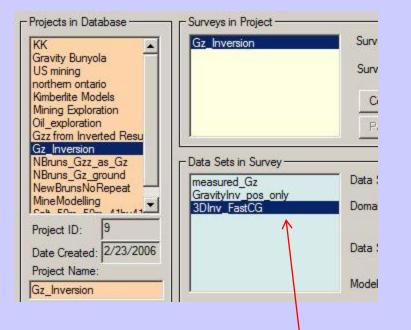
- 2. Examine data
- 3. Perform initial modeling
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- 5. Check model and create plots

Gravity Inverse 18

Executing the Inversion



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

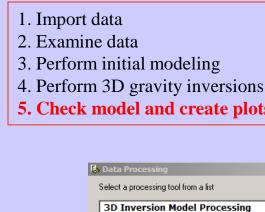


Our 3D gravity inversion model dataset

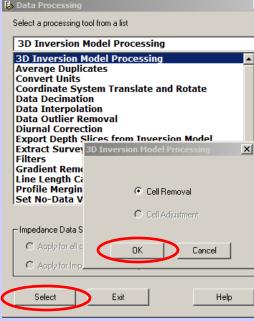
Gravity Inverse 19

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.



5. Check model and create plots



Click "Apply" button when it is done

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

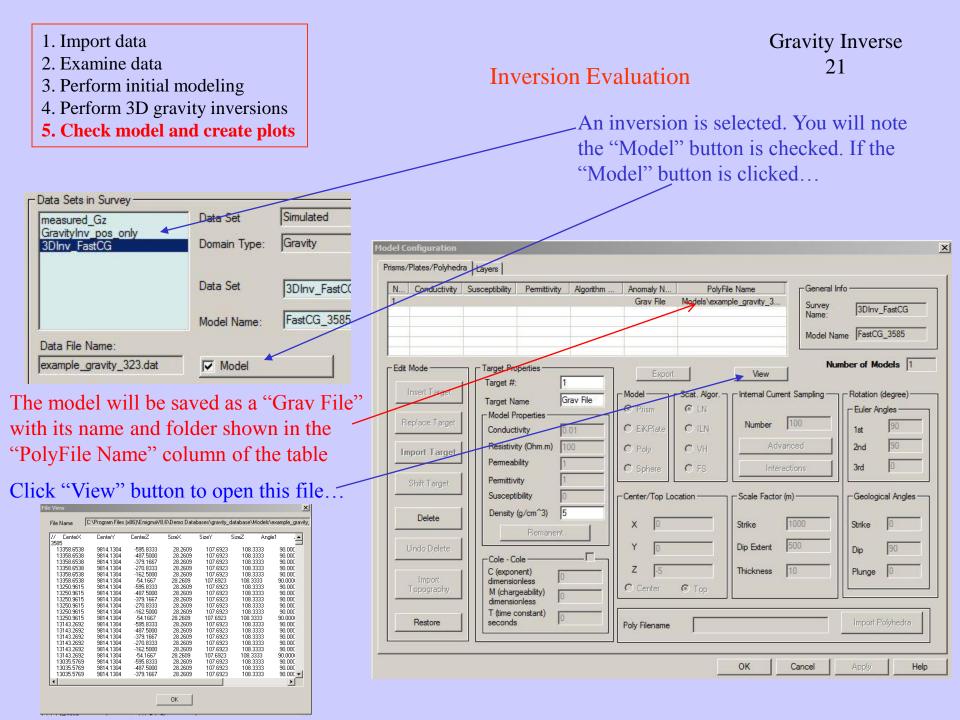
Inversion Evaluation



×

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) /

C	ell Removal				
	Gz_Inversion - Gz_Inversion - 3DInv_FastCG Inversion File: example_gravity_323.grv Model: FastCG_3585	Data Se	Data Set ID: 323		
*	# of Cells 3585 Minimum -0.1393 g/cm3 Maximum 0.6571 g/cm3	Distribution of Values -0.140 -> 0.020 0.020 -> 0.179: 0.179 -> 0.339: 0.339 -> 0.498: 0.498 -> 0.658:	20.8089% 71.4086% 5.5788% 1.7015% 0.5020%		
her	Remove ce Low Limit -0.1393 Reset Apply	ells in this range: High Limit 0.6571 Save	Cancel		

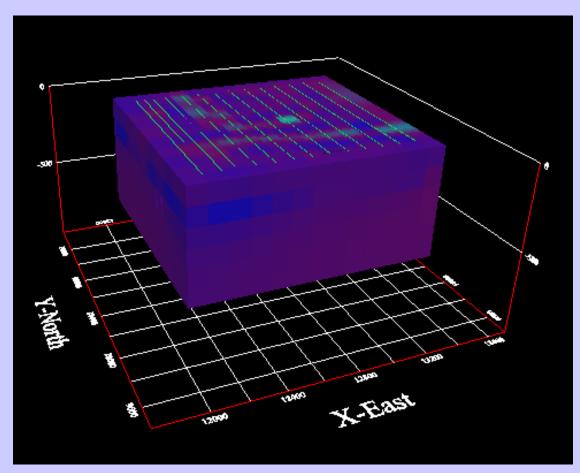


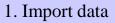
- 2. Examine data
- 3. Perform initial modeling
- 4. Perform 3D gravity inversions
- **5.** Check model and create plots

Inversion Evaluation

Gravity Inverse 22

Click viz button to open Visualizer tool to view the inverted 3D model...





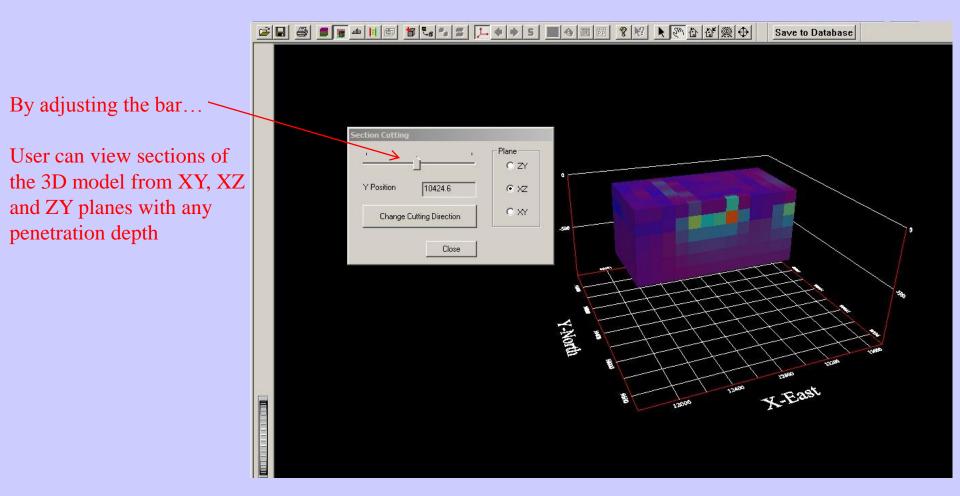
- 2. Examine data
- 3. Perform initial modeling
- 4. Perform 3D gravity inversions
- 5. Check model and create plots

Inversion Evaluation

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

Gravity Inverse

23



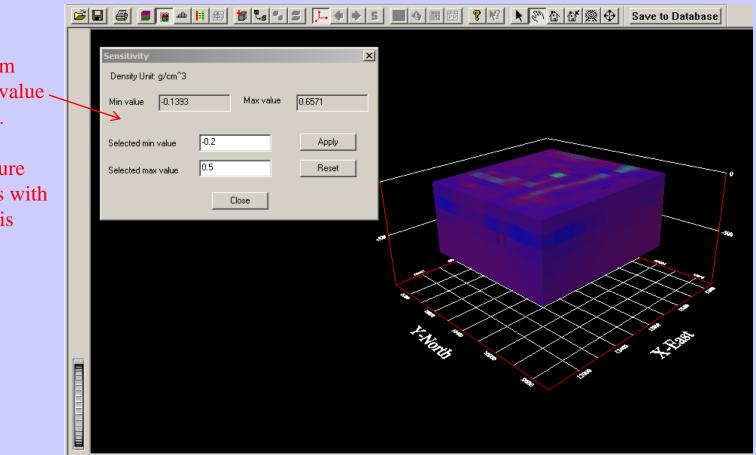
- 2. Examine data
- 3. Perform initial modeling
- 4. Perform 3D gravity inversions
- 5. Check model and create plots

Inversion Evaluation

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

Gravity Inverse

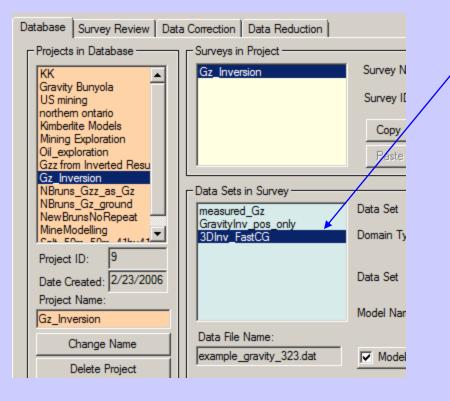
24



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

- 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.



Load Data Set					×
?	Do you want to	compare with othe	er Data Sets?		
Yes	No	Load Settings	Cancel	Help	

Select "Yes", if this dialog is appeared

Gravity Inverse 25

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

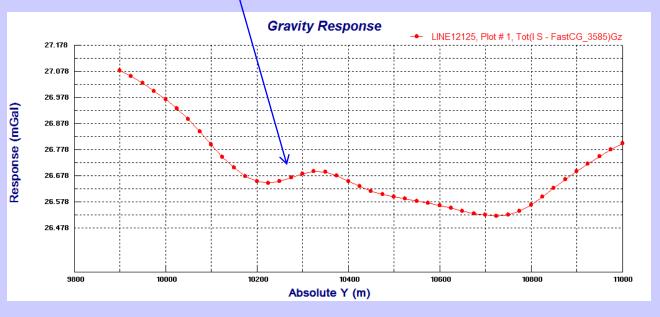
All selected data sets are then loaded to the Plotter application and the plot appears showing the simulated data of the first profile.

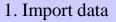
Inversion Evaluation

Gravity Inverse 26

Select the data sets required for comparison and then click "Load"

ata Sets in Survey:		II.		Selected Data Sets to	o pioc	2
Name	Model Name	Туре	Data Units:	Name	Model Name	Туре
GravityInv_pos_only	GravInv_20954	S	mGal	3DInv_FastCG measured_Gz	FastCG_3585	S M
			Add to>			
			Add All to>			
			< Remove from			
		I	Show IMPEDANCE Data	Sets in Survey		
Loading			Show IMPEDANCE Data	Sets in Survey	Lo	ad



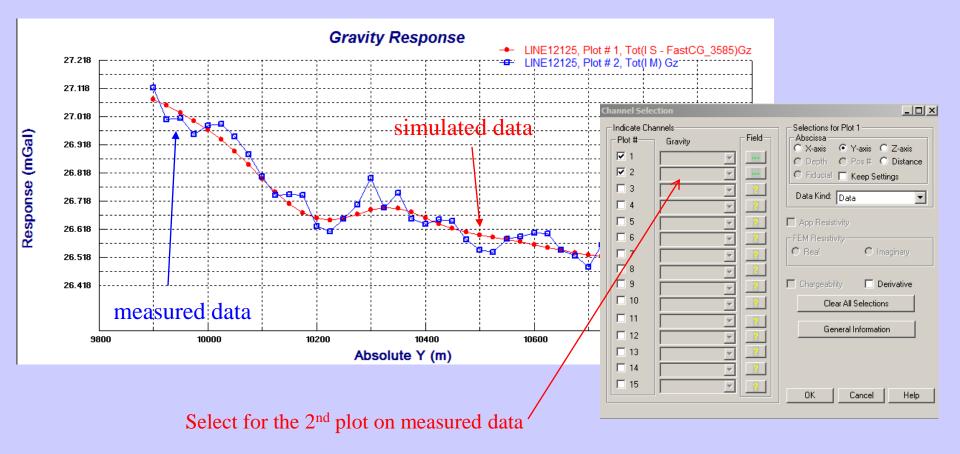


- 2. Examine data
- 3. Perform initial modeling
- 4. Perform 3D gravity inversions
- 5. Check model and create plots

Inversion Evaluation

Gravity Inverse 27

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



- 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.

