

3D Inversion in GM-SYS 3D Modelling

GM-SYS 3D provides a wide range of inversion options including inversion for both layer structure and physical properties for gravity and magnetic data. There is an option for joint inversion of the gravity gradient tensor components and magnetics. All of the inversion options enable the user to constrain the area being inverted, set bounds on the range of results allowed, and filter the spatial wavelengths of the results. Inversion is performed using the *Calculate* menu.

Constant Density Inversion

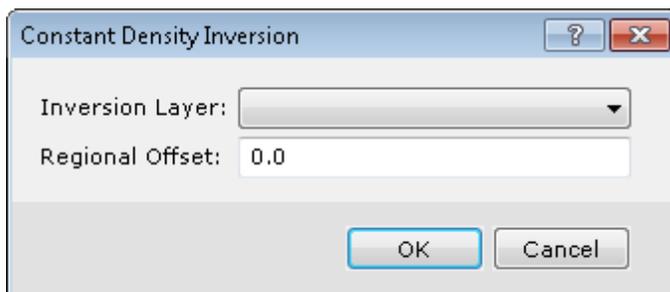
Perform an inversion to optimize the constant density of the selected model layer. The inversion recalculates the error cell by cell and does an estimate of the density for all cells, then averages them to get an overall density change. You then must recalculate the model to reflect this change in the calculated anomaly.

To Perform a Constant Density Inversion

1. On the *Calculate* menu, select **Constant Density Inversion**. The *Constant Density Inversion* dialog appears.



*This dialog can also be accessed by right-clicking the model layer in the Layers menu and selecting **Constant Density Inversion** from the pop-up menu.*



2. From the dropdown list, select the *Inversion Layer*. Calculates the optimum single density for the chosen layer which minimizes the misfit.
3. Enter the *Regional Offset*. This constant will be subtracted from the observed gravity before inverting.
4. Click **OK**.
5. If prompted, click **Yes** to recalculate. The calculation is processed.

Lateral Density Inversion

The *Lateral Density Inversion* function optimizes the lateral density distribution in the selected model layer in order to minimize the misfit for the selected gravity component.



*Inversion modifies the lateral density distribution in the model, but automatically creates a back-up copy of the original density distribution layer, which may be recovered by re-running the inversion and clicking **Undo**.*

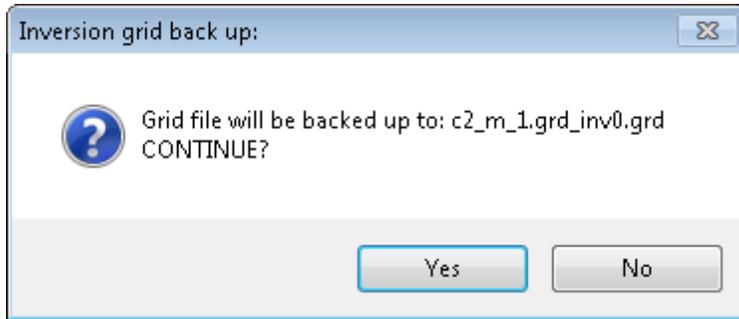
To Perform a Lateral Density Inversion

1. From the *Calculate* menu, select **Lateral Density Inversion**. The *Lateral Density Inversion* dialog appears.



*This dialog can also be accessed by right-clicking the model layer in the Layers menu and selecting **Lateral Density Inversion**.*

2. From the dropdown list, select the *Top Surface of Inversion Layer*. The lateral density distribution of this layer will be altered.
3. Enter a *Maximum Number of Inversion Iterations*. Inversion process will stop after this many iterations, even if the convergence target has not been reached.
4. Enter the *Convergence Limit*. Inversion will stop when either the mean error or the standard deviation of the error is less than this limit. Note that under certain conditions, the calculations may not converge at all. The GX attempts to detect this and terminate accordingly.
5. Enter the *Lower High-Cut Limit*. A cosine roll-off high-cut filter is applied to the error before inverting. This is the beginning of the cosine taper. The default value is equivalent to 0.5 times the Nyquist.
6. Enter the *Upper High-Cut Limit* (the short-wavelength end of the taper. The default is the wavelength equivalent to 0.7 times the Nyquist. If you enter numbers that are ≤ 1.0 , they are interpreted as fractions of Nyquist. If you enter numbers that are > 1.0 , they will be interpreted as wavelengths (distances) in ground units.
7. Enter the *Regional Offset*. This constant will be subtracted from the observed gravity before inverting.
8. Browse to the load an existing *Constraints Grid*. Values in this grid control where the inversion surface may change. Values of 0 indicate no change; 1 indicates maximum change.
9. Optionally, you may click **Limits** to activate a dialog that specifies the minimum and maximum density values allowed in the resulting density layer. By default, the limits are -5 to +5 g/cm³.
10. Click **OK**. You are prompted to back up the grid file.



11. Click **Yes** to continue.
12. If prompted, click **Yes** to recalculate. The calculation is processed.

Gravity Structural Inversion

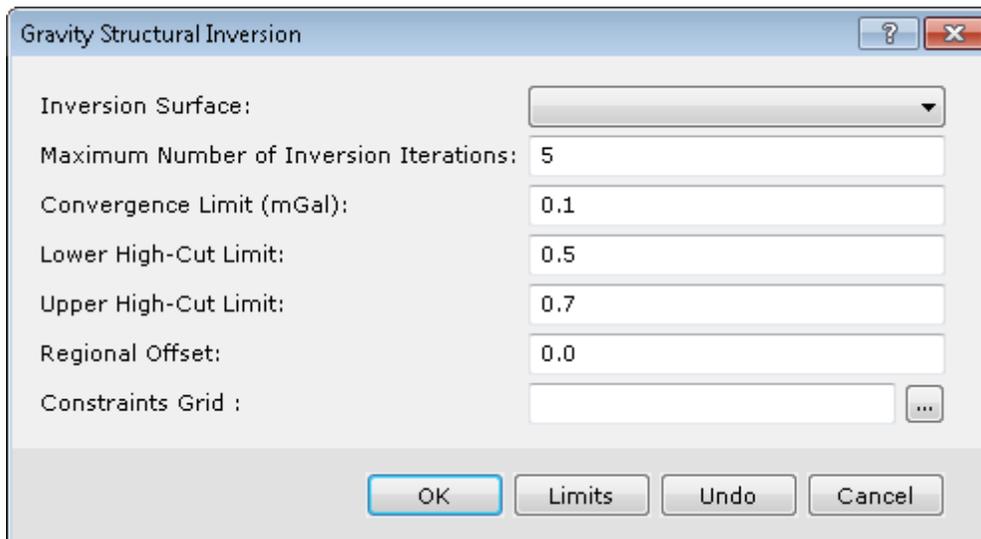
The *Gravity Structural Inversion* function modifies the elevation of the selected layer in order to minimize the gravity misfit. Inversion updates the calculated response and error to reflect the structural changes.

 *Inversion modifies the layer elevation in the model, but automatically creates a back-up copy of the original layer, which may be recovered by re-running the inversion and clicking **Undo**.*

To Perform a Gravity Structural Inversion

1. On the *Calculate* menu, select **Gravity Structural Inversion**. The *Gravity Structural Inversion* dialog appears.

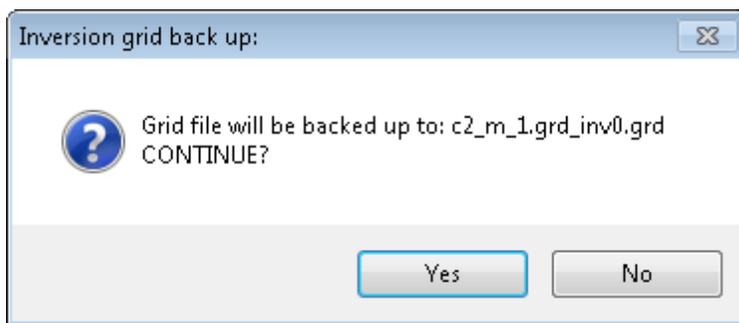
 *This dialog can also be accessed by right-clicking the model layer in the *Layers* menu and selecting **Gravity Structural Inversion**.*



2. From the dropdown list, select the *Inversion Surface*. This layer will be altered.
3. Enter a *Maximum Number of Inversion Iterations*. Inversion process will stop after this many iterations, even if the convergence target has not been reached.
4. Enter the *Convergence Limit*. Inversion will stop when either the mean error or the standard deviation of the error is less than this limit. Note that under certain conditions, the calculations may not converge at all. The GX attempts to

detect this and terminate accordingly.

5. Enter the *Lower High-Cut Limit*. A cosine roll-off high-cut filter is applied to the error before inverting. This is the beginning of the cosine taper. The default value is equivalent to 0.5 times the Nyquist.
6. Enter the *Upper High-Cut Limit* (the short-wavelength end of the taper. The default is the wavelength equivalent to 0.7 times the Nyquist. If you enter numbers that are ≤ 1.0 , they are interpreted as fractions of Nyquist. If you enter numbers that are > 1.0 , they will be interpreted as wavelengths (distances) in ground units.
7. Enter the *Regional Offset*. This constant will be subtracted from the observed gravity before inverting.
8. Browse to the *Constraints Grid*. This controls where the inversion surface may change. Values of 0 indicate no change; 1 indicates maximum change.
9. Optionally, you may click **Limits** to activate a dialog that limits the amount of change possible during inversion.
10. Click **OK**. You are prompted to back up the grid file.



11. Click **Yes** to continue.
12. If prompted, click **Yes** to recalculate. The calculation is processed.

Magnetic Structural Inversion

The *Magnetic Structural Inversion* function modifies the elevation of the selected layer in order to minimize the magnetic misfit. Inversion updates the calculated response and error to reflect the structural changes.

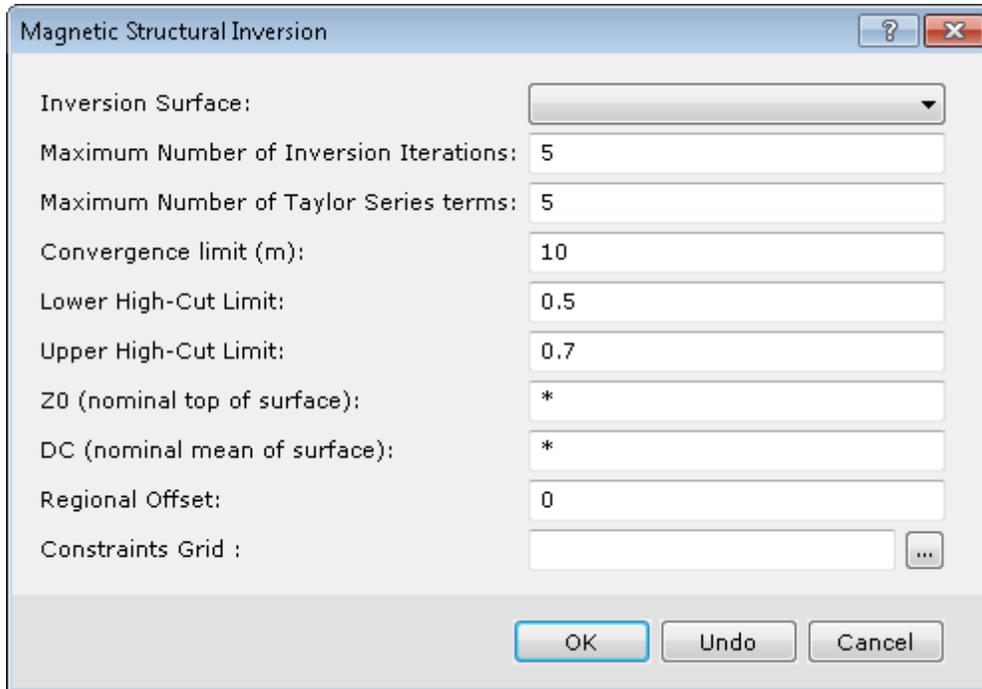
Because the magnetic structural inversion involves a downward continuation of the magnetic anomaly data to the "Z0" depth, a high-cut filter is necessary to prevent the input anomaly from "blowing up" when the highest frequencies are amplified by the downward continuation filter.

 *Inversion modifies the layer elevation in the model, but automatically creates a back-up copy of the original layer, which may be recovered by re-running the inversion and clicking **Undo**.*

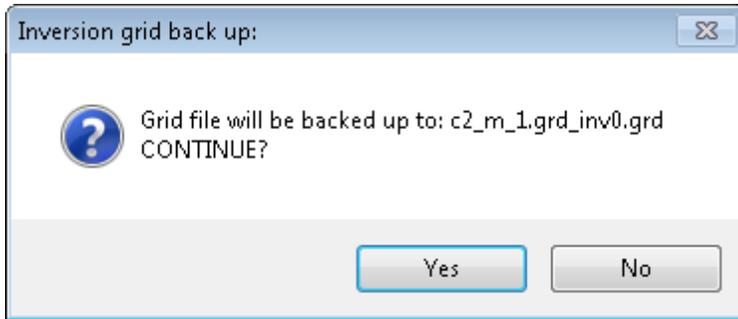
To Perform a Magnetic Structural Inversion

1. On the *Calculate* menu, select **Magnetic Structural Inversion**. The *Magnetic Structural Inversion* dialog appears.

 *This dialog can also be accessed by right-clicking the model layer on the Layers tab of the Model Explorer and selecting **Magnetic Structural Inversion**.*



2. From the dropdown list, select the *Inversion Surface*. This layer will be altered.
3. Enter a *Maximum Number of Inversion Iterations*. Inversion process will stop after this many iterations, even if the convergence target has not been reached.
4. Enter the *Maximum Number of Taylor Series terms*. This should be odd number less than 12. Higher values put more emphasis on short wavelengths. More than 5 terms are seldom useful.
5. Enter the *Convergence Limit*. Inversion will stop when either the mean error or the standard deviation of the error is less than this limit. Note that under certain conditions, the calculations may not converge at all. The GX attempts to detect this and terminate accordingly.
6. Enter the *Lower High-Cut Limit*. A cosine roll-off high cut filter is applied to the error before inverting. This is the beginning of the cosine taper. The default value is equivalent to 0.5 times the Nyquist.
7. Enter the *Upper High-Cut Limit*, which is the short-wavelength end of the taper. If you enter numbers that are ≤ 1.0 , they are interpreted as fractions of Nyquist. If you enter numbers that are > 1.0 , they will be interpreted as wavelengths (distances) in ground units.
8. Enter the *Z0*. This is the downward continuation depth relative to sea level. This level should be above the highest elevation you expect in the inverted structure. If *Z0* is too deep, the inversion will fail to converge. The default value is the magnetic survey elevation.
9. Enter the *DC*. This is the mean depth of the resulting inverted surface relative to sea level, which must be deeper than *Z0*. The default value is the mean of the selected layer's relief surface. If the inversion is triggered from the layer context menu, the default is calculated from the selected layer's relief surface and displayed; otherwise "*" is displayed to indicate that it will be calculated during the inversion.
10. Enter the *Regional Offset*. This constant will be subtracted from the observed magnetic data before inverting.
11. Browse to the *Constraints Grid*. This controls where the inversion surface may change. Values of 0 indicate no change; 1 indicates maximum change.
12. Click **OK**. You are prompted to back up the grid file.



13. Click **Yes** to continue.
14. If prompted, click **Yes** to recalculate. The calculation is processed.

Lateral Susceptibility Inversion

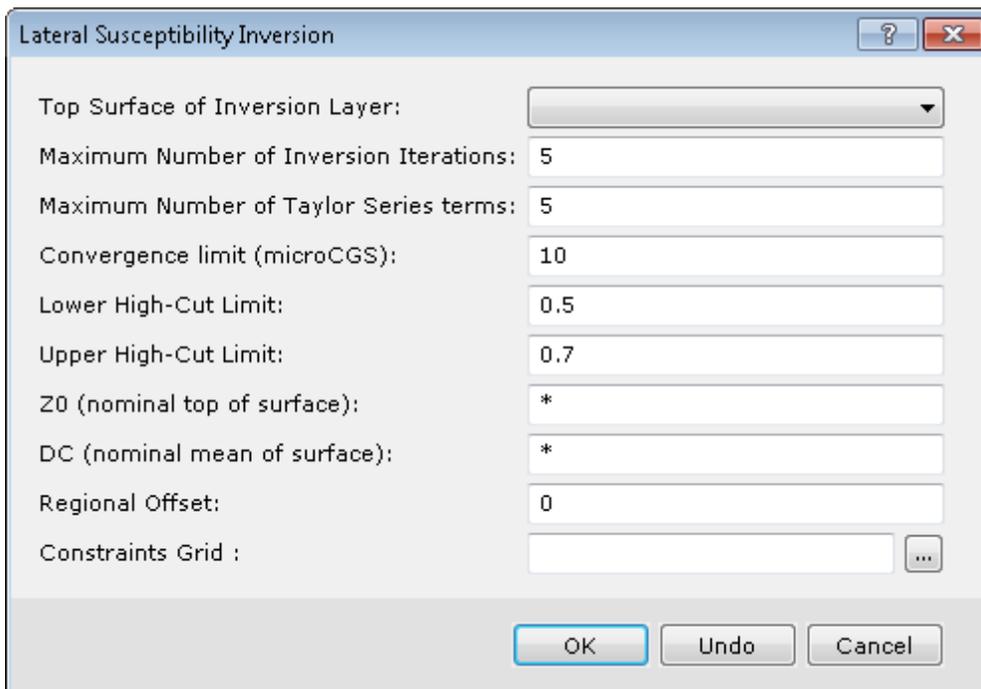
The Lateral Susceptibility Inversion function optimizes the lateral susceptibility distribution in the selected model layer, in order to minimize the misfit for the selected magnetic anomaly component.

 *Inversion modifies the lateral susceptibility in the model, but automatically creates a back-up copy of the original layer, which may be recovered by re-running the inversion and clicking **Undo**.*

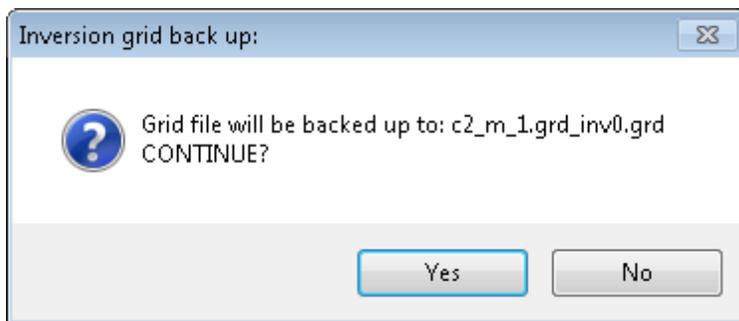
To Perform a Lateral Susceptibility Inversion

1. On the *Calculate* menu, select **Lateral Susceptibility Inversion**. The *Lateral Susceptibility Inversion* dialog appears.

 *This dialog can also be accessed by right-clicking the model layer on the Layers tab of the Model Explorer and selecting **Lateral Susceptibility Inversion**.*



2. From the dropdown list, select the *Top Surface of Inversion Layer*. The layer's corresponding lateral susceptibility distribution will be altered.
3. Enter a *Maximum Number of Inversion Iterations*. Inversion process will stop after this many iterations, even if the convergence target has not been reached.
4. Enter the *Maximum Number of Taylor Series terms*. This should be odd number less than 12. Higher values put more emphasis on short wavelengths. More than 5 iterations are seldom useful.
5. Enter the *Convergence Limit* in μggs , if possible. Inversion will stop when either the mean error or the standard deviation of the error is less than this limit. Note that under certain conditions, the calculations may not converge at all. The GX attempts to detect this and terminate accordingly.
6. Enter the *Lower High-Cut Limit*. A cosine roll-off high cut filter is applied to the error before inverting. This is the beginning of the cosine taper. The default value is equivalent to 0.5 times the Nyquist.
7. Enter the *Upper High-Cut Limit*. This is the short wavelength end of the taper. The default is the wavelength equivalent to 0.7 times the Nyquist. If you enter numbers that are ≤ 1.0 , they are interpreted as fractions of Nyquist. If you enter numbers that are > 1.0 , they will be interpreted as wavelengths (distances) in ground units.
8. Enter the *Z0*. This is the downward continuation depth relative to sea level. This level should be above the highest elevation you expect in the inverted structure. If *Z0* is too deep, the inversion will fail to converge. The default value is the magnetic survey elevation.
9. Enter the *DC*. This is the mean depth of the resulting inverted surface relative to sea level, which must be deeper than *Z0*. The default value is the mean of the selected layer's relief surface. If the inversion is triggered from the layer context menu, the default is calculated from the selected layer's relief surface and displayed; otherwise "*" is displayed to indicate that it will be calculated during the inversion.
10. Enter the *Regional Offset*. This constant will be subtracted from the observed gravity before inverting.
11. Browse to the *Constraints Grid*. This controls where the inversion surface may change. Values of 0 indicate no change; 1 indicates maximum change.
12. Click **OK**. You are prompted to back up the grid file.



13. Click **Yes** to continue.
14. If prompted, click **Yes** to recalculate. The calculation is processed.

1-Step Susceptibility Inversion

The *1-Step Susceptibility Inversion* function applies the Oasis MAGMAP Apparent Susceptibility Filter (SUSC) to arrive at the lateral susceptibility variation. This is a somewhat faster process than the "normal" GM-SYS 3D routines which are used by the *Lateral Susceptibility Inversion* function.

The apparent susceptibility filter is a compound filter that performs a reduction to the pole, downward continuation to the source depth, correction for the geometric effect of a vertical square ended prism, and division by the total magnetic field to yield susceptibility. Using this approach we assume that there is no remanent magnetization and that the magnetic response is caused by a collection of vertical, square-ended prisms of infinite depth extent.

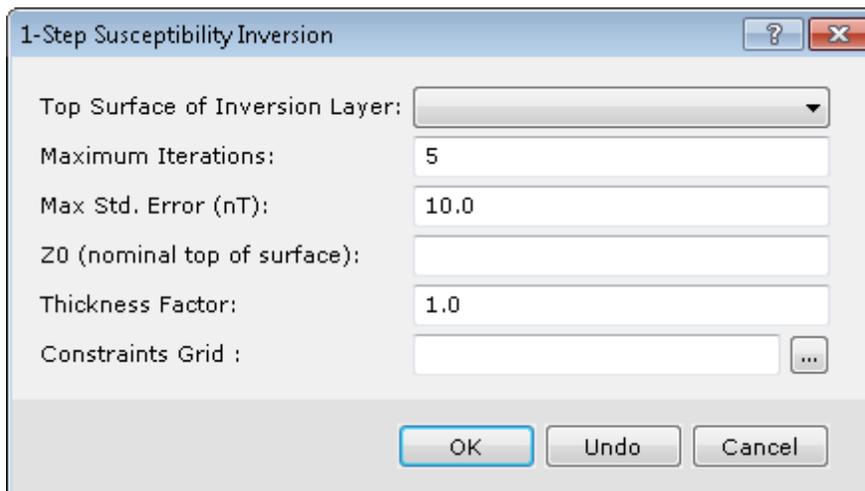
The function applies the apparent susceptibility filter to the magnetic error and adds the result to the existing lateral susceptibility distribution. This is a faster process than the “normal” GM-SYS 3D routines and can be run multiple times to improve the fit.

 *Inversion modifies the susceptibility in the model, but automatically creates a back-up copy of the original layer, which may be recovered by re-running the inversion and clicking **Undo**.*

To Perform a 1-Step Susceptibility Inversion

1. On the *Calculate* menu, select **1-Step Susceptibility Inversion**. The *1-Step Susceptibility Inversion* dialog appears.

 *This dialog can also be accessed by right-clicking the model layer in the *Layers* menu and selecting **1-Step Susceptibility Inversion** from the pop-up menu.*



2. From the dropdown list, select the *Top Surface of Inversion Layer*.
3. Enter the *Maximum Iterations*. The Inversion process will stop after this many iterations, even if the convergence target has not been reached. The default is 5.
4. Enter the *Maximum Std. Deviation*. Inversion will stop when the standard deviation of the error is below this limit. Note that under certain conditions, the calculations may not converge at all. The GX attempts to detect this and terminate accordingly.
5. Enter the downward continuation depth relative to sea level. This level should be above the highest elevation you expect in the inverted structure. If *Z0* is too deep, the inversion will fail to converge.
If you leave this parameter blank, the GX sets it to the maximum elevation in the "Top Surface of Inversion Layer" plus 25% of the standard deviation of the elevation of that surface.
6. Enter the *Thickness Factor*. This normally should be 1.0. Calculated susceptibilities will be multiplied by this factor after inversion. Acts as an acceleration factor if convergence is slow.
7. Browse to the *Constraints Grid*.

8. Click **OK**.
9. If prompted, click **Yes** to recalculate. The calculation is processed.

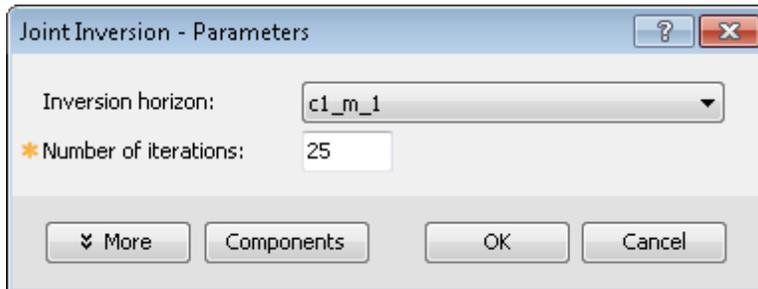
 *This inversion tool typically produces both negative and positive susceptibility distributions that average approximately zero. You can add a constant to the resulting lateral susceptibility grid to make all the susceptibilities positive. This typically does not change the calculated results (Blakely, 1995 page 97). Alternatively, you may treat the negative susceptibilities as remanent magnetization.*

Joint Inversion

The GM-SYS 3D Full-Tensor Gradient (FTG) Joint Inversion is based on the methods of Jorgensen and Kisabeth (2000), licensed from Conoco-Phillips. The inversion utilizes a Monte-Carlo simulation and combined space-domain and FFT methods. Use the *Joint Inversion - Parameters* dialog to set up a structural inversion using the Conoco-Phillips algorithm.

Set Joint Inversion Parameters

1. On the *Calculate* menu, select **Joint Structural Inversion**. The *Joint Inversion - Parameters* dialog appears.



2. From the dropdown list, select the *Inversion horizon*. Structural inversion may not be performed on the uppermost horizon.
3. Enter the *Number of iterations*. The inversion will run this many times.

Joint Inversion - Parameters

Inversion horizon: c1_m_1

* Number of iterations: 25

Less Components OK Cancel

Upper Bound (Z): m

Lower Bound (Z): m

Constraints Grid: ...

* Depth step size: 455 m

* Vertical resolution: 75 m

* Integration radius: 1 x 500 m cells

Iteration interval: 0

Aperture tangent angle: degrees

4. Click **More** to set specific parameters for the inversion.
5. Enter an elevation for *Upper Bound* if you wish to limit the inversion surface from moving above a specific elevation.
6. Enter an elevation for *Lower Bound* if you wish to limit the inversion surface from moving below a specific elevation.
7. You may specify a *Constraints Grid* if change in the inversion surface should be constrained horizontally.
8. Enter the *Depth step size*. Each inversion iteration can move the cells up to this amount.
9. Set the *Vertical resolution*. This is the distance over which the density is averaged for purposes of the iteration.
10. Enter the *Integration radius*. This is the distance from the cell being inverted upon, in grid cells, over which the intermediate calculations are performed.
11. Specify an *Iteration interval* 'n' if you wish to apply smoothing of the inversion surface every 'n' iterations.
12. The *Aperture tangent angle* defines the cone-shaped averaging filter that is applied to the surface every 'n' iterations. Larger values filter the model more heavily and reduce the degree of fit, but produce a smoother surface.
13. Click **Components** to set the *Joint Inversion Components*. The *Joint Inversion - Components* dialog appears.

Joint Inversion - Components

Gravity (Gz) Weight: 1

Magnetic Weight: 0.7

More OK Cancel

Set Joint Inversion Components

1. Use the *Joint Inversion - Components* dialog to specify the weighting of the model anomaly components to be used in the joint inversion.
2. Enter the *Weight* for each data component in your model. Components are disabled if they are not present in your model. This should be a real value between 0 and 1.0, inclusive.
3. To specify *Weight* for Gradient components, click **More**. Note that the weights will be normalized to total 1.0.
4. Click **OK**. You are returned to the *Joint Inversion - Parameters* dialog.
5. Click **OK** to start the inversion.

How-To Guide Publication Date: 21/01/2015

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