User Guide

for Grav/Mag Interpretation Extension

Oasis montaj 2023.2

This course was developed using Oasis montaj version 2023.2. If you are using a different version of Oasis montaj, some features may not be available or may work differently from what is described in this course. Courses are regularly updated. To see the latest courses, visit Seequent Learning Centre and search the catalogue for “Oasis montaj.”

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Contents

Getting Started with Grav/Mag Interpretation

This user guide describes how to use the various tools available within the *Grav/Mag Interpretation* extension to estimate magnetic and density source geometries and depths below surface from gridded magnetic and gravity data. This *Getting Started* section covers the following topics:

Grav/Mag Interpretation Overview

One of the most common uses of potential field data in early stage exploration is the estimation of depth and geometry of magnetic or density sources from magnetic and gravity anomalies. In hydrocarbon exploration, it can help estimate the thickness of sedimentary sequences that overlie dense or magnetic basement, or for the identification of igneous intrusive or extrusive rocks. For mineral exploration, it can help identify the thickness of non-economic rocks that overlie the magnetic and dense "basement" rocks that contains the exploration target.

The *Grav/Mag Interpretation* extension is centered around an automated *Euler 3D* processing tool that utilises Euler Deconvolution to calculate magnetic and density source geometries and depths from gridded magnetic and gravity data.

The extension also includes several other automated source geometry and depth estimation tools:

- *Keating Magnetic Correlation Coefficients (Keating)*, which is designed specifically for diamond exploration. This tool uses a simple pattern recognition technique to locate magnetic anomalies that resemble the response of a vertical cylinder model typical of Kimberlite pipes
- *Source Edge Detection (SED)*, which is used for locating edges (e.g. physical property contrasts) or peaks from potential field data by analyzing gradients within gridded data
- *Source Parameter Imaging (SPI)*, which automatically calculates the depth of magnetic sources from a gridded magnetic data set. Using this method has the advantage of generating source depths for multiple source types (Structural Indices) in one pass.

This guide describes in detail how to use the Euler 3D tool. The Keating, SED and the SPI tools are described within the *Specialized Grav/Mag Interpretation Processing Tools* section.

The following tasks can be performed with the Grav/Mag Interpretation extension:

- Generate source depth geometry and depth estimates very quickly from large gridded datasets
- Apply FFT and Convolution filters to generate derivative grids
- Display Total Field and Derivative grids
- Display solutions in Geosoft database and on maps
- Use various source parameters and calculation statistics to rapidly "window" (isolate) geologically reasonable solutions from unrealistic ones.

Euler 3D Deconvolution Theory and Methodology

The Euler 3D tool contains two varying applications of Euler Deconvolution, *Standard Euler* and *Located Euler* to rapidly delineate magnetic and gravimetric boundaries and calculate source depths.

Understanding Euler Deconvolution

Any three-dimensional $f(x,y,z)$ function is said to be homogeneous of degree n if the function obeys the expression.

$$f(tx,ty,tz) = t^n f(x,y,z)$$

From this, it can be shown that the following (known as Euler's equation) is also satisfied:

$$x\frac{\partial f}{\partial x} + y\frac{\partial f}{\partial y} + z\frac{\partial f}{\partial z} = nf$$

Considering potential field data, Euler's equation can be re-stated as follows:

$$(x - x_0)\frac{\partial T}{\partial x} + (y - y_0)\frac{\partial T}{\partial y} + (z - z_0)\frac{\partial T}{\partial z} = N(B - T)$$

where (x_0, y_0, z_0) is the position of a magnetic source whose total field T is measured at (x, y, z). The total field has a regional value of B. Note that N in this expression is equivalent to *-n* in Euler's equation.

It can easily be shown that simple magnetic and gravity models conform to Euler's equation (Thompson, 1982). The degree of homogeneity, N, can be interpreted as a Structural Index (SI), which is a measure of the rate of change with distance of a potential field.

A magnetic point dipole corresponds to N = 3, while a gravity point mass, a magnetic pole (theoretical) and a line of magnetic dipoles corresponds to N = 2; whereas a magnetic dyke and an anomalous pipe mass corresponds to N = 1. Reid et. al. (1990) have shown that a magnetic contact will yield an index of 0.5 provided that an offset A is introduced to incorporate anomaly amplitude, strike and dip factors:

$$A = (x - x_0)\frac{\partial T}{\partial x} + (y - y_0)\frac{\partial T}{\partial y} + (z - z_0)\frac{\partial T}{\partial z}$$

Given a set of observed total field data, we can determine an optimum source location (x_0, y_0, z_0) by solving Euler's equations for a given index N by least-squares inversion of the data. The process will also yield an uncertainty (standard deviation) for each of the fitted parameters, and this can be used as a criterion to accept or reject a solution.

Standard Euler Deconvolution

The Standard Euler workflow employs a least squares method to solve Euler's equation simultaneously for each cell in a grid, using data from a surrounding square calculation window of predetermined size (e.g. 10 x 10 grid cells). For a 10 x 10 window, there will be 100 equations for each grid cell, from which source locations and their uncertainties are obtained for a specified SI. Then the calculation window is moved over the next grid cell.

Solutions with a depth error (standard deviation) that exceeds a defined tolerance (typically 15%), and which are within a certain distance from the centre of the calculation window. Sources are considered more reliable the closer they lie to the centre of that window, because the curvature of the field as it falls off away from the source is captured within the calculation window. The calculation window should be large enough to include each solution anomaly of interest in the total field magnetic grid, but ideally not large enough to include any adjacent anomalies. Accepted solutions are saved in a Geosoft database, each with accompanying parameters and statistics that can be used to further "window" (reject) less statistically and geologically reasonable solutions.

Note that the standard deviation is a measure only of how well the measured field conforms to Euler's equations for a given index. This assumes that the SI chosen is correct for the source of the field observed in the sample window, and that only one source is producing the field observed in the window. In practice, any area will likely contain sources that can be approximated using each SI, therefore it is common to run a pass Standard Euler for each relevent SI and combine the results .

For magnetic data, a significant advantage of using Euler Deconvolution is that it is insensitive to magnetic inclination, declination and remanence since these become a part of the constant in the anomaly function of a given model. However, low magnetic latitude problems will still exist for magnetic North-South trending features because the physics of this situation dictates a low signal to noise ratio in the data. Pole reduction and careful North-South leveling noise rejection filters can be applied to low-latitude data to improve the situation somewhat.

For a more complete discussion of the Euler Deconvolution method described in this manual, please refer to Reid et. al. (1990)

Located Euler Deconvolution

Unlike Standard Euler, which is run on each cell within a grid, Located Euler begins by calculating an Analytic Signal grid, finding peaks in that grid, then running Euler deconvolution at each peak. As a result, this method produces far fewer solutions than Standard Euler and is therefore easier to process and should contain a greater proportion of statistically and geologically reasonable results. Let's look at the process in more detail:

1. Calculate and Display Analytic Signal Grid

To perform the Located Euler Deconvolution you must first calculate and display an Analytic Signal (AS) grid. This grid is computed from derivative grids, which are either preexisting or can be calculated as part of the process.

The Analytic Signal is the square root of the sum of the squares of the derivatives in the x, y, and z directions:

AS = sqrt (dx*dx + dy*dy + dz*dz)

The Analytic Signal is particularly useful in locating the edges of magnetic sources in areas where remanence and/or the inducing magnetic field can distort the shape of their associated anomalies.

2. Locate Peaks in Analytic Signal Grid

The second step is to use the Blakely peak-picking algorithm to identify peaks in the AS grid, which are written to a solutions database and displayed as symbols on the current map.

The Blakely method compares each grid cell value with the values of the eight neighboring grid cells (along the grid row, along the grid column and along both diagonals). There are four sensitivity levels, which may be used to determine whether a grid cell will be selected as a peak:

- Normal (4) - grid values in all of the nearest grid cells are lower
- More peaks (3) - grid values in any three directions are lower
- Even more peaks (2) - grid values in any two directions are lower
- All ridge peaks (1) - grid values in one direction are lower

3. Run Located Euler Deconvolution

The final step is to run Euler Deconvolution on each peak location identified in the previous step.

References

Blakely, R. J., 1996, Potential theory in gravity & magnetic applications: Cambridge University Press, New York, p117.

Thompson, D. T., 1982, EULDPH: A new technique for making computer-assisted depth estimates from magnetic data. Geophysics, Vol.47, pp.31-37.

Reid, A. B., Allsop, J. M., Granser, H,, Millett, A. J., Somerton, I. W., 1990, Magnetic interpretation in three dimensions using Euler Deconvolution, Geophysics. Vol.55, pp.80-91.

Esther Harris, Mark Jessell, Terence Barr, 1996, Analysis of the Euler deconvolution technique for calculating regional depth to basement in an area of complex structure, SEG Technical Program Expanded doi: 10.1190/1. 1826363.

Using Standard vs Located Euler Deconvolution

The Standard Euler Deconvolution (Reid, A. B., et al, 1990., Thompson, D. T., 1982.) obtains its solutions by inverting Euler's homogeneity equation over a window of data at every grid point. As a result, solutions may be generated in areas that are free of anomalies or on the edges of anomalies, even if it is inappropriate to do so.

The Standard Euler method also has an unchanging window size, creating a bias towards solutions that are in magnitude, on the order of the window size.

Over a 1000 by 1000 data grid approximately 1,000,000 solutions will be generated these are then refined, based on error estimates and other criteria. However, the final solution set will still retain a large number of erroneous depth estimates. Therefore further windowing of solutions based on solution statistics and other parameters is often required. We will look at the process of windowing in detail later in this guide.

Because it is only run over peaks, Located Euler typically produces far fewer solutions than Standard Euler. The solutions are also generally more statistically reasonable because the window is optimally sized and located to analyze the field fall off in all directions away from the peak.

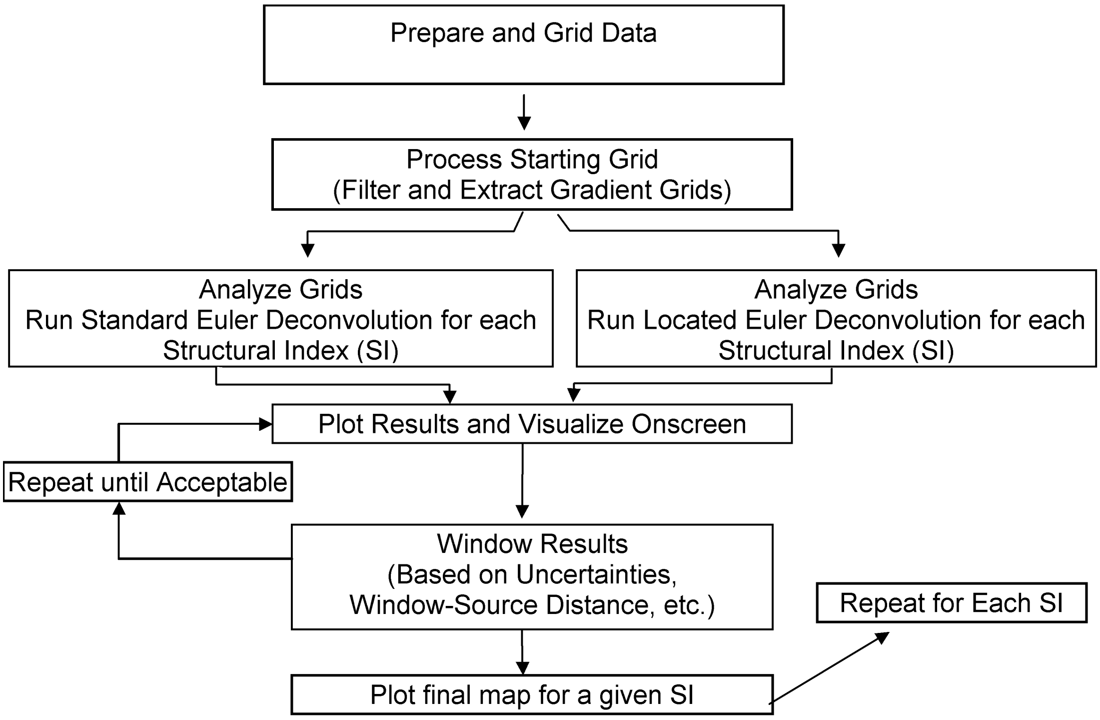
The advantages of using Located Euler over Standard Euler can be summarized as follows:

1. Solutions are only generated over identified anomalies
2. The window size is optimized for the size of each anomaly
3. Because of 1 and 2, fewer solutions are generated that are more likely to be statistically and (depending on the suitability of the SI used) geologically reasonable.

Generating a geologically reasonable depth value for a given source body depends on an appropriate choice of structural index. Because the processes are automated, it does not take much time to experiment with different structural indices and window sizes, based on your understanding of the nature of the sources in your area of interest.

Understanding the Workflow

The objective of the Euler 3D workflow is to produce a map that shows the locations and depths of the geologic sources of magnetic or gravity anomalies observed in a two-dimensional grid. The ideal workflow is described below:



In situations where low SI sources (less than 1) are sought, it may be better to use a grid of the first vertical derivative rather than one of the total field. For a discussion of using the first vertical derivative, please refer to the Understanding Solution Uncertainties section.

Before You Begin Using the Grav/Mag Interpretation Extension

This guide is intended for Earth Scientists who are familiar with methodologies for acquiring, processing and presenting earth science data. To use these guides effectively, you should:

1. Be familiar with working with earth science potential field data in Oasis montaj.
2. Understand basic methodologies for processing data – including preparing data for processing, evaluating quality before and after processing, displaying data in profile formats, running computer-based algorithms and preparing data for final presentation.
3. Understand how to create and manipulate data within Geosoft databases; importing and exporting data, storing, analyzing and applying processes to data.

Workflow steps described in this guide will refer to a sample dataset that can be downloaded by clicking on this link. You can also use your own data while working through the guide if you wish. Whichever data you decide to use should be stored in a single, convenient location on your computer.

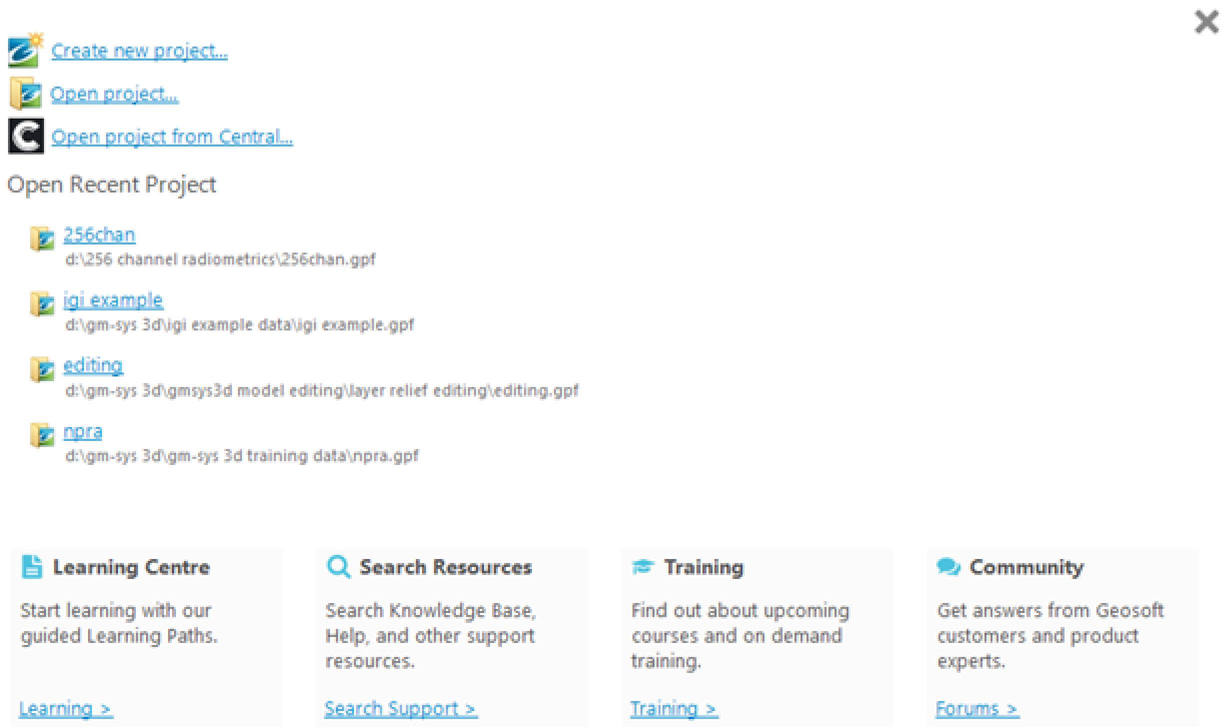
Create a Project in Oasis montaj

Working in Oasis montaj requires a project. You can customize the setup of the project and select the desired menus and toolbars. Projects inherently remembers their saved state; if you save, close and later reopen the project, it will recover all its elements in their last state. All files in an open project are listed in the Project Explorer.

Geosoft Projects files are created with the extension (*.gpf). In the absence of an explicit folder path the extension assumes that you are accessing files and saving files in the project working folder. To streamline your work, as well as keep it organized, you may wish to make sure that your project file is in the same folder as the other files you want to use. We recommend that each project you work on have its own project (*.gpf) file. If you use a number of applications or extension tools in Oasis montaj, you can use the individual projects to display only the menus you require.

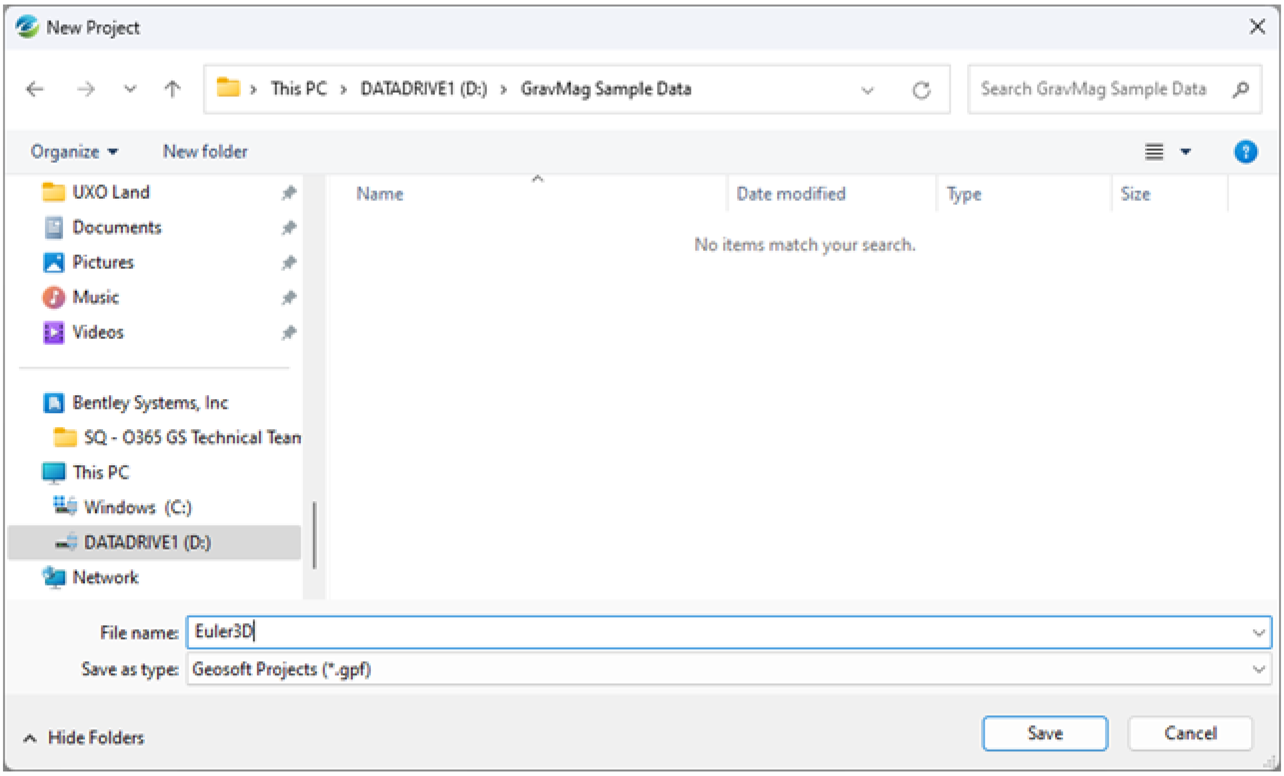
To Create a Project

1. **Launch** Oasis montaj. The *Projects* dialog appears.



This dialog allows you to create new projects, open existing ones and access various support and learning resources.

2. Click on the **Create new project** option. The *New Project* window opens.



3. Navigate to the folder that contains your data and then specify a name for the project. For example, we will name the project for the sample data **Euler3D**.

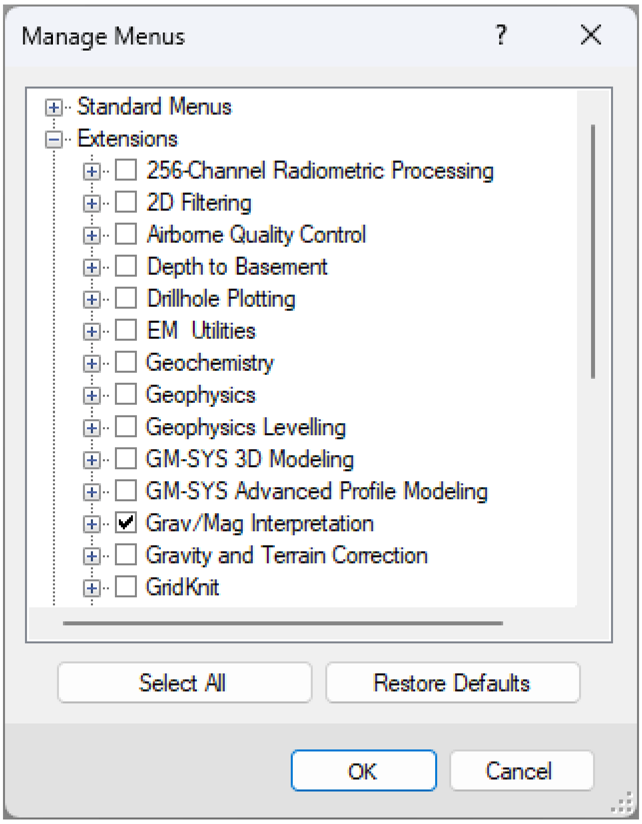
4. Click **Save**. The system saves the project and indicates it is open by adding menus to the menu bar, adding buttons to the Standard Short-cut bar and by displaying the *Project Explorer*.

Load the Euler 3D Menu

Before you can start working with the Grav/Mag Interpretation extension, you have to load the Euler 3D menu into your project.

To Load the Euler 3D Menus

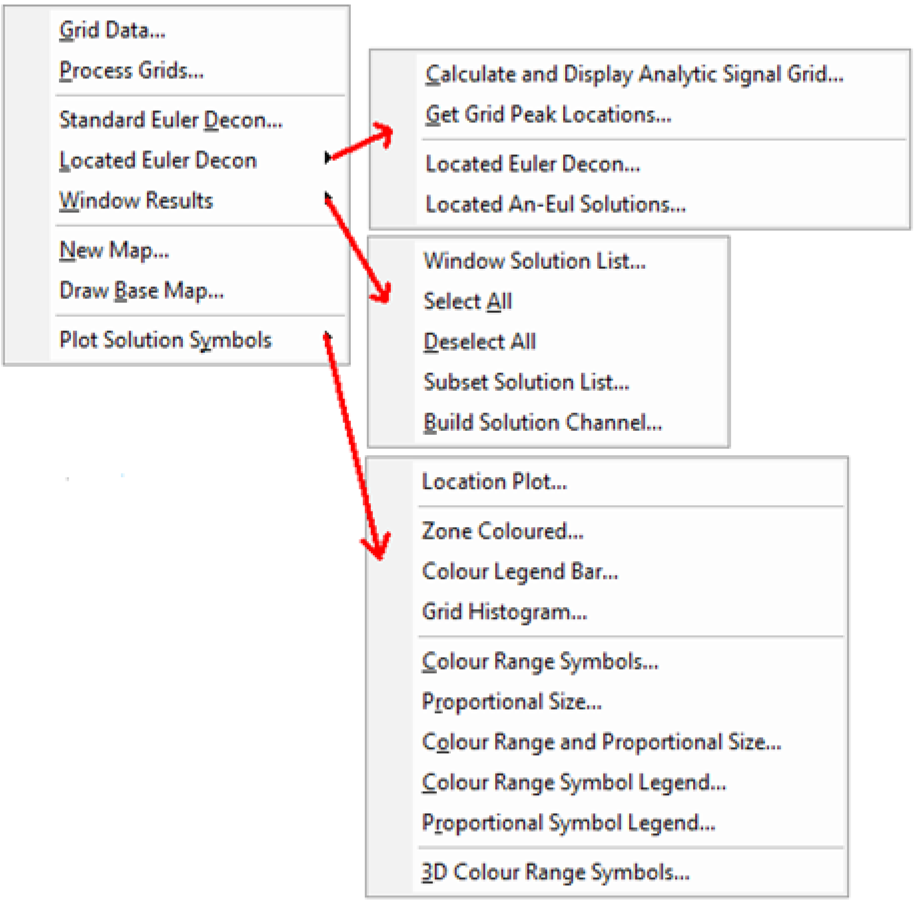
1. Open the *Project* menu and select **Manage Menus**, or click the *Manage Menus* icon () on the *Project Manager* toolbar. The *Manage Menus* dialog appears.



2. Expand the *Extensions* tree and select **Grav/Mag Interpretation** (see image above) and then click **OK**. Several new menus are added to the Oasis montaj menu bar:

The Euler 3D Menu

The Euler 3D menu is designed to guide you through the steps of the workflow, with a series of sub-menus for related tasks. The main and sub menus are shown below:



We will be walking through most of these options in the coming pages.

Preparing and Processing Field Data for Grav/Mag Interpretation

This section describes how to optimally prepare and process your field data for Euler 3D Deconvolution. The topics discussed include:

- Data requirements
- Gridding data
- Generating and displaying derivative grids

Data Requirements

Our implementation of Euler Deconvolution requires four Geosoft grids as inputs:

- A starting grid, which may be the total magnetic field, gravity field, or the first vertical derivative of these fields
- The first vertical derivative
- The first horizontal derivative in the X direction
- The first horizontal derivative in the Y direction

You may already have these grids, but if you don't, the *Grid Data* and *Process Grids* menu options to generate total field and derivative grids respectively. The latter option computes the X and Y derivatives in the space domain using a simple nine-point convolution filter. The Z derivative filter does not have such a simple spatial representation, so it is created in the frequency domain using a Fast Fourier Transform (FFT) procedure.

Implications of Convolution Filtering

Using FFT methods to calculate derivatives can produce undesirable side effects such as ringing and edge distortion. Although first vertical derivatives are best calculated in the frequency domain, horizontal derivatives are better obtained with a simple 3 x 3 convolution filter. This avoids side effects due to the grid filling in the FFT filter process. Examples of the convolution filters are shown below:

X horizontal derivative		
0	0	0
-1/2*cell	0	1/2*cell
0	0	0

Y horizontal derivative		
0	1/2*cell	0
0	0	0
0	-1/2*cell	0

Implications of FFT Filtering

FFT filtering is used to calculate the z-derivative. This involves expanding and filling the input grid before calculating the Fourier transform. The default is to expand to a square grid, but if the input grid is long and narrow, it is more accurate and time-efficient to expand to a rectangle.

It may be necessary to upward continue your data if that data contains significant short wavelength noise. Upward continuation effectively attenuates this noise without changing the physical significance of the data (as opposed to a low-pass filter, which does change the significance of the data). An option to upward continue data is available when generating derivative grids. This option applies an FFT continuation filter to each derivative grid.

A common approach is to upward continue data by a distance equivalent to the cell size. The continuation distance should be carefully chosen to avoid losing anomalies of interest. If the derivative data is upward continued, the total field grid must also be upward continued so that all grids represent data observed at the same elevation. You must specify a new grid file name for the upward continued grid and this grid must be used during Euler Deconvolution processing. You can upward a total field grid in two ways:

- A vertical continuation filter can be found here: Grid and Image menu >> Filters >> Vertical continuation convolution
- If you are subscribed to the 2D Filtering extension, an upward continuation FFT filter is available within

> This guide does not explicitly describe the procedure for filtering your data although in practice, you may be required to filter the data yourself prior to using the Euler 3D system. Filtering grids using filters available within 'base' Oasis montaj is described in this course, whereas filtering grids using the 2D Filtering extension is described here.
>
> Preparing a grid for FFT can be computationally expensive and therefore take a long time to complete if using very large grids. Note that you will need at least eight times the size of input grid in available free disk space to complete this process.

Preparing Data and Grids

Euler 3D operates on gridded data (*.GRD) files. Since the quality of your results depends directly on the quality of gridded data, we strongly recommend that you carefully evaluate your starting grid (and data, if you are gridding data first) for any potential problems before starting the deconvolution process.

Factors that you should consider in identifying potential problems include:

- Survey height above sources
- Leveling (and other systematic errors)
- Line spacing or sample interval
- Grid interval relative to the line or sample interval.

For line-based data, a grid interval 1/8 to 1/4 the line spacing is normally chosen, and for randomly located data, an interval of 1/4 to 1/2 the nominal sample interval is often used. The interval chosen also depends upon the depth of geologic sources of interest, since the minimum depths returned are about the same as the grid interval.

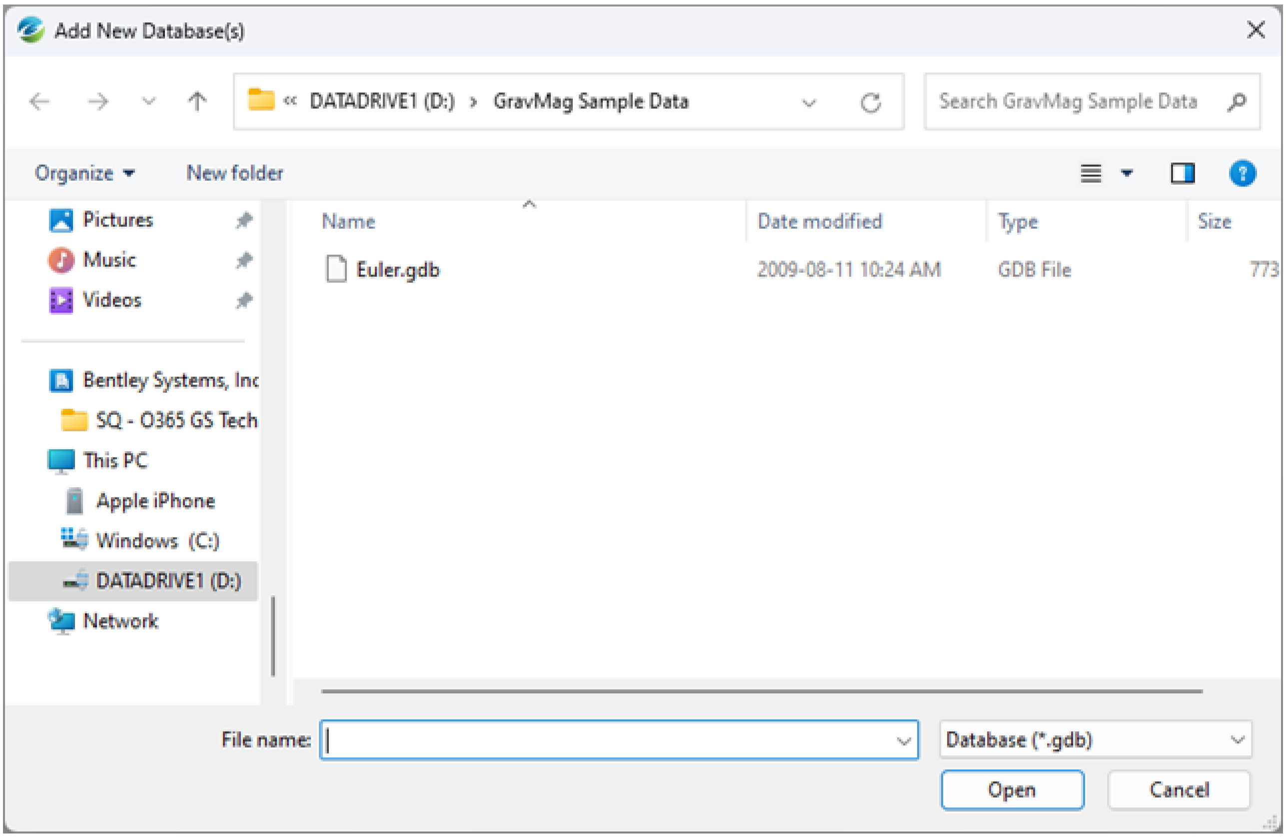
Because aliasing, levelling, and location errors mostly affect shorter wavelengths, data quality can sometimes be improved by judicious low-pass filtering at the expense of resolution and of the representation of the effects of shallower sources. The most effective way to do this is to apply a small upward continuation to the grid during calculation of the gradients. A distance of up to one grid cell should be sufficient. However, such filtering should only be applied if necessary and the upward continuation distance should be minimized to remove only the noise, which is causing a problem.

Creating a Grid

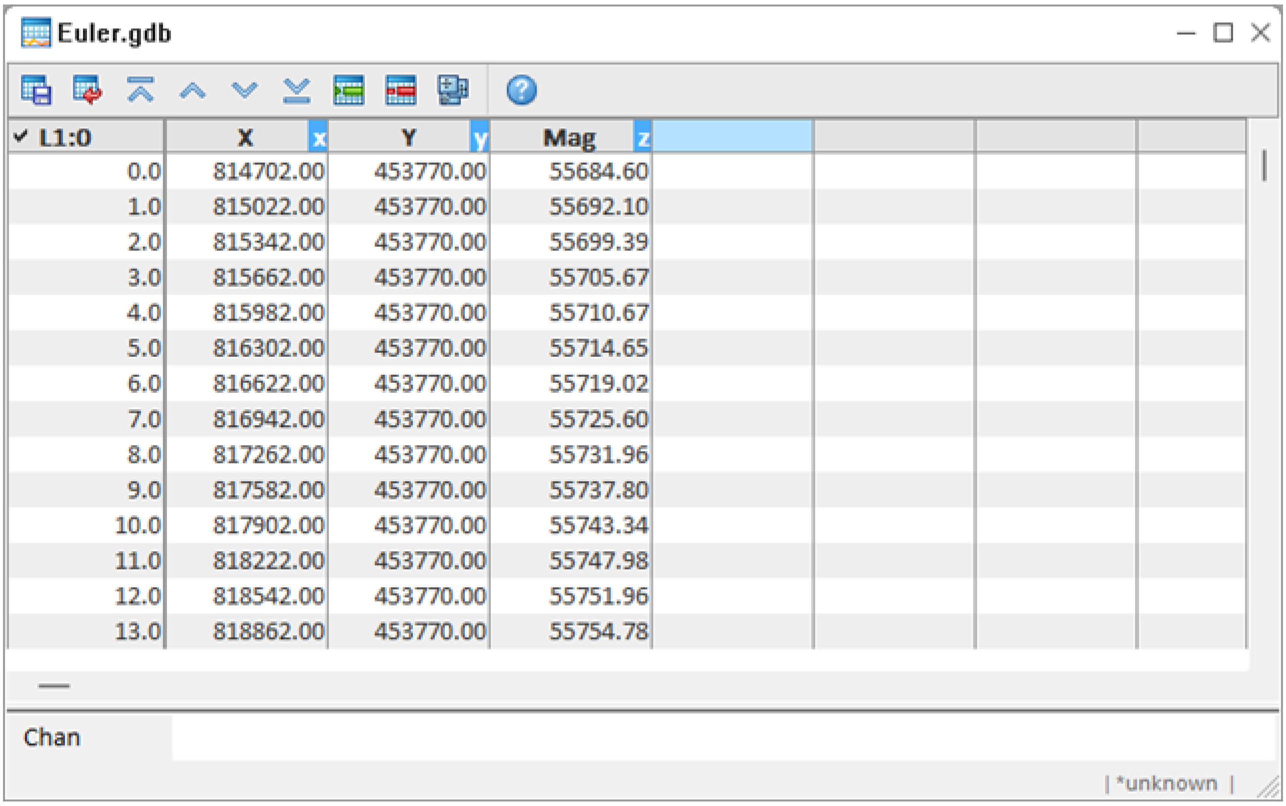
If you don't happen to have your data gridded, the extension provides the ability to create a gravity or total magnetic field grid from a Geosoft database using the minimum curvature method. We will now go through the process of creating this grid from the database that comes with the sample data.

To Open a Database

1. In the *Project Explorer*, **right-click** on the *Database* tree and select **Open Databases**. The *Add New Database(s)* window appears.



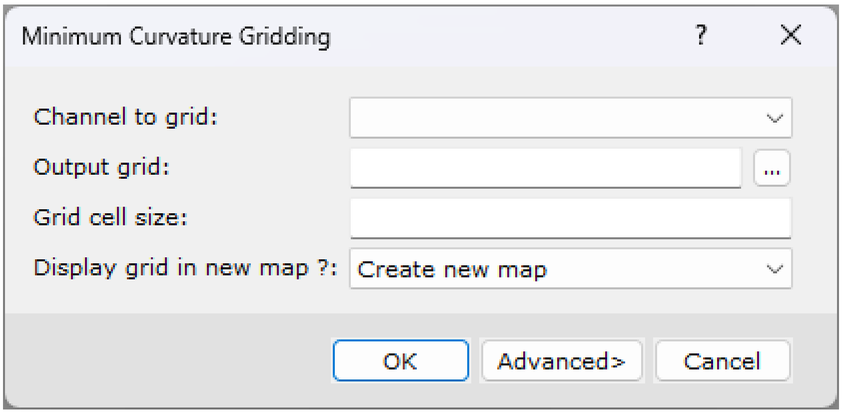
2. Select the database (Euler.gdb in the case of the sample data) from your working folder and then click **Open**. The database appears in the project.



L1:0	X	Y	Mag
0.0	814702.00	453770.00	55684.60
1.0	815022.00	453770.00	55692.10
2.0	815342.00	453770.00	55699.39
3.0	815662.00	453770.00	55705.67
4.0	815982.00	453770.00	55710.67
5.0	816302.00	453770.00	55714.65
6.0	816622.00	453770.00	55719.02
7.0	816942.00	453770.00	55725.60
8.0	817262.00	453770.00	55731.96
9.0	817582.00	453770.00	55737.80
10.0	817902.00	453770.00	55743.34
11.0	818222.00	453770.00	55747.98
12.0	818542.00	453770.00	55751.96
13.0	818862.00	453770.00	55754.78

To Grid Data using the Minimum Curvature Gridding Method

1. Open the *Euler 3D* menu and select **Grid Data**. The *Minimum Curvature Gridding* dialog appears.



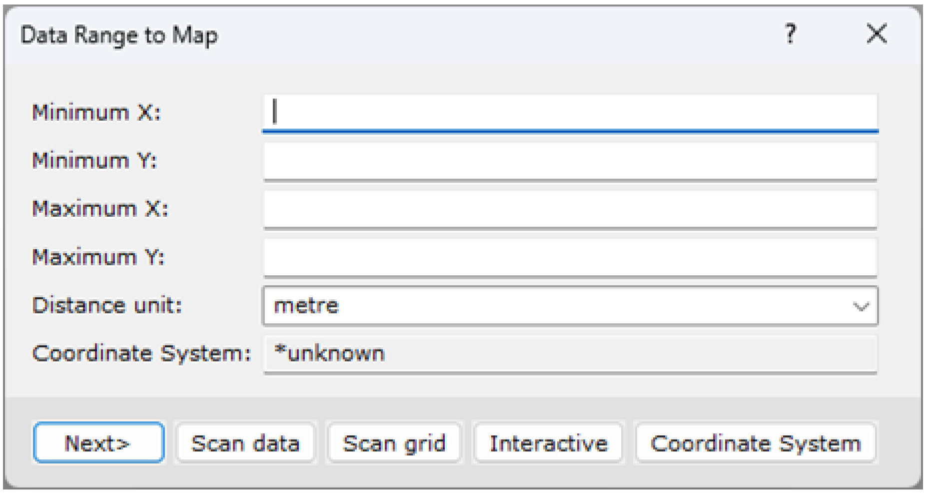
2. From the *Channel to grid* drop down list, select the channel name (**Mag** for the sample data).
3. Specify the name of the *Output grid* (e.g. **EulerMag** for the sample data).
4. Specify the *Grid cell size* (**320** m for the sample data).

> This field can be left blank and the program will calculate an appropriate cell size for the methid, based on the size of the area to be gridded and the number of data points within.

5. Using the *Display grid in new map?* dropdown list, select either *Current map*, *Create new map*, or *Do not plot*.

> Clicking on the *Advanced* button opens a second dialog containing several parameters that can be adjusted in order to optimise the output grid.

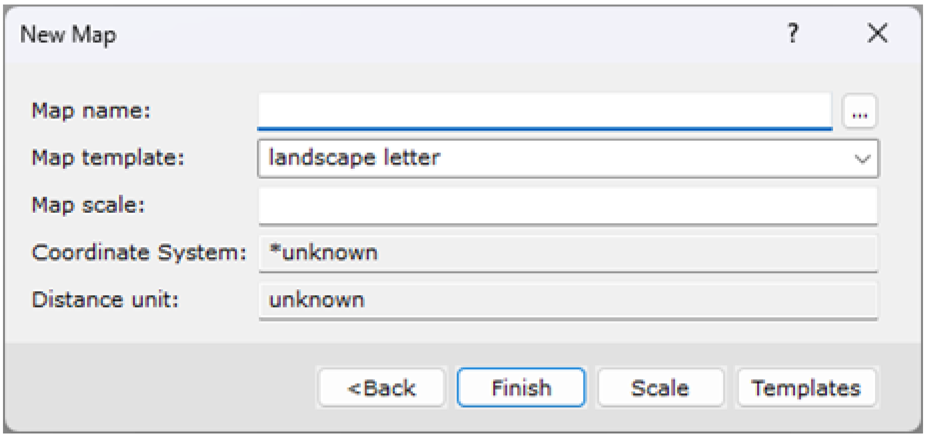
6. Click **OK**. The *Data Range to Map* dialog opens.



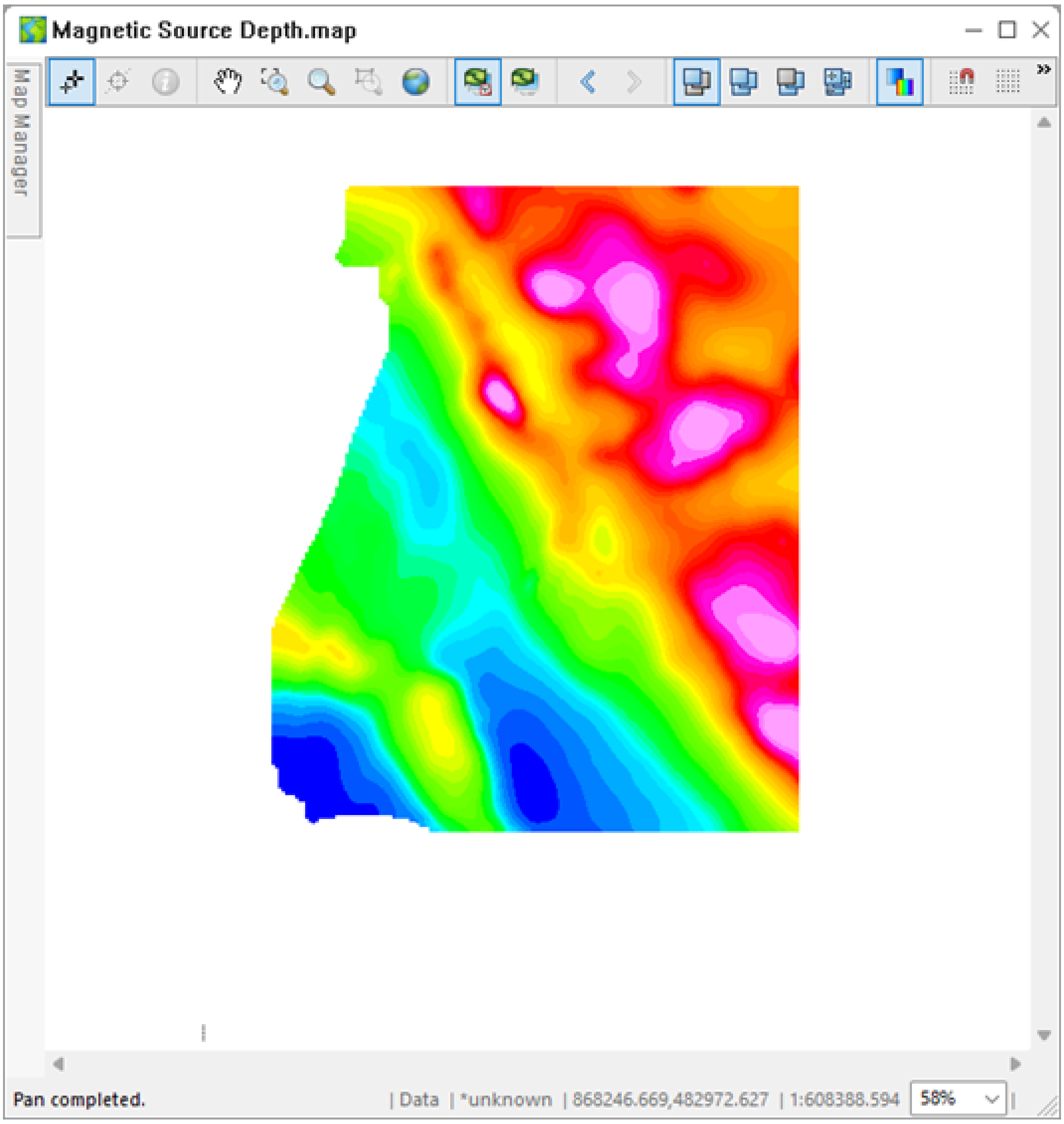
7. Click on the *Scan Data* button to calculate the extents of the data to grid from the database.

> The *Scan Grid* and *Interactive* buttons can be used to define the data range from either a grid file or by drawing on a map respectively. The *Coordinate System* button can be used to assign a coordinate system to the grid, noting that if the input database has a system assigned to it the grid will inherit that system.

8. Click **Next**. The *New Map* dialog opens.



9. Specify a *Map name* (e.g. **Magnetic Source Depth** for the sample data).
10. Specify a *Map template* (page size) for the map (e.g. *Portrait A4* for the sample data).
11. Click on the **Scale** button to calculate and populate the *Map scale* field.
12. Click **Finish**. The grid and map are created and displayed in the project.



> A base map (coordinate grid, scale bar, north arrow etc) can be added to this map using the *Base Map* option from the *Map Tools* menu.

> If you are gridding airborne data, you may want to use a more appropriate method for that data, such as Bi directional gridding. An alternative tool that contains that and other gridding methods can be launched via the *Gridding > Grid Data* option within the *Grid and Image* menu.

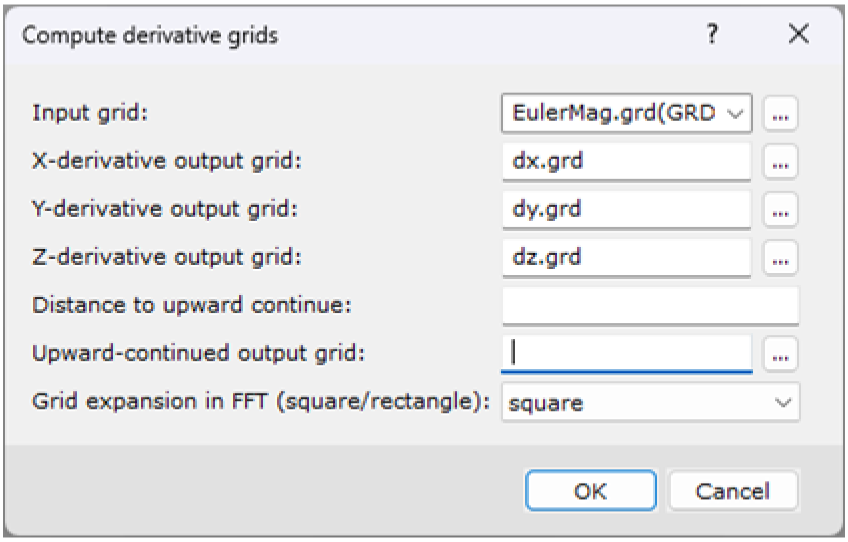
Creating Derivative Grids

Once we have a grid of magnetic or gravity field data, the next step in the inversion process is to create vertical and two (x and y) horizontal derivative grids from that grid. If you already have these derivative grids, you do not have to perform this step.

The *Process Grids* workflow calculates and creates these gradient grids from a starting grid, using a FFT. The tool also provides the option to apply an upward continuation to filter your data. As discussed earlier, an upward continuation can effectively remove high-frequency, short-wavelength anomalies from data that may be caused by noise or cultural sources (i.e. infrastructure) on the Earth's surface.

To Create Derivative Grids

1. Open the *Euler 3D* menu and select **Process Grids**. The *Compute derivative grids* dialog appears.



2. Using the dropdown list, select the *Input grid* file. If you have already created a grid in your project, you will see that grid (e.g. EulerMag.grd for the sample data) .

3. For the *X, Y and Z-derivative output grids* you can specify new names or accept the default names of **dx.grd**, **dy.grd** and **dz.grd** respectively.

4. You can use the *Distance to upward continue* and *Upward-continued output grid* fields to upward continue if necessary. In the case of the sample data there is no need to do this.

> If upward continuation is required, it needs to be applied, using the same distance, to both the derivative and total field grids.

5. The **Grid expansion in FFT** method as, *square* or *rectangular*. The square option can be used for the sample data grid.

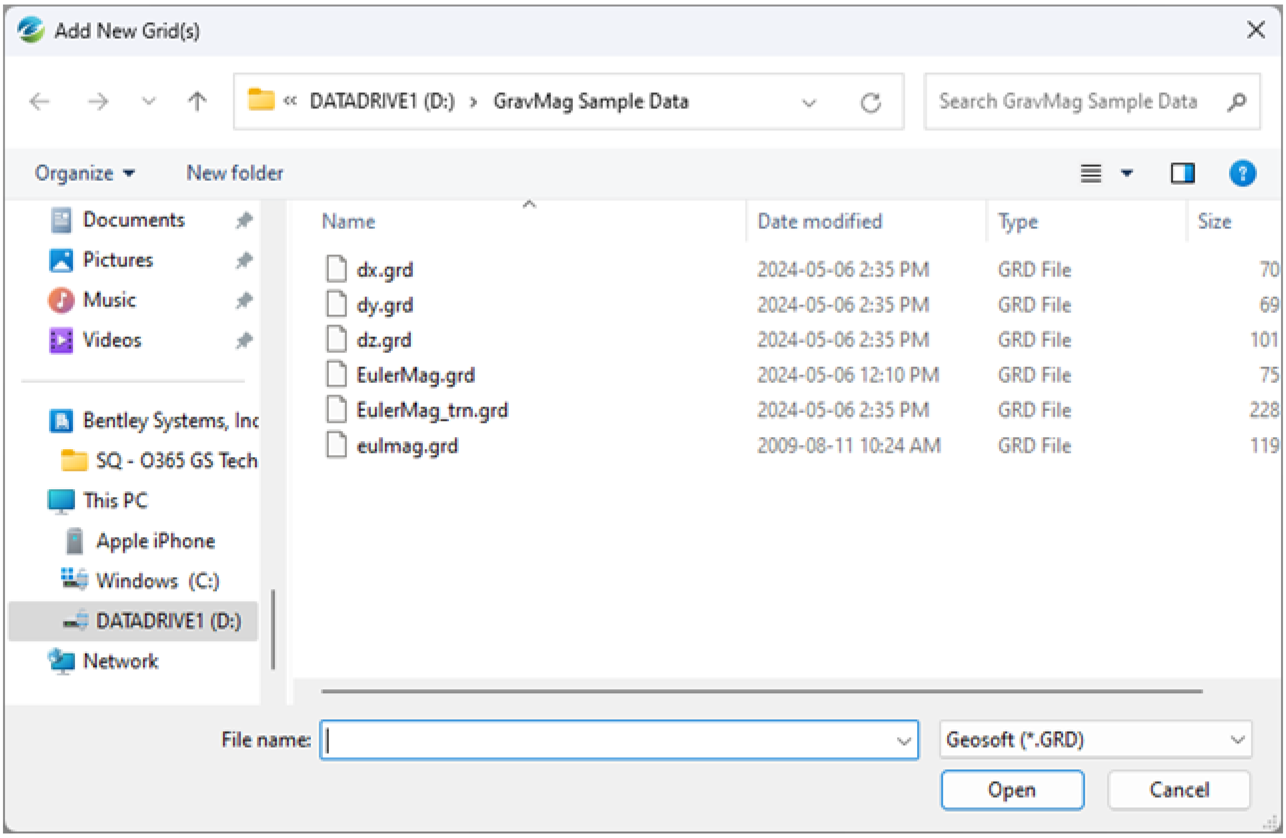
6. Click **OK**. The derivative grids are created and saved to the project folder.

Displaying Derivative Grids

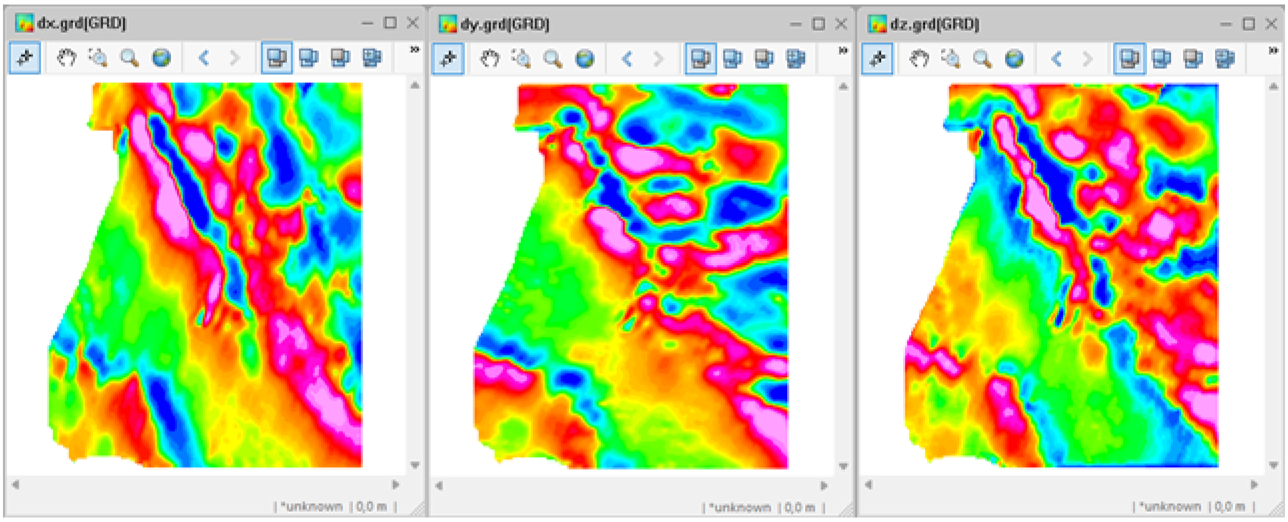
The derivative grids are created and saved to the project folder, but not automatically displayed within the project. You may want to display them on your screen for comparison with the original total field grid and to check for noise.

To Display Derivative Grids

1. In the *Project Explorer*, right-click on *Grids* and select **Open grids**. The *Add New Grids* window opens.



2. Select the grids (dx.grd, dy.grd and dz.grd in the case of the sample data) and click Open. The grids open in the project; the sample data grids are shown below.



Performing Euler Deconvolution

This section describes how to perform both Standard and Located Euler 3D to estimate the depth and geometry of magnetic sources from magnetic field data. The topics discussed include:

- Performing Euler deconvolution
- Standard Euler deconvolution
- Located Euler deconvolution
- Displaying Solution Statistics

Choosing an Appropriate Structural Index

Euler's homogeneity relationship does not assume any particular geologic model. Because of this, Euler Deconvolution can rapidly provide source depth estimates for a wider variety of geological settings than traditional model-dependent methods. The degree of homogeneity N (-n in the Euler's equation) may be interpreted as a Structural Index (SI) – a measure of the rate of change with distance of the field.

The Structural Index (geometry of the source) is integral to performing Euler Deconvolution and interpreting the results, and you should consider or identify which types of sources are likely to occur in your area of interest before beginning. For example, when exploring for Kimberlite-hosted diamonds, using an SI of 2 for magnetic data is likely most appropriate. If you are interested in identifying contacts and faults, an SI between 0 and 1 could be used (an SI of 0.5 is also common). The following table summarizes the structural indices for simple models in a magnetic field and for a gravity field:

SI	magnetic field	gravity field
0.0	contact	sill/dyke/step
0.5	thick step	ribbon
1.0	sill/dyke	pipe
2.0	pipe	sphere
3.0	sphere	

A simple way to determine an appropriate structural index is to determine how many infinite or reasonably large dimensions are present for each. This number subtracted from the maximum SI for a given field, which is 3 for magnetic data (the magnetic field from a point dipole falls off as 1/r3) and 2 for gravity data (the gravity field from a point source or sphere falls off as 1/r2):

Geologic model	number of infinite dimensions	Magnetic SI	Gravity SI
sphere	0	3	2
pipe	1 (z)	2	1
horizontal cylinder	1 (x-y)	2	1
dyke	2 (z and x-y)	1	0
sill	2 (x and y)	1	0
contact	3 (x, y and z)	0	NA

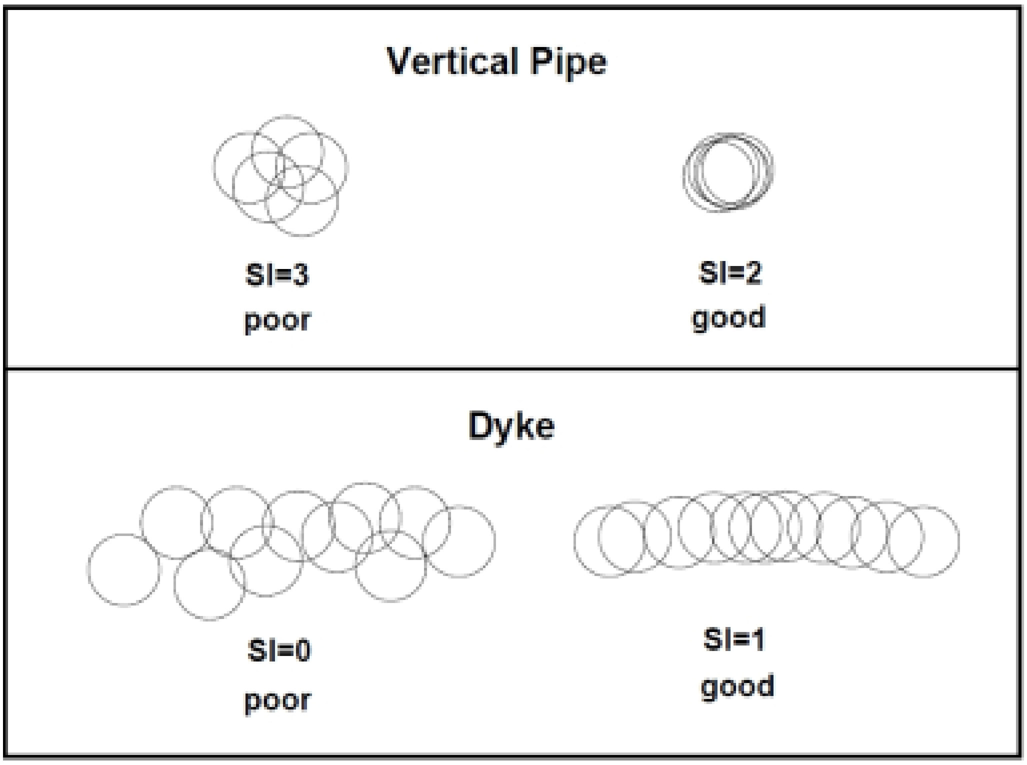
Note that a 0 index implies that the field is a constant regardless of distance from the source model. In the case of a gravity contact, the field would be infinite. These situations are physically impossible for real data, and a zero index represents a physical limit, which can only be approached as the so-called 'infinite' dimensions of the real source increase. In practice, an index of 0.5 can often be used to obtain reasonable results when an index of 0 would otherwise be indicated.

However, this presents a problem when we wish to obtain results from a 'contact' model with gravity data. A solution is to work with the first vertical derivative of the gravity field in place of the original gravity field. This increases the rate of fall-off by one power (one SI) and makes the gravity SI equivalent to the magnetic SI for the same model source. The four component grids provided to the Euler 3D System would then be:

$$\frac{\partial g}{\partial z}, \frac{\partial^2 g}{\partial z^2}, \frac{\partial^2 g}{\partial z \, \partial x} \text{ and } \frac{\partial^2 g}{\partial z \, \partial y}$$

So if you want to identify contacts from gravity data, your starting grid should be the first vertical derivative instead of a total field grid and the vertical and horizontal derivative grids should be calculated from this.

The most appropriate SI for a given anomaly is that which returns the tightest (spatial) clustering of sources. This is illustrated in the following diagram:

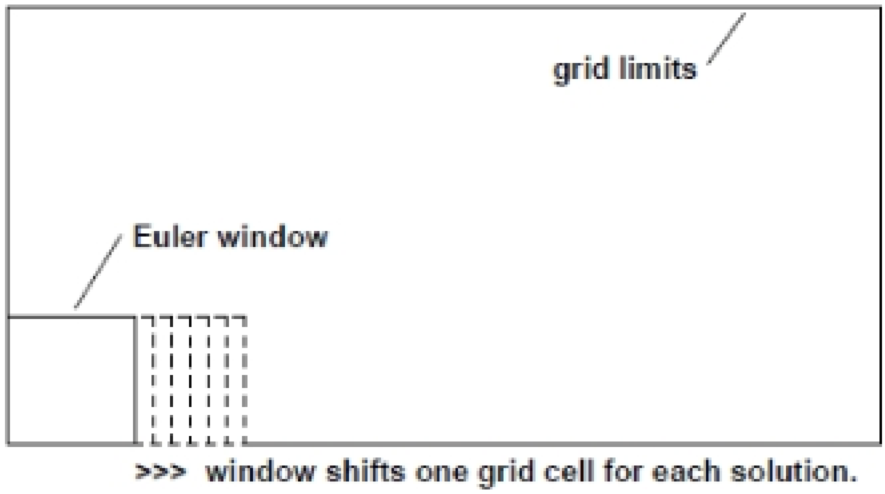


The solutions on the right represent the appropriate SI for a pipe-like body (top) and a dyke (bottom), for magnetic field data. In situations where your understanding of the geology of your area of interest is limited, you can run multiple passes of Euler Deconvolution with different Structural Indices for each, and then use clustering to judge which indices are the most geological reasonable.

It has also been demonstrated that depths are generally slightly under-estimated for low SI sources, whereas depths are generally slightly over-estimated for high SI sources. Reid et al. (1990) state that even if the SI is geologically reasonable, it is clear that depth estimates are more precise for high-index sources than for low.

Understanding the Processing Sequence

The *Standard Euler Decon* tool processes the four data grids (the total field magnetics or gravity grid and its three orthogonal derivatives) and runs Euler Deconvolution for each cell in the total field grid, using data that is extracted from a square window (typically 10 by 10 grid cells in size) around each. The window is then shifted one grid cell and a new solution is calculated. This procedure continues until the window has moved across the entire grid, as illustrated in the following figure:



The *Located Euler Decon* tool operates in an almost identical way, except that it is only run on grid cells that contain peaks identified from the Analytic Signal grid.

Solutions that are found to pass the following "fit" criteria are written to an output database:

1. The solution depth uncertainty is smaller than the defined tolerance (typically 15% of the depth)
2. The distance from the centre of the window to the source is less than a specified limit

Choosing a Window Size for Computation

A window size should be chose according to these criteria:

1. It should be large enough to incorporate any anomalies and their fall off to the 'background' value
2. It should be small enough not to include multiple anomalies

If multiple anomalies occur within any given window, the solution will be rejected because it won't meet the "fit" statistics criteria. Solutions will also be rejected where an anomaly is too large for the specified Euler window.

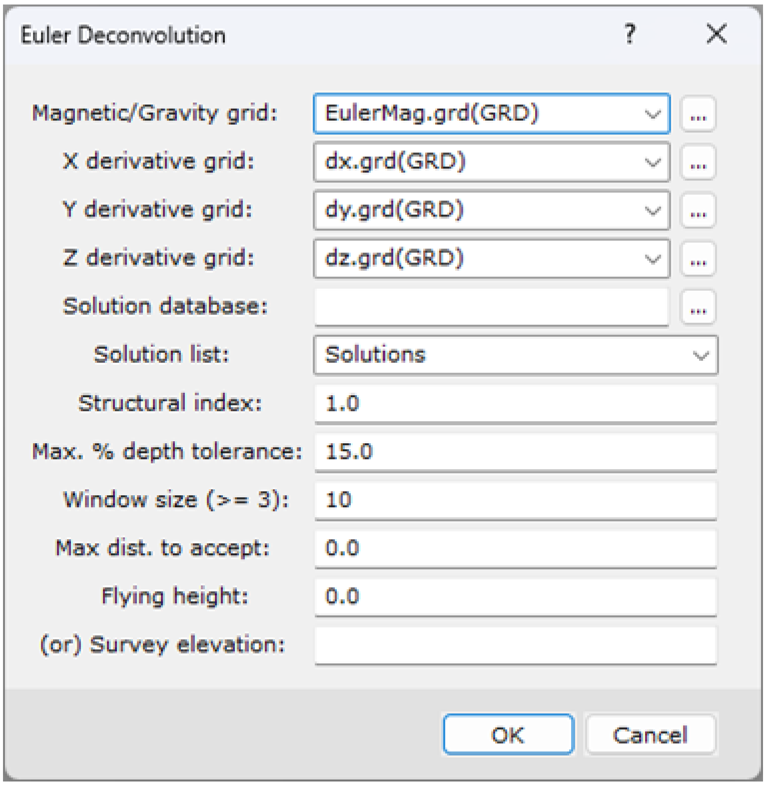
The default window size of 10 x 10 grid cells should be adequate for most situations. You may want to run alternative or additional passes of Euler Deconvolution with smaller or larger window sizes, depending on the size and distribution of anomalies in your data.

Standard Euler Deconvolution

We will now perform Standard Euler Deconvolution, using the sample data.

To Perform Standard Euler Deconvolution

1. Open the *Euler 3D* menu and select **Standard Euler Decon**. The *Euler Deconvolution* dialog appears.



2. If you used the Grav/Mag Interpretation extension to generate the derivative grids, the *Magnetic/Gravity grid* and the *X, Y and Z derivative grids* will be populated with these grids. Otherwise the *Browse* buttons can be used to locate them.

3. Specify the new *Solution database* name as **Standard_Euler**.

4. Specify the *Solution list* name as **SI_1**.

> The *Solution list* is a group (line) in the output database to which the solutions are to be written. Up to 20 different sets of solutions can be written to a database.

5. The *Structural index* should be set to **1.0** for this exercise, as the data contains some relatively narrow, linear anomalies that may correspond to dykes.

6. Leave the *Max. % depth tolerance* set to **15** %.

> The Depth Uncertainty (dZ), expressed as a percentage, is a measure of the (mathematical) validity of each solution. Solutions can also be removed (windowed) from the results post Euler Deconvolution, which we will discuss in the next section.

7. Specify the *Window size (>=3)* as **20** grid cells. We use this value because the majority of anomalies within the input grid are 3-6 km wide, therefore the window size should be 6000 m. The input grid cell size is 320 m so the window will be 6400 m wide.

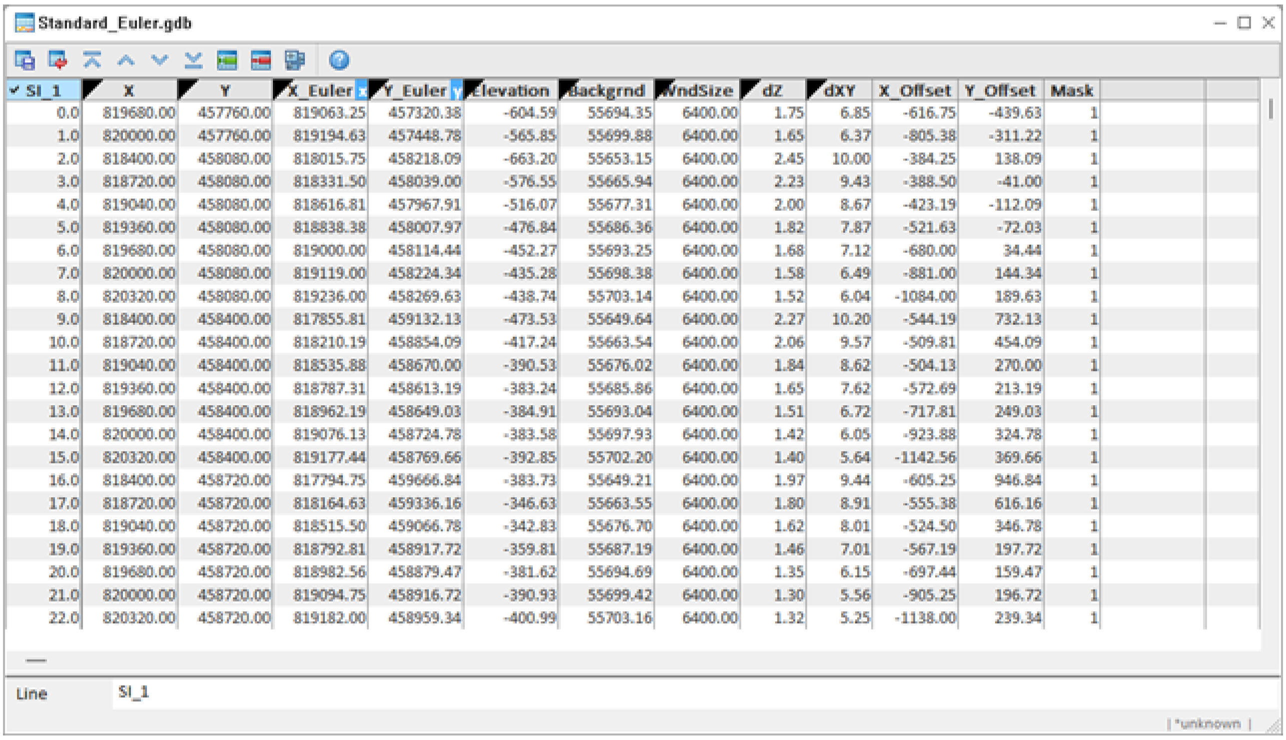
8. Specify the *Max dist. to accept* as **3200** m, which is 50% of the window size. Solutions at a distance (from window center) greater than this maximum will not be accepted.

> Solutions are considered less reliable the further they are located from the centre of the search window. This results from the failure to place a valid source within the window that matches the chosen SI, or because in the anomaly and its fall off to the "background" are not fully captured within the search window.
>
> The X and Y locations of each solution relative to the center of the window are written to the output database, and can therefore be removed (windowed) from the results post Euler Deconvolution, which we will discuss in the next section.

9. The sample data was acquired by a barometric airborne survey flown at a height of 2500 m, so leave the *Flight height* set to 0 and specify the *Survey elevation* as **2500** m.

> The last two parameters, *Flying height* and *Survey elevation* determine the manner in which the results are displayed. The units in which the solution z (depth) values are given are taken from the grids. For drape airborne surveys, enter the flying height, and the dialog will return z values as depth below the ground surface. For barometric airborne surveys, enter the survey elevation, and the dialog will give z values as elevations (i.e. height above sea level).

10. Click **OK**. The system creates a new group/line in the database that contains ~5500 Euler solutions with the following channels:


Standard_Euler.gdb

SI_1	X	Y	X_Euler	Y_Euler	Elevation	Backgrnd	WndSize	dZ	dXY	X_Offset	Y_Offset	Mask
0.0	819680.00	457760.00	819063.25	457320.38	-604.59	55694.35	6400.00	1.75	6.85	-616.75	-439.63	1
1.0	820000.00	457760.00	819194.63	457448.78	-565.85	55699.88	6400.00	1.65	6.37	-805.38	-311.22	1
2.0	818400.00	458080.00	818015.75	458218.09	-663.20	55653.15	6400.00	2.45	10.00	-384.25	138.09	1
3.0	818720.00	458080.00	818331.50	458039.00	-576.55	55665.94	6400.00	2.23	9.43	-388.50	-41.00	1
4.0	819040.00	458080.00	818616.81	457967.91	-516.07	55677.31	6400.00	2.00	8.67	-423.19	-112.09	1
5.0	819360.00	458080.00	818838.38	458007.97	-476.84	55686.36	6400.00	1.82	7.87	-521.63	-72.03	1
6.0	819680.00	458080.00	819000.00	458114.44	-452.27	55693.25	6400.00	1.68	7.12	-680.00	34.44	1
7.0	820000.00	458080.00	819119.00	458224.34	-435.28	55698.38	6400.00	1.58	6.49	-881.00	144.34	1
8.0	820320.00	458080.00	819236.00	458269.63	-438.74	55703.14	6400.00	1.52	6.04	-1084.00	189.63	1
9.0	818400.00	458400.00	817855.81	459132.13	-473.53	55649.64	6400.00	2.27	10.20	-544.19	732.13	1
10.0	818720.00	458400.00	818210.19	458854.09	-417.24	55663.54	6400.00	2.06	9.57	-509.81	454.09	1
11.0	819040.00	458400.00	818535.88	458670.00	-390.53	55676.02	6400.00	1.84	8.62	-504.13	270.00	1
12.0	819360.00	458400.00	818787.31	458613.19	-383.24	55685.86	6400.00	1.65	7.62	-572.69	213.19	1
13.0	819680.00	458400.00	818962.19	458649.03	-384.91	55693.04	6400.00	1.51	6.72	-717.81	249.03	1
14.0	820000.00	458400.00	819076.13	458724.78	-383.58	55697.93	6400.00	1.42	6.05	-923.88	324.78	1
15.0	820320.00	458400.00	819177.44	458769.66	-392.85	55702.20	6400.00	1.40	5.64	-1142.56	369.66	1
16.0	818400.00	458720.00	817794.75	459666.84	-383.73	55649.21	6400.00	1.97	9.44	-605.25	946.84	1
17.0	818720.00	458720.00	818164.63	459336.16	-346.63	55663.55	6400.00	1.80	8.91	-555.38	616.16	1
18.0	819040.00	458720.00	818515.50	459066.78	-342.83	55676.70	6400.00	1.62	8.01	-524.50	346.78	1
19.0	819360.00	458720.00	818792.81	458917.72	-359.81	55687.19	6400.00	1.46	7.01	-567.19	197.72	1
20.0	819680.00	458720.00	818982.56	458879.47	-381.62	55694.69	6400.00	1.35	6.15	-697.44	159.47	1
21.0	820000.00	458720.00	819094.75	458916.72	-390.93	55699.42	6400.00	1.30	5.56	-905.25	196.72	1
22.0	820320.00	458720.00	819182.00	458959.34	-400.99	55703.16	6400.00	1.32	5.25	-1138.00	239.34	1

Line SI_1

Each of the database channels are described in the table below:

Channel	Description
X_Euler	Solution x coordinate.
Y_Euler	Solution y coordinate.
Depth (or Elevation)	Solution Depth (z coordinate). If a survey elevation is entered, the channel name becomes "Elevation".
Backgrnd	Magnetic field data value at the sloution location
WndSize	Window size in ground units

dZ	Percentage depth uncertainty
dXY	Location uncertainty as a percentage of solution depth/elevation
Window_X	X coordinate of the center of the search window
Window_Y	Y coordinate of the center of the search window
X_offset	Offset in X (in ground units) of the solution from the centre of the search window
Y_offset	Offset in Y (in ground units) of the solution from the centre of the search window
MASK	A flag indicating whether this solution is to be included in further processing or plotting (1 for yes, * for no). Initially all Mask channel values are set to 1

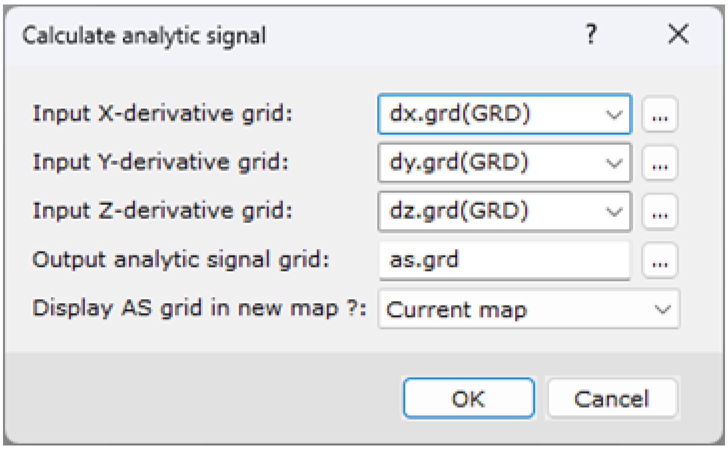
Located Euler Deconvolution

As described earlier Located Euler Deconvolution involves first calculating an Analytic Signal grid and then running a Blakely test to identify peaks (anomalies) in that grid. Euler deconvolution is then performed at the identified anomaly locations, with windows that are sized according to the size of each peak. This process almost always results a smaller number of more geologically reasonable solutions than Standard Euler Deconvolution.

A reminder that orthogonal (X, Y and Z) derivative grids are required in order to calculate the Analytic Signal grid. We will now run Located Euler Deconvolution on the sample data.

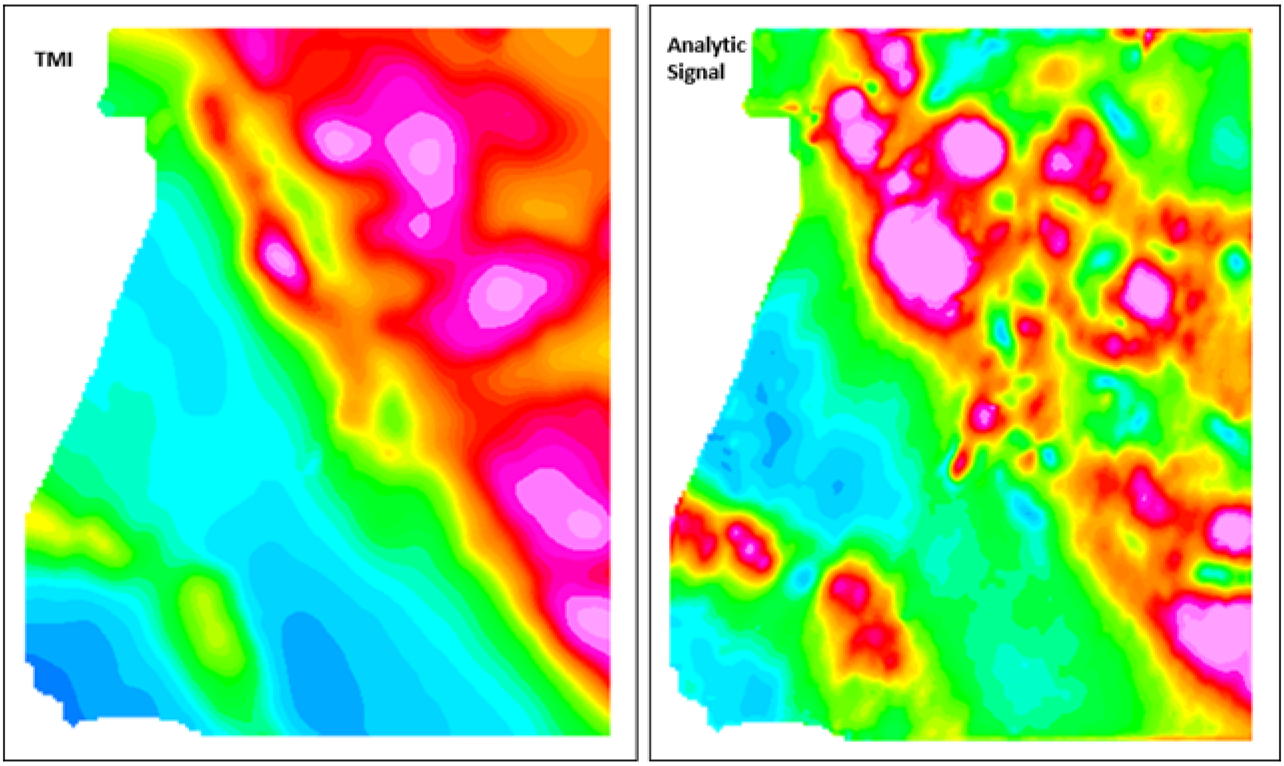
To Calculate and Display the Analytic Signal Grid

1. Use the *Project Explorer* to open the **Magnetic Source Depth** map that was created earlier. We will display the output grid on this map.
2. Open the *Euler 3D* menu, select *Located Euler Decon* and then select **Calculate and Display Analytic Signal Grid**. The *Calculate analytic signal* dialog is displayed.



3. If you used the Grav/Mag Interpretation extension to generate the derivative grids, the *Input X, Y and Z derivative grid* fields should already be populated with those grids. If not, use the Browse button to locate them.
4. We will accept the default name for the *Output analytic signal grid*, which is **as.grd**.
5. For the *Display AS grid in new map?* option, select **Current map** from the drop down.
6. Click **OK** and the Analytic Signal grid is plotted on the map.

Below we compare this grid to the input TMI grid. Note that the Analytic Signal grid is output using a different (Normal) colour distribution than the TMI grid (Histogram Equalization), so below we have recoloured the TMI grid with a Normal distribution in order to directly compare them.



Note the anomalies appear to be slightly smeared within the Analytic Signal grid, due to the introduction of some high-frequency noise. Such noise is not uncommon and can negatively affect the peak finding process. Because of this, that process includes an option to apply a smoothing filter.

Finding Peak Locations

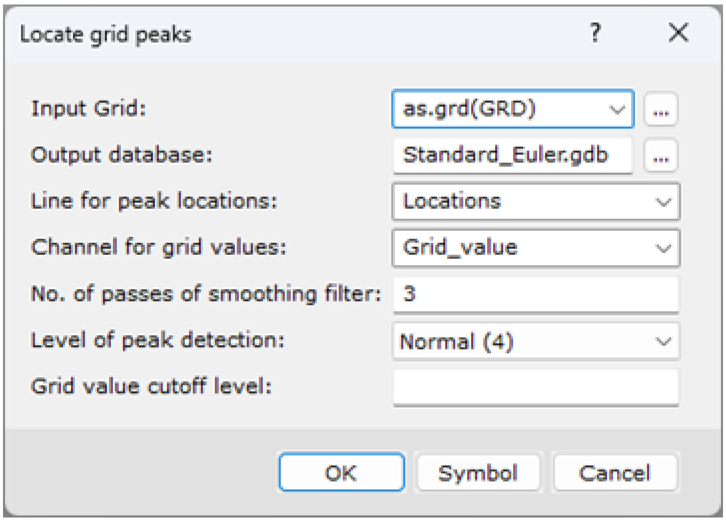
The next step is to identify peak (anomaly) locations in the Analytic Signal grid. The Blakely method is used to find peaks in a grid. Each grid cell value is compared with the those from its eight neighbouring grid cells in four directions (along the row, along the column, and along both diagonals). An accompanying *Level of peak detection* parameter is used to define which peaks are accepted, based on the field fall off in each of the neighbouring grid cells:

- Normal (4) - grid values in all of the nearest grid cells are lower
- More peaks (3) - grid values in any three directions are lower
- Even more peaks (2) - grid values in any two directions are lower
- All ridge peaks (1) - grid values in one direction are lower

The "Normal" setting results in the smallest number of peaks being chosen, which in turn should result in higher quality Euler solutions.

To Find Peak Locations

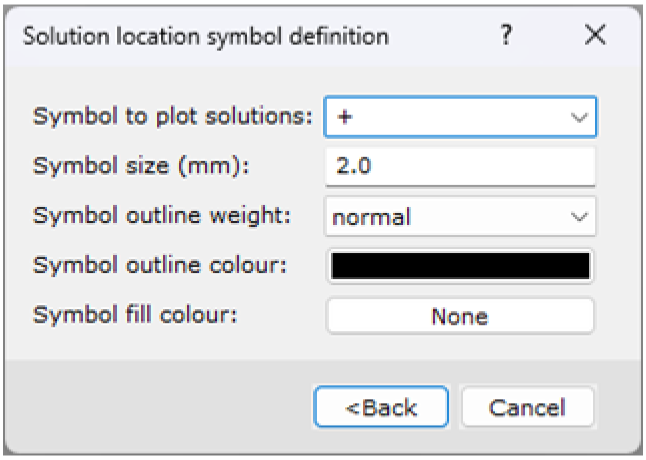
1. Open the *Euler 3D* menu, select *Located Euler Decon* and then select **Get Grid Peak Locations**. The *Locate grid peaks* dialog appears.



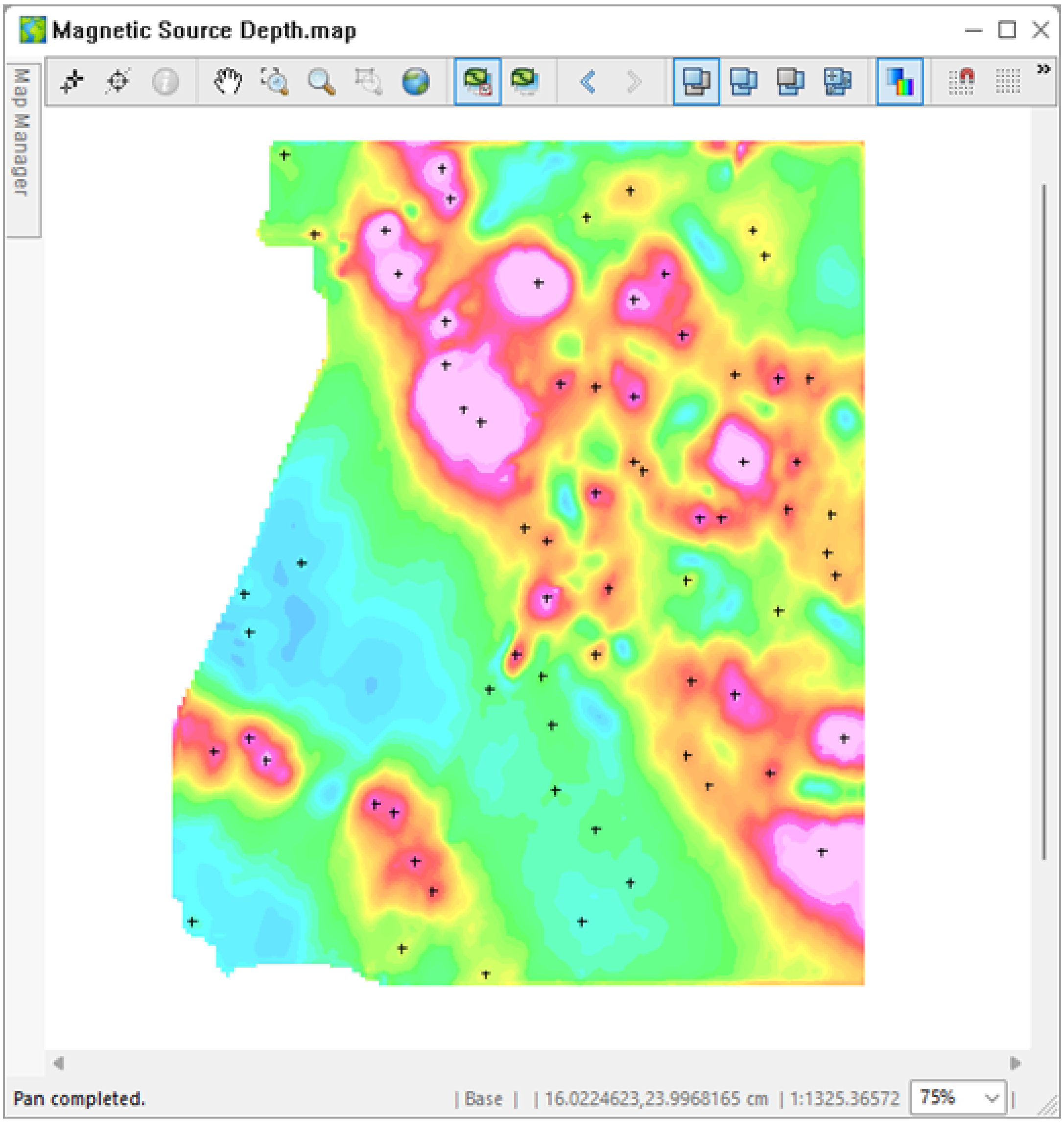
2. The *Input Grid* field should be populated with the Analytic Signal grid (**as.grd** for the sample data).
3. Specify the name of the *Output database* as **Located_Euler**.
4. Specify the *Line for peak locations* (the database group/line name) as **SI_1**.
5. Specify the *Channel for grid values* as **Grid_value**.
6. The *Level of peak detection* can be left at the default setting of **Normal (4)**.
7. Leave the *Grid value cutoff level* field empty.

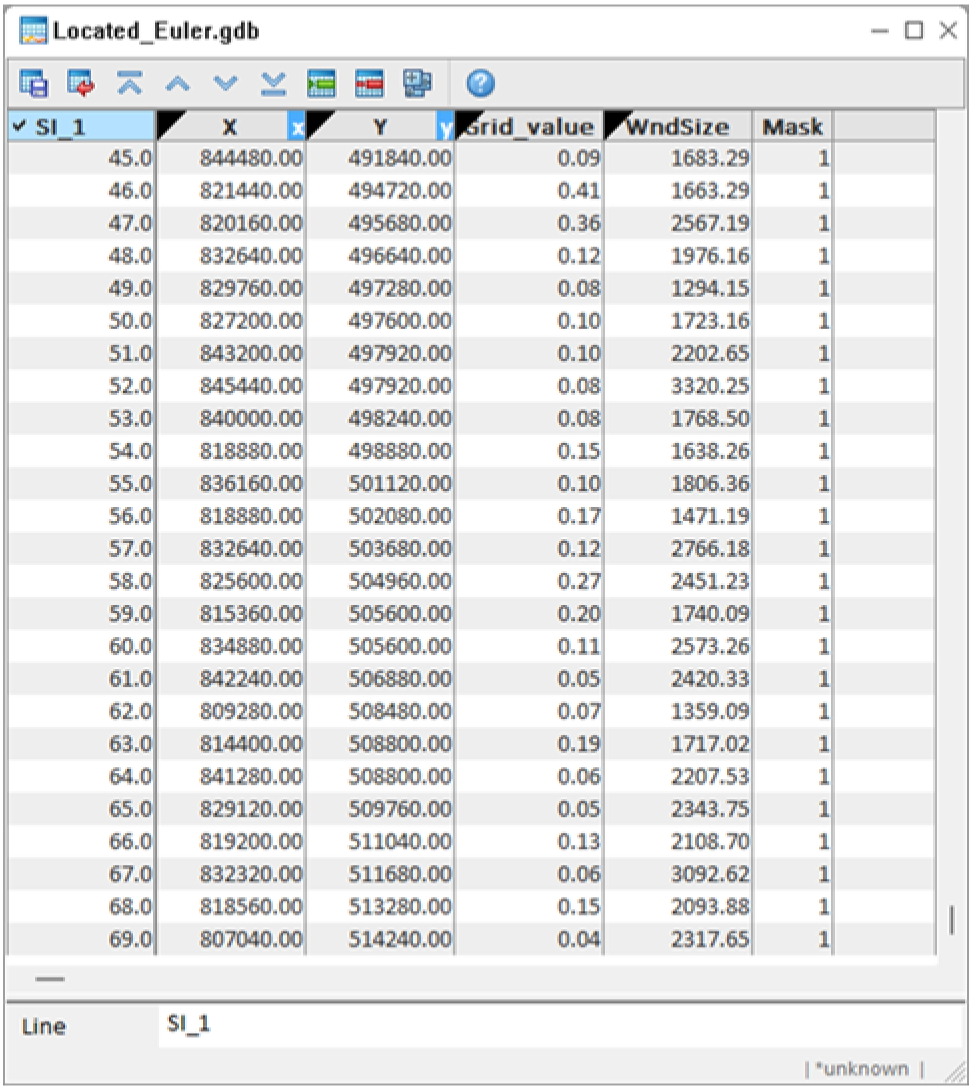
> The grid cutoff can be used to remove lower amplitude peaks from the results, should those peaks be intrepreted to be "noise" or not of geological significance. It is common to set the cutoff to the mean value of the grid.

8. Click the **Symbol** button to display the *Solution location symbol definition* dialog.



9. This dialog is used to specify how peak location symbols are displayed. In this case we will use the default display parameters and click the **<Back** button to return to the *Locate Solutions* dialog.
10. Click **OK**. The Located Euler database is created and the peaks are displayed on the map.


Magnetic Source Depth.map
Map Manager
Pan completed.
| Base |
| 16.0224623,23.9968165 cm
| 1:1325.36572
75%



SI_1	X	Y	Grid_value	WndSize	Mask
45.0	844480.00	491840.00	0.09	1683.29	1
46.0	821440.00	494720.00	0.41	1663.29	1
47.0	820160.00	495680.00	0.36	2567.19	1
48.0	832640.00	496640.00	0.12	1976.16	1
49.0	829760.00	497280.00	0.08	1294.15	1
50.0	827200.00	497600.00	0.10	1723.16	1
51.0	843200.00	497920.00	0.10	2202.65	1
52.0	845440.00	497920.00	0.08	3320.25	1
53.0	840000.00	498240.00	0.08	1768.50	1
54.0	818880.00	498880.00	0.15	1638.26	1
55.0	836160.00	501120.00	0.10	1806.36	1
56.0	818880.00	502080.00	0.17	1471.19	1
57.0	832640.00	503680.00	0.12	2766.18	1
58.0	825600.00	504960.00	0.27	2451.23	1
59.0	815360.00	505600.00	0.20	1740.09	1
60.0	834880.00	505600.00	0.11	2573.26	1
61.0	842240.00	506880.00	0.05	2420.33	1
62.0	809280.00	508480.00	0.07	1359.09	1
63.0	814400.00	508800.00	0.19	1717.02	1
64.0	841280.00	508800.00	0.06	2207.53	1
65.0	829120.00	509760.00	0.05	2343.75	1
66.0	819200.00	511040.00	0.13	2108.70	1
67.0	832320.00	511680.00	0.06	3092.62	1
68.0	818560.00	513280.00	0.15	2093.88	1
69.0	807040.00	514240.00	0.04	2317.65	1

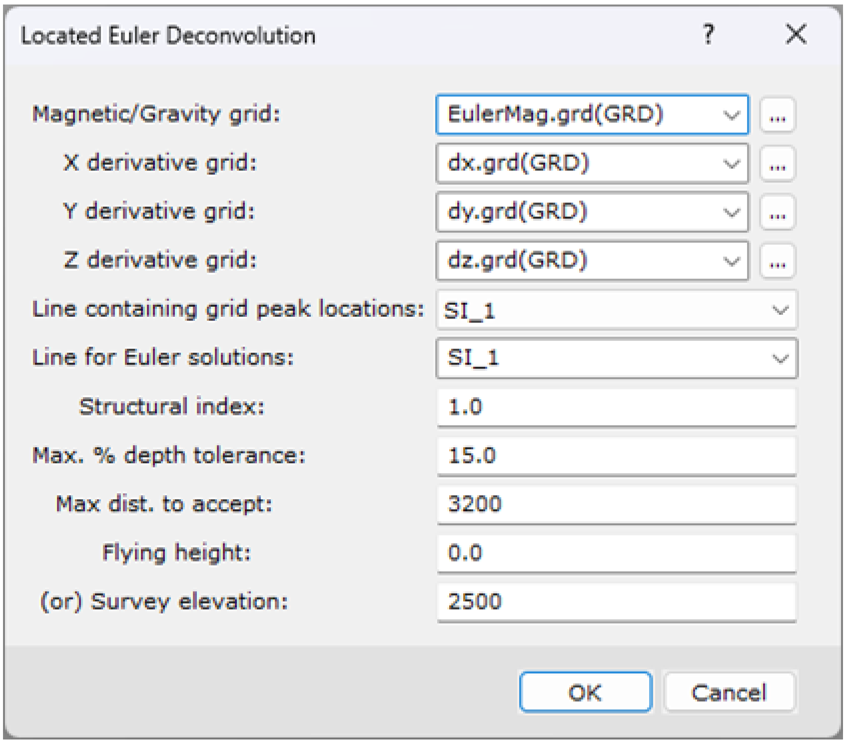
There should be ~70 solution locations in this database, a vast reduction on the ~5500 solutions that were generated via Standard Euler! The table below describes the contents of each channel:

Channel	Description
X_Window	X window centre location.
Y_Window	Y window centre location.
Grid_value	Analytic signal grid value at each location.
WndSize	This is the window size that will be used during Euler Deconvolution. It is based on the extents of each peak.
Mask	A flag indicating whether this solution is to be included in further processing or plotting (1 for yes, * for no). Initially all Mask channel values are set to 1

We can now proceed with Euler Deconvolution.

To Perform Located Euler Deconvolution

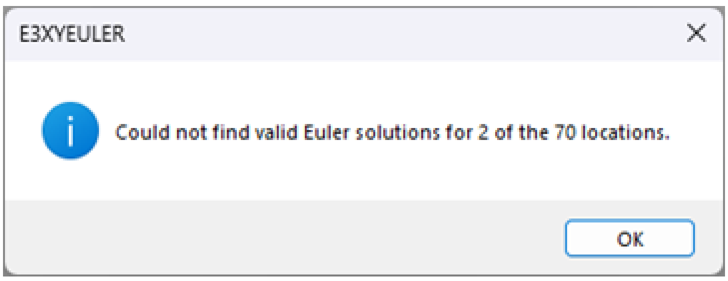
1. Make sure that the *Located_Euler* database is the current database (open and selected).
2. Open the *Euler 3D* menu, select *Located Euler Decon*, and then select **Located Euler Decon**. The *Located Euler Deconvolution* dialog is displayed.



3. The *Magnetic/Gravity grid* and the *X, Y and Z derivative grid* fields should already be populated with the appropriate grids; if not, the *Browse* button can be used to locate each.
4. Both the *Line containing grid peak locations* and *Line for Euler solutions* options should be set to **SI_1**.
5. Specify the *Structural index*as **1.0**.
6. Specify the *Max. depth tolerance* as **15** %.
7. Specify the *Max dist. to accept* as **3200** m.
8. Leave the *Flying height* set to **0** and the *Survey elevation* to **2500** m.

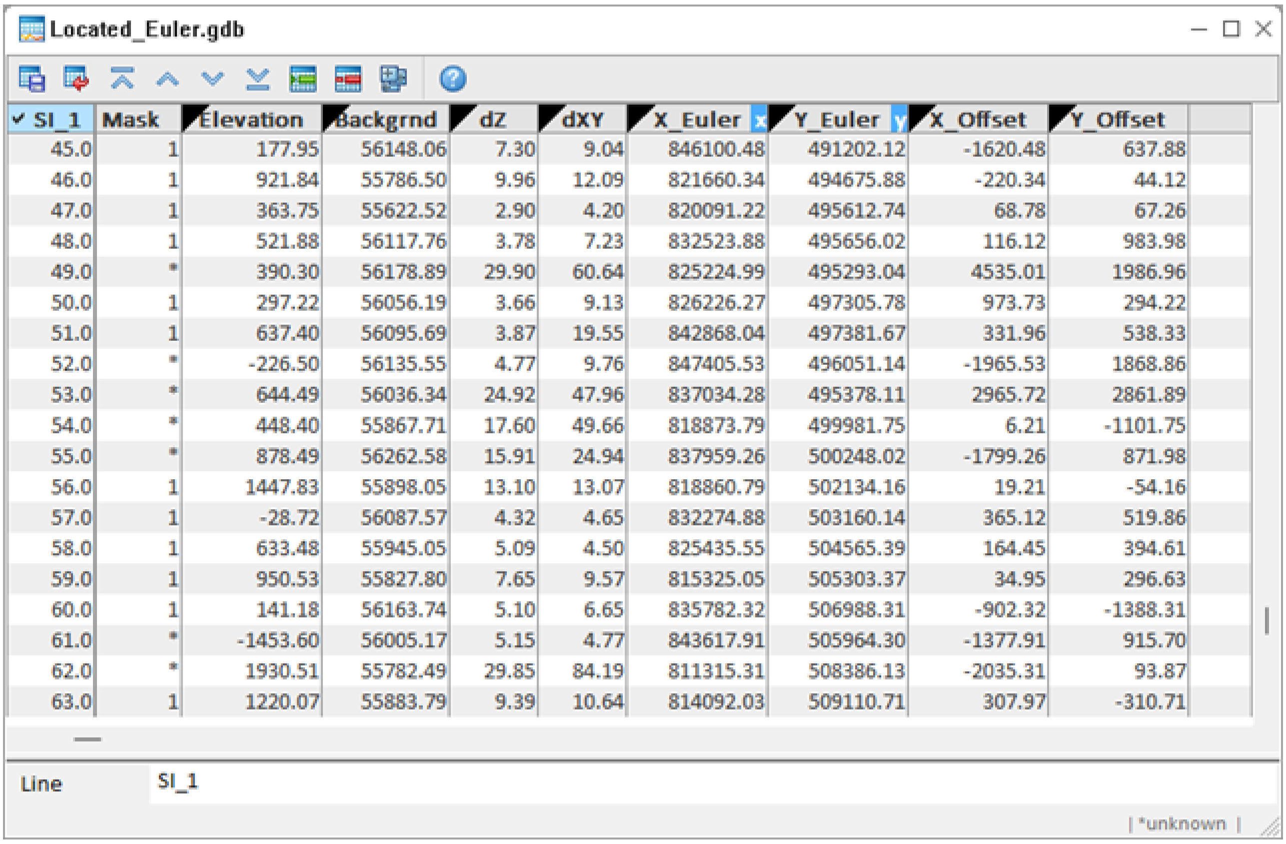
We are using identical parameters to those used in Standard Deconvolution in order to directly compare the results.

9. Click **OK**. A notification appears that informs that valid Euler solutions could not be found for two of the 70 locations.



10. Click **OK**. The results are written to the database. The *Elevation* channel is shown, but the other new channels are hidden.

11. **Right-click** in the first empty channel header cell of the database and select **Display All** to display all channels.



Located_Euler.gdb

SI_1	Mask	Elevation	Backgrnd	dZ	dXY	X_Euler	Y_Euler	X_Offset	Y_Offset
45.0	1	177.95	56148.06	7.30	9.04	846100.48	491202.12	-1620.48	637.88
46.0	1	921.84	55786.50	9.96	12.09	821660.34	494675.88	-220.34	44.12
47.0	1	363.75	55622.52	2.90	4.20	820091.22	495612.74	68.78	67.26
48.0	1	521.88	56117.76	3.78	7.23	832523.88	495656.02	116.12	983.98
49.0	*	390.30	56178.89	29.90	60.64	825224.99	495293.04	4535.01	1986.96
50.0	1	297.22	56056.19	3.66	9.13	826226.27	497305.78	973.73	294.22
51.0	1	637.40	56095.69	3.87	19.55	842868.04	497381.67	331.96	538.33
52.0	*	-226.50	56135.55	4.77	9.76	847405.53	496051.14	-1965.53	1868.86
53.0	*	644.49	56036.34	24.92	47.96	837034.28	495378.11	2965.72	2861.89
54.0	*	448.40	55867.71	17.60	49.66	818873.79	499981.75	6.21	-1101.75
55.0	*	878.49	56262.58	15.91	24.94	837959.26	500248.02	-1799.26	871.98
56.0	1	1447.83	55898.05	13.10	13.07	818860.79	502134.16	19.21	-54.16
57.0	1	-28.72	56087.57	4.32	4.65	832274.88	503160.14	365.12	519.86
58.0	1	633.48	55945.05	5.09	4.50	825435.55	504565.39	164.45	394.61
59.0	1	950.53	55827.80	7.65	9.57	815325.05	505303.37	34.95	296.63
60.0	1	141.18	56163.74	5.10	6.65	835782.32	506988.31	-902.32	-1388.31
61.0	*	-1453.60	56005.17	5.15	4.77	843617.91	505964.30	-1377.91	915.70
62.0	*	1930.51	55782.49	29.85	84.19	811315.31	508386.13	-2035.31	93.87
63.0	1	1220.07	55883.79	9.39	10.64	814092.03	509110.71	307.97	-310.71

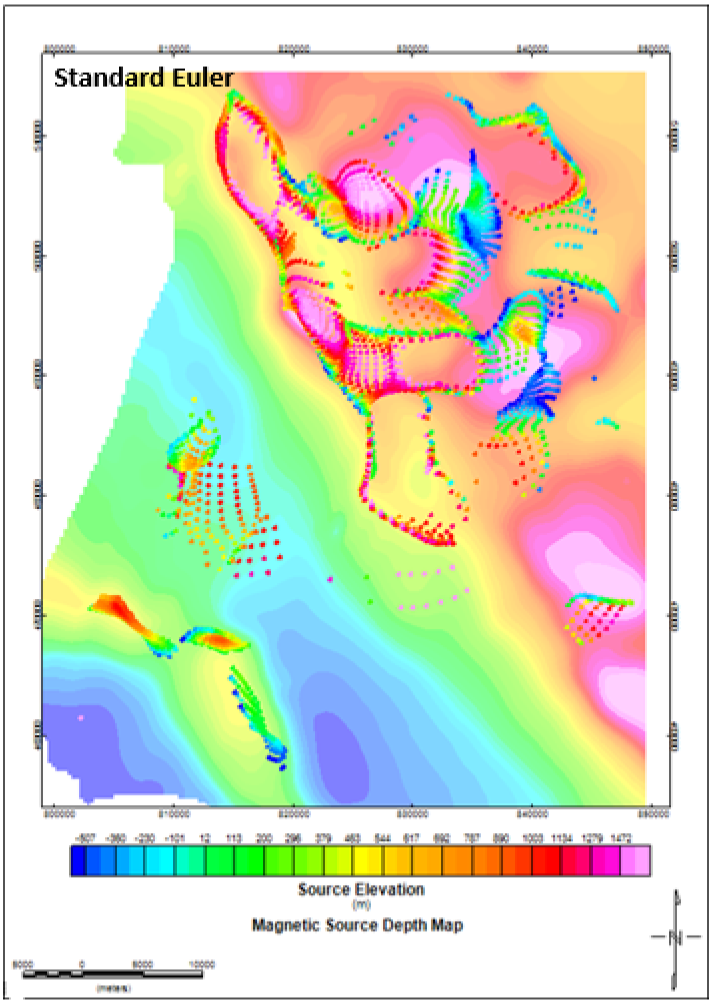
Line SI_1

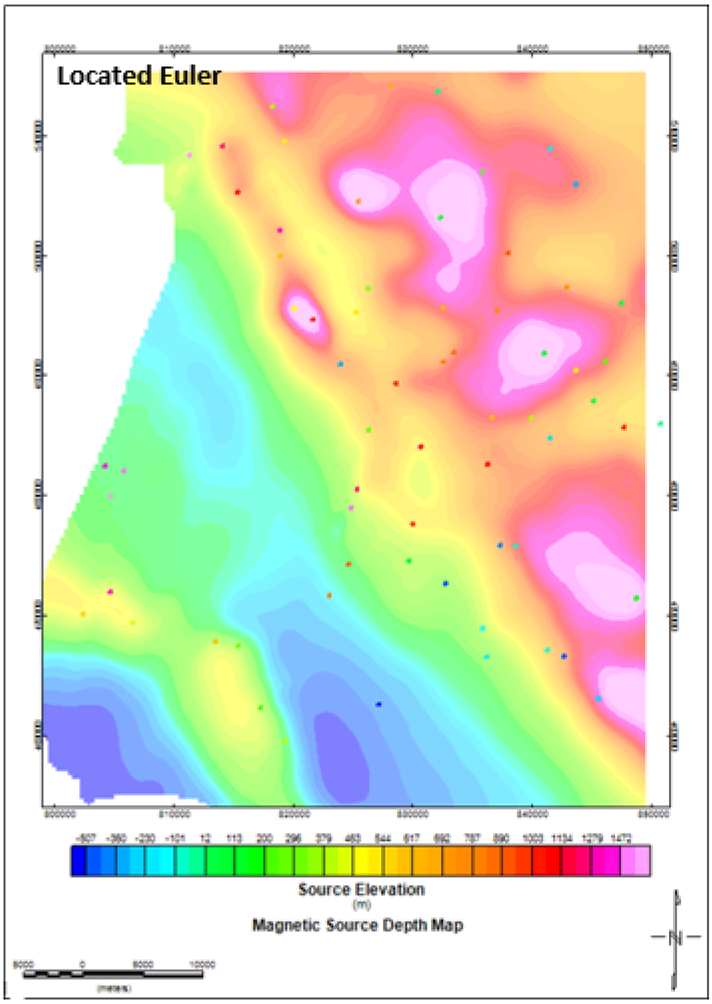
| *unknown |

Inspect the *MASK* channel and note how many (33) of the solutions have had dummy (*) values assigned, meaning that those solutions do not meet the *Max % depth tolerance* and *Max dist to accept* criteria we specified. With Standard Euler Deconvolution, these solutions would not be written to the database, but with Located Euler, the locations are written to the database during peak identification, so cannot be removed.

Comparing Results of Located and Standard Euler Deconvolution

We will look at visualising and iterpreting solutions in more detail in the next section, but for now let us take a quick look at the results:





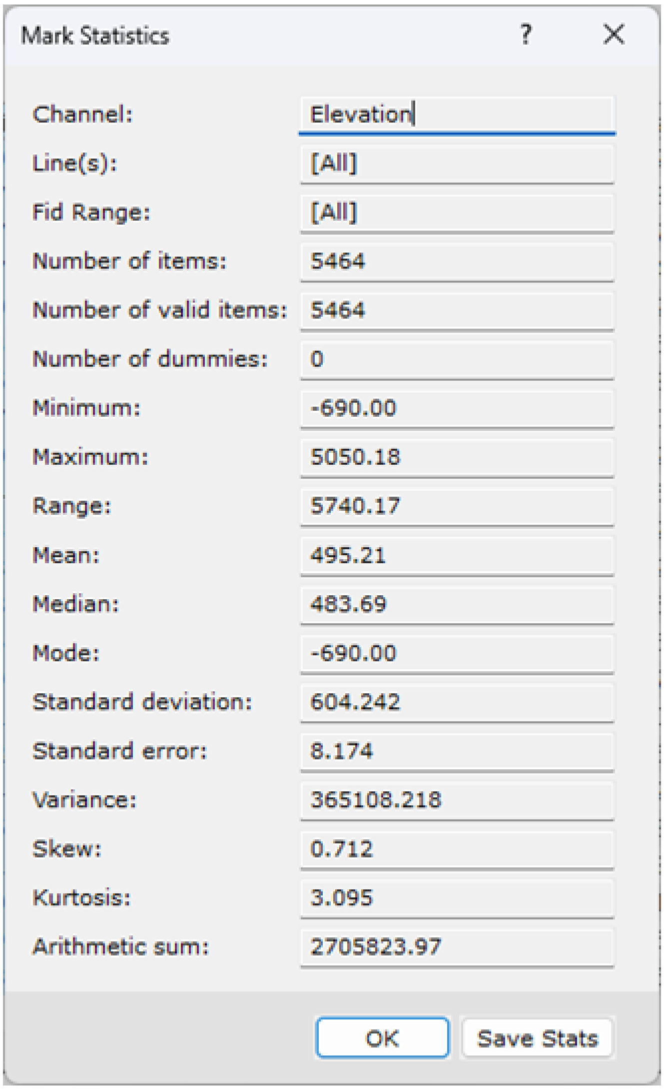
As described previously, Located Euler deconvolution returns far fewer solutions than Standard Euler deconvolution. We will now look at how one can reduce the amount of solutions from the Standard Euler database, through use of windowing.

Displaying Solution Statistics

Typically, there will be thousands of solutions in the Standard Euler solutions database or hundreds of solutions in the Located Euler solution database so it is not practical to examine them individually. Instead we can calculate channel statistics to get an idea of how many solutions there are, what their depth range is, what the typical position accuracy is, and so on.

To Calculate the Statistics of the Depth (Elevation) Channel

1. Open the *Standard_Euler* database.
2. **Left-click** three times on the *Elevation* channel header cell. The entire column will be highlighted.
3. *Right-click* and from the pop-up menu, select **Statistics**. The *Mark Statistics* window appears.


Mark Statistics
Channel:
Elevation
Line(s):
[All]
Fid Range:
[All]
Number of items:
5464
Number of valid items:
5464
Number of dummies:
0
Minimum:
-690.00
Maximum:
5050.18
Range:
5740.17
Mean:
495.21
Median:
483.69
Mode:
-690.00
Standard deviation:
604.242
Standard error:
8.174
Variance:
365108.218
Skew:
0.712
Kurtosis:
3.095
Arithmetic sum:
2705823.97
OK
Save Stats

The following table summarizes the significant statistics reported for the Depth (or Elevation) channel

Reported Value	Significance
Channel	The name of the currently selected channel.
Line(s)	The currently selected line or lines.
Fid. Range	The fiducial range of the selection.
Num. of items	Number of items. This represents the total number of Depth (or Elevation) solutions in the database.
Num. of dummies	The number of dummy values in the selected data.
Minimum	Minimum depth solution for flying height case (or Minimum elevation solution for survey elevation case). If you computed solutions using the survey "Elevation", the value is reported in absolute terms (i.e. a solution of -687 means 687 units below zero elevation). If you computed solutions using the "Flying height" then this value would be reported in relative terms (i.e. a solution of -100 would be 100 units above the ground surface).
Maximum	Maximum depth solution for flying height case (or Maximum elevation solution for survey elevation case). If we computed solutions using the survey "Elevation" , the value is reported in absolute terms (i.e. a solution of 687 means 687 units above zero elevation). If we computed solutions using the "Flying height" then this value would be reported in relative terms (i.e. a solution of 100 would be 100 units below the ground surface).
Mean	Statistical mean of all values.
Standard deviation	Spread of data around the mean in depth units.
Arithmetic Sum	Arithmetic sum of all depth values.

4. Click **OK** to close the **Mark Statistics** dialog or click the **Save Stats** button to save the report to a file.

Visualizing and Interpreting Solutions

In this section we will walk through the process of visualizing and interpreting Euler solutions. The process of interpreting involves windowing (removing solutions), which is an iterative process of trial and error. The topics discussed include:

- Interpreting solutions
- Windowing solutions
- Creating a subset solution list
- Building a solution channel
- Visualizing results

Interpreting Solutions

Interpreting solutions is essentially an iterative, two-step process:

1. Removing ("windowing") spurious solutions that do not meet the solution quality criteria
2. Determining which solutions are geologically reasonable

Deriving a set of geologically reasonable solutions can involve changing the SI, the window size, and the uncertainty tolerances. For large data sets, it may be best to select a smaller subset, perhaps over an area where you have the greatest understanding of the geology, and run tests to obtain the optimum deconvolution parameters. The entire area can then be processed using those parameters.

Windowing Solutions

Windowing is the process of modifying one (or more) Mask channels in the solution database, to prevent solutions from being included in the final results. A Mask channel value of 1 indicates that the solution will be retained, whereas a dummy (*) value indicates that the solution be rejected.

The *Window Solution List* tool enables you to select which solutions to mask, based on certain solution parameters. There are four methods that you can use to eliminate solutions:

- Windowing on Depth Uncertainty (dZ)
- Windowing on Location Uncertainty (dXY)
- Windowing on depth (or elevation)
- Windowing on X and Y Offset

These methods can be used in isolation or in combination.

Understanding Solution Uncertainties

Euler Deconvolution is a statistical process and the resulting solutions have associated positional uncertainties with respect to their depth and location. Both are reported as a percentage of the depth below the sensor. The general level of uncertainty depends on the data quality and the SI used. Solutions with a Low SI tend to have higher uncertainties, because those sources tend to have smaller and more variable gradients.

These uncertainties are used to reduce the amount of solutions to be interpreted. A depth uncertainty tolerance can be set when running Euler Deconvolution so that solutions that exceed the defined tolerance are not included in the output database. Testing has demonstrated that acceptable results are obtained if selection criteria are set more or less as follows:

SI	Depth uncertainty	Horizontal uncertainty
0	20%	40%
0.5	15%	30%
1.0	10%	20%
2.0	5%	10%

Solution uncertainties are written to the output database, so solutions can also be removed after deconvolution has been run. Some prefer to run Euler deconvolution without any solution uncertainty tolerances and then use the *Window Solution List* tool to further reduce the number of solutions based on reductions in the depth and location uncertainty tolerance.

Windowing on Depth Uncertainty (dZ)

As we observed when running the *Standard Euler Decon* tool, it enables you to reject solutions with a depth uncertainty greater than a certain percentage (the default is 15%). However it is best not to set this parameter too low, since it is easy to eliminate solutions afterward with the *Window Results* menu option, but the only way to add solutions is to use the *Standard Euler Decon* menu option again, which is more time-consuming.

In addition, the uncertainty is not necessarily the best criterion for rejecting solutions, since a geological anomaly may be important even if it does not exactly conform to the shape of the model anomaly you used.

Windowing on Locational Uncertainty (dXY)

The *Standard Euler Decon* tool does not provide an option to remove solutions based on locational uncertainty, so it is generally a good idea to window on dXY with the *Window Solution List* tool to remove soltuions with high locational uncertainties.

However, the maximum dXY limit need not be the same as the maximum dZ limit. For instance if Euler Deconvolution is being used to locate drill targets, then the location error will likely be more critical than the depth error.

Windowing on Depth (or Elevation)

Windowing on solution depths requires some knowledge of the geology of the area of interest, in order to remove those solutions that are unrealistically shallow or deep.

When windowing on depth, you should also keep in mind that the width of the search window used with the *Standard Euler Decon* menu option determines the depth range for which solutions are meaningful. The relationship is complex and depends on the Structural Index and character of the data. Generally, ***solutions at depths much (i.e more than two times) greater or smaller than the width of the search window are likely to be spurious***.

Windowing on X and Y Offset

Similarly to above, solutions lying too far from the centre of the Euler window are likely to be spurious and result from the failure to place a valid source within the window that matches the chosen SI, or because in the anomaly and its fall off to the "background" are not fully captured within the search window. We have seen that both the Standard and Located Euler deconvolution tools contain an option to window out solutions (the *Max dist. to accept*) that are located beyond a specified distance from the center of the window.

Windowing on New Channels

The user may wish to add new channels to the solution database to help select more meaningful or relevant solutions. For example, if geological information is available in digital format, then the user may create a geology channel, and then use windowing to select or reject solutions that are associated with a certain rock type.

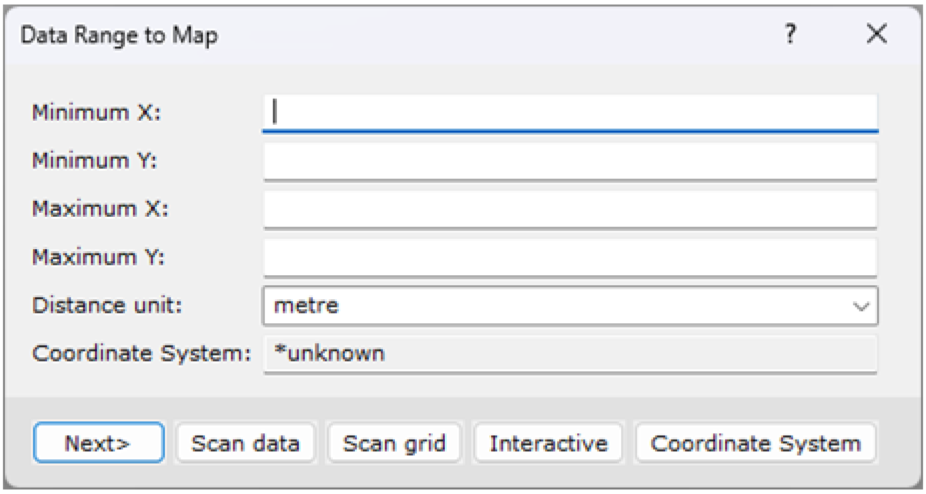
We are now going to visualize our solutions before windowing them.

Visualizing Results

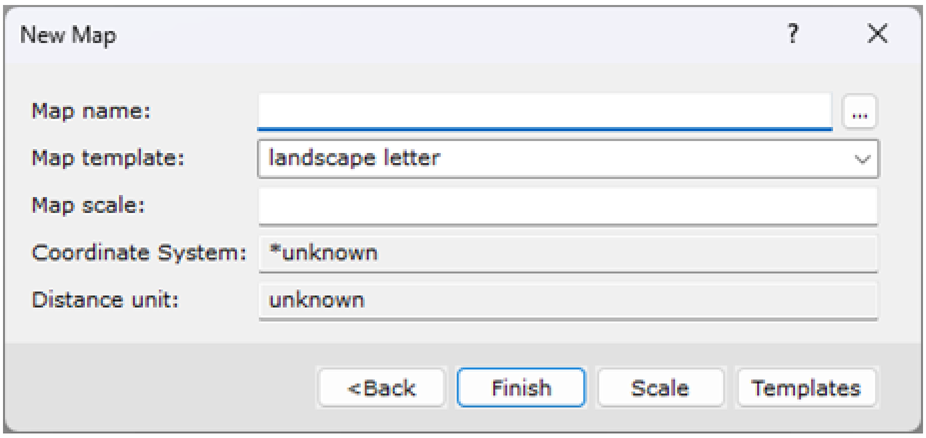
The *Plot Solution Symbols* men option contains all the options required to plot solutions on a map for the purpose of interpretation. It is often necessary to create several plots to represent the results from different structural indices. We will now create a new map and plot the Euler solutions from the sample data on that map.

To Create a New Map

1. **Open** the *Standard_Euler* database.
2. Open the *Euler 3D* menu and select **New Map**. The *Data range to map* dialog appears.



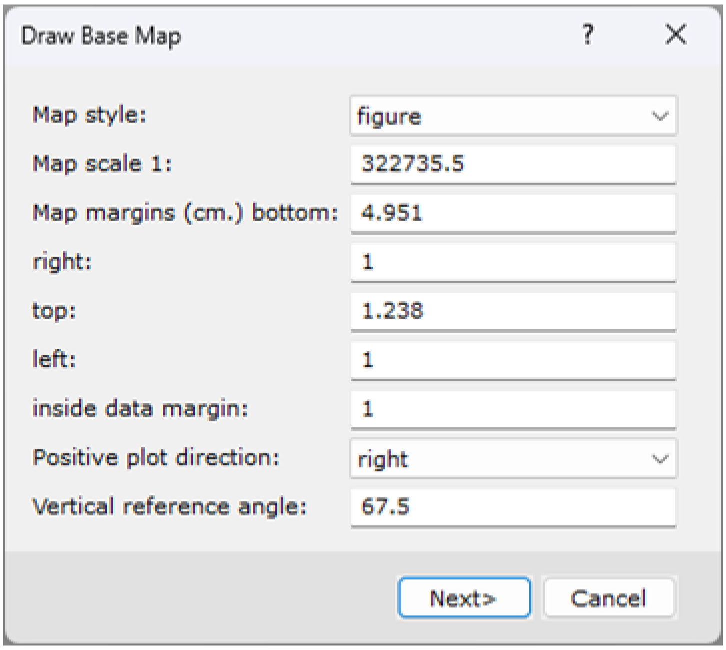
3. Click the **Scan data** button to query the database for the **Minimum X, Y** and **Maximum X,Y** coordinates.
4. Click the **Next>** button. The *New Map* dialog appears.



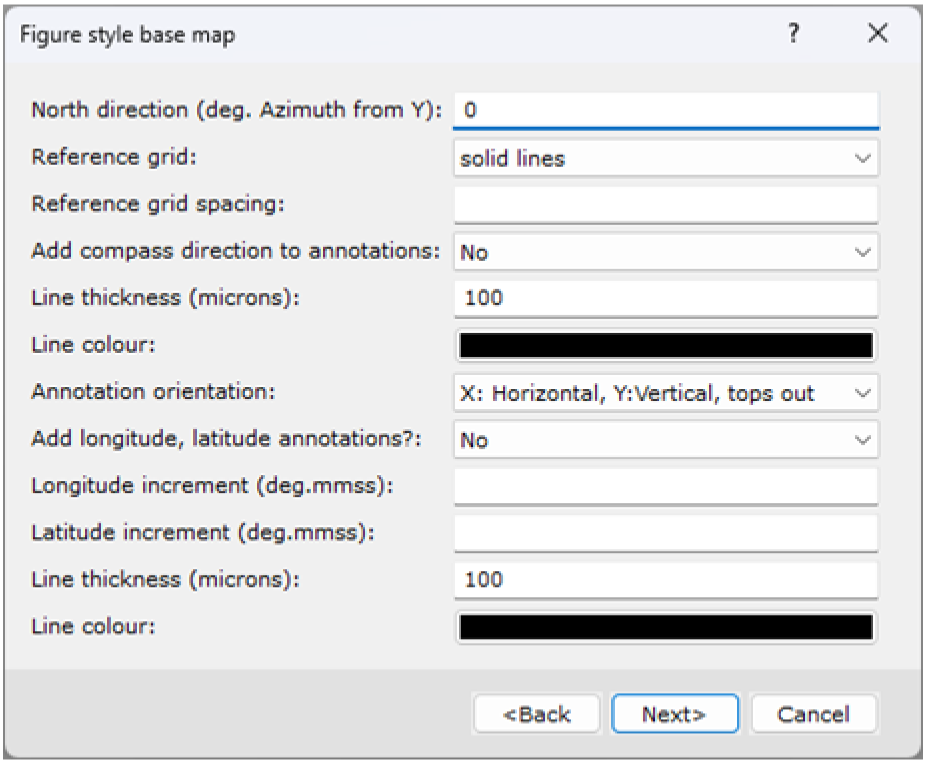
5. Specify the *Map name* as **Magnetic Source Depths**.
6. Specify the *Map template* as **Portrait A4**.
7. Click the **Scale** button to calculate the scale based on the defined data range and the specified map template.
8. Click the **Finish** button. A new, blank map window appears. We will now add a Base Map.

To Add a Base Map

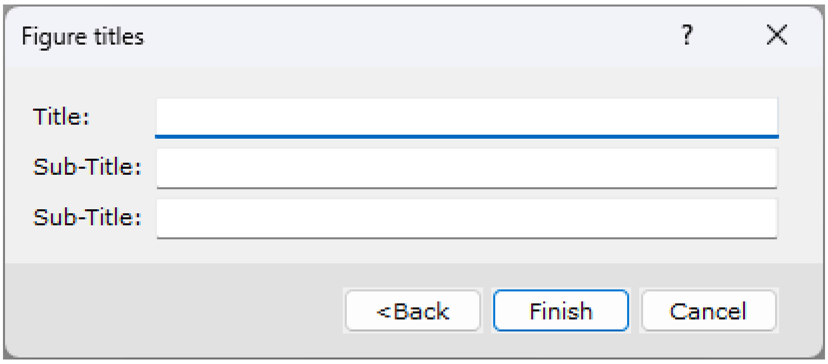
1. Open the *Euler 3D* menu and select **Draw Base Map**. The *Draw Base Map* dialog appears.



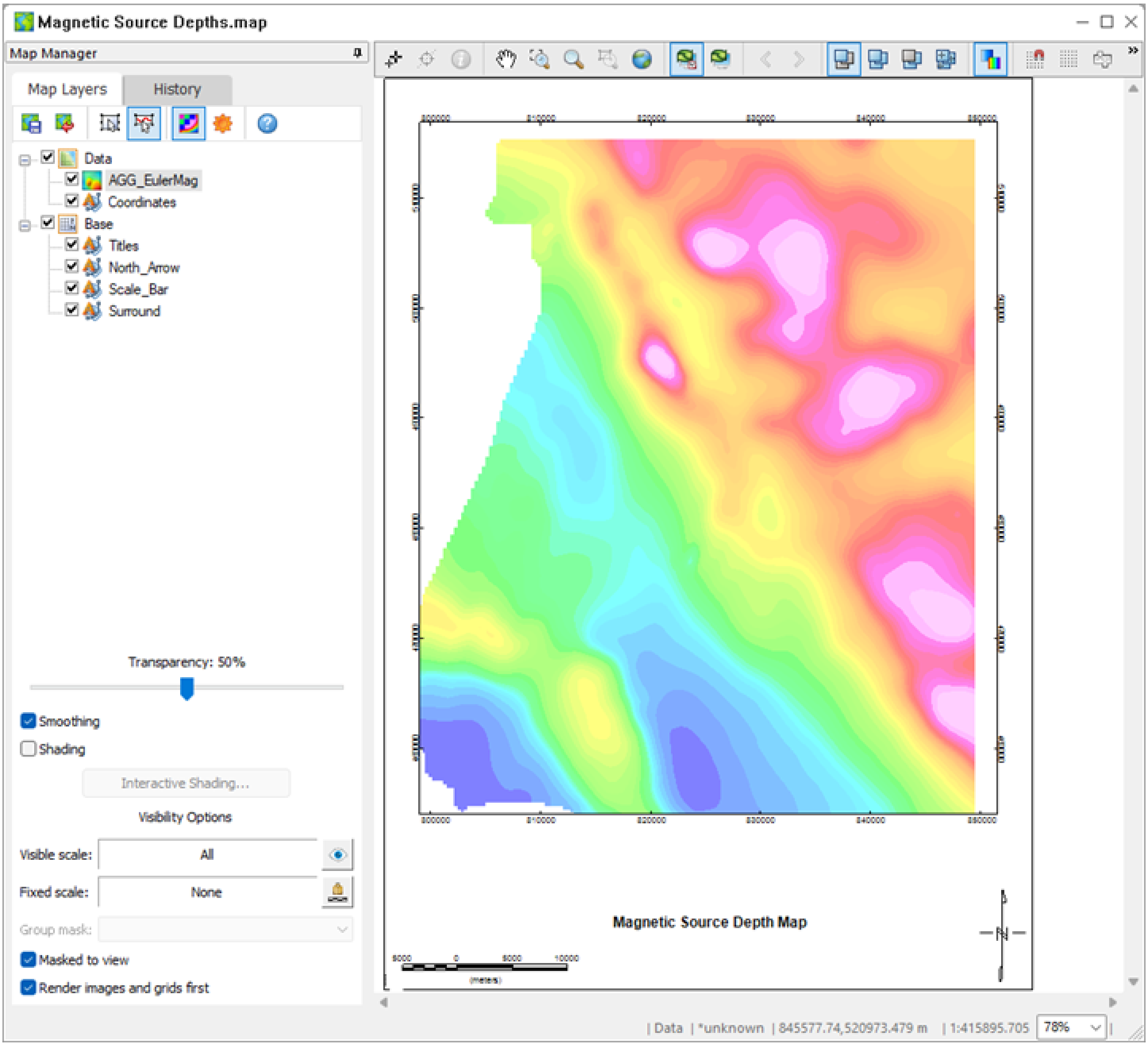
2. Specify the *Map style* as **figure**.
3. Leave the remaining parameters as they are and click **Next>**. The *Figure style base map* dialog opens.



4. Change the *Reference grid* option to **edge ticks**.
5. Leave all the other parameters at their defaults and click **Next>**. The *Figure titles* dialog appears.



6. Specify the *Title* as **Magnetic Source Depth Map**.
7. Click **Finish**, the base map is plotted in the map window.
8. Open the *Grids* section of the *Project Explorer*, click on **EulerMag.grd** and drag and drop the file into the map to display it.
9. Within the *Map Manager*, select the **AGG_EulerMag** group, then adjust the **Transparency** slider to **50** %. This will make it easier to see the Euler solutions after they are plotted. The map should now look similar to what is shown below.



In the above image, we have 'pinned' the *Map Manager* so it remains open. We will now plot the Euler solutions on this map as coloured symbols.

Plotting Solution Symbols

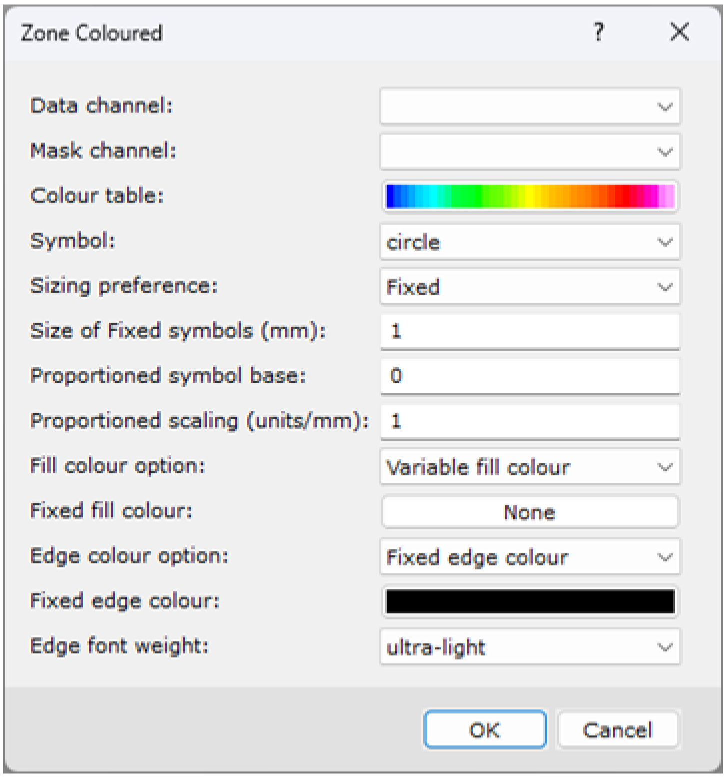
Euler solutions are generally plotted on a map as some form of coloured symbology. The Grav/Mag Interpretation extension offers several different variants of this style of plotting

- *Zone Coloured* - Symbols are coloured by applying a Geosoft colour table to the solution depths. The colour stretch can be modified in the same way you can modify the colour of a grid
- *Colour Range Symbols* - The user defines the number colours to be used and what solution depth ranges those colours represent
- *Proportional Size* - Symbols are sized by the user according to the solution depths
- *Colour Range and Proportional Size* - Symbols are sized and coloured according to soltuion depths

Note also that there is an option to plot solution symbols within a 3D view. For the sample data, we will be using the *Zone Coloured* method, which is the quickest and easiest option to use.

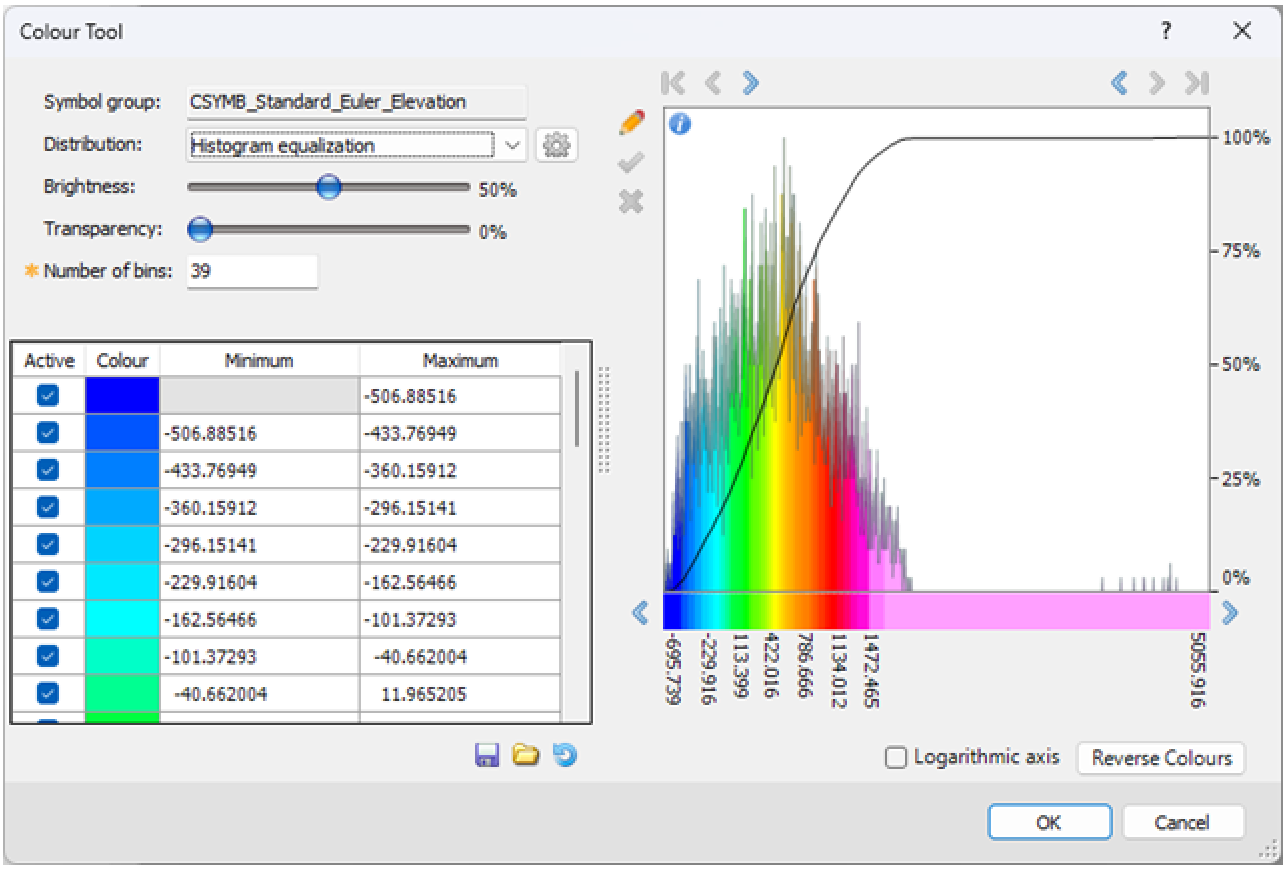
To Plot Zone Coloured Symbols

1. Make sure that the **Magnetic Source Depths** map and the **Standard_Euler** database are open and selected.
2. Open the *Euler 3D* menu, select *Plot Solution Symbols* and then select **Zone Coloured**.
   The *Zone Coloured* dialog appears.



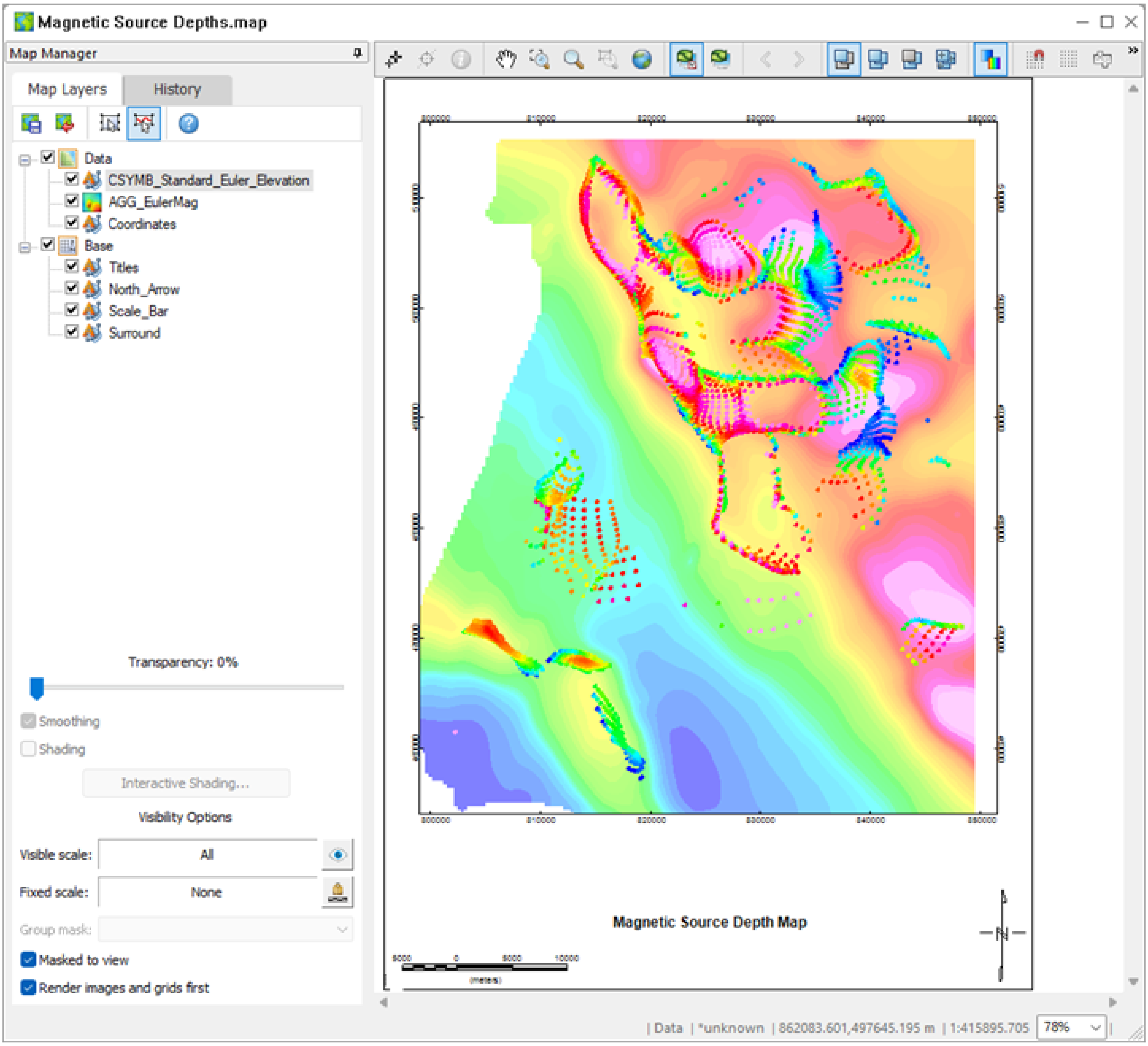
3. For the *Data channel*, click on the drop down and select **Elevation** from the list.
4. For the *Mask channel*, click on the drop down and select **Mask** from the list.
5. We will use the default *Colour table*. It can be changed by clicking on the colour bar and selecting an alternative.

6. The *Symbol* should be set to **Circle** and the *Sizing preference* as **Fixed**.
7. The *Size of Fixed symbols (mm)* should be set to **1**.
8. The *Proportioned symbol base* and *Proportioned scaling (units/mm)* are not used if the *Sizing preference* is set to *Fixed*.
9. The *Fill colour* option should be set to **Variable fill colour** and the *Fixed fill colour* set to **None**.
10. Set the *Edge colour option* to **Variable edge colour**.
11. Leave the *Fixed edge colour* and *Edge font weight* options set to their default and click **OK**. The symbols are plotted on the map and the *Colour Tool* appears.



> The *Colour Tool* appears to allow you to modify the colour distribution if you wish. In this case we will not modify it.

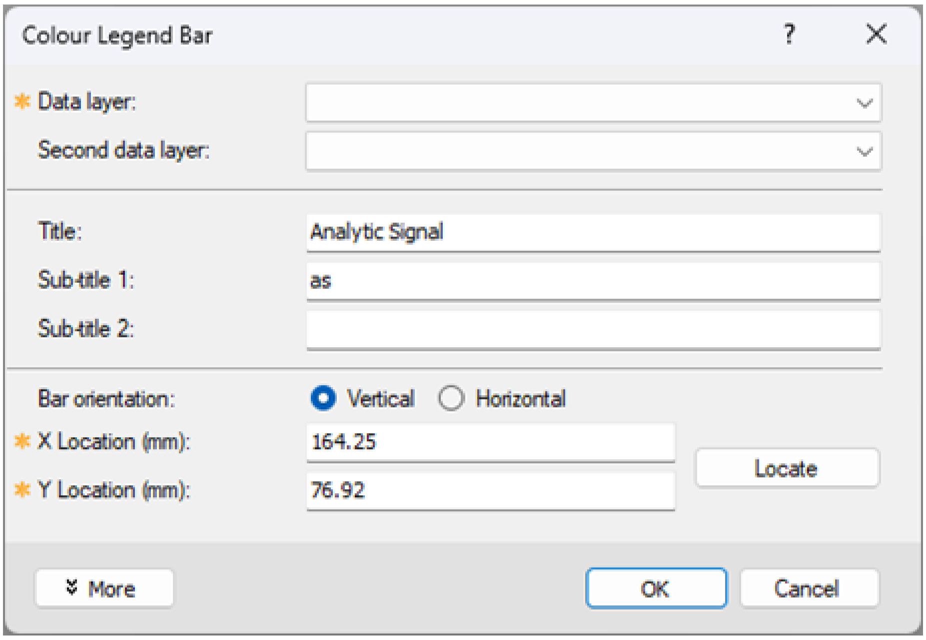
12. Click **OK**. The map should look similar to what is shown below.



We will now plot a colour bar for the symbol plot to show what elevations the colours represent.

To Plot a Colour Bar

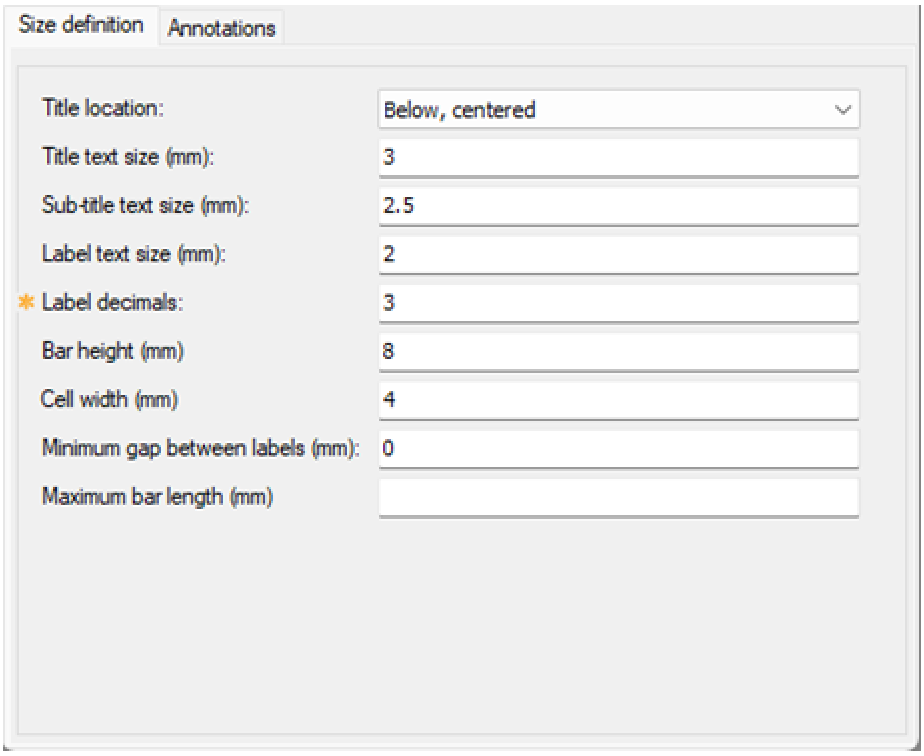
1. Open the *Euler 3D* menu, select *Plot Solution Symbols* and then select **Colour Legend Bar**. The *Colour Legend Bar* dialog appears.



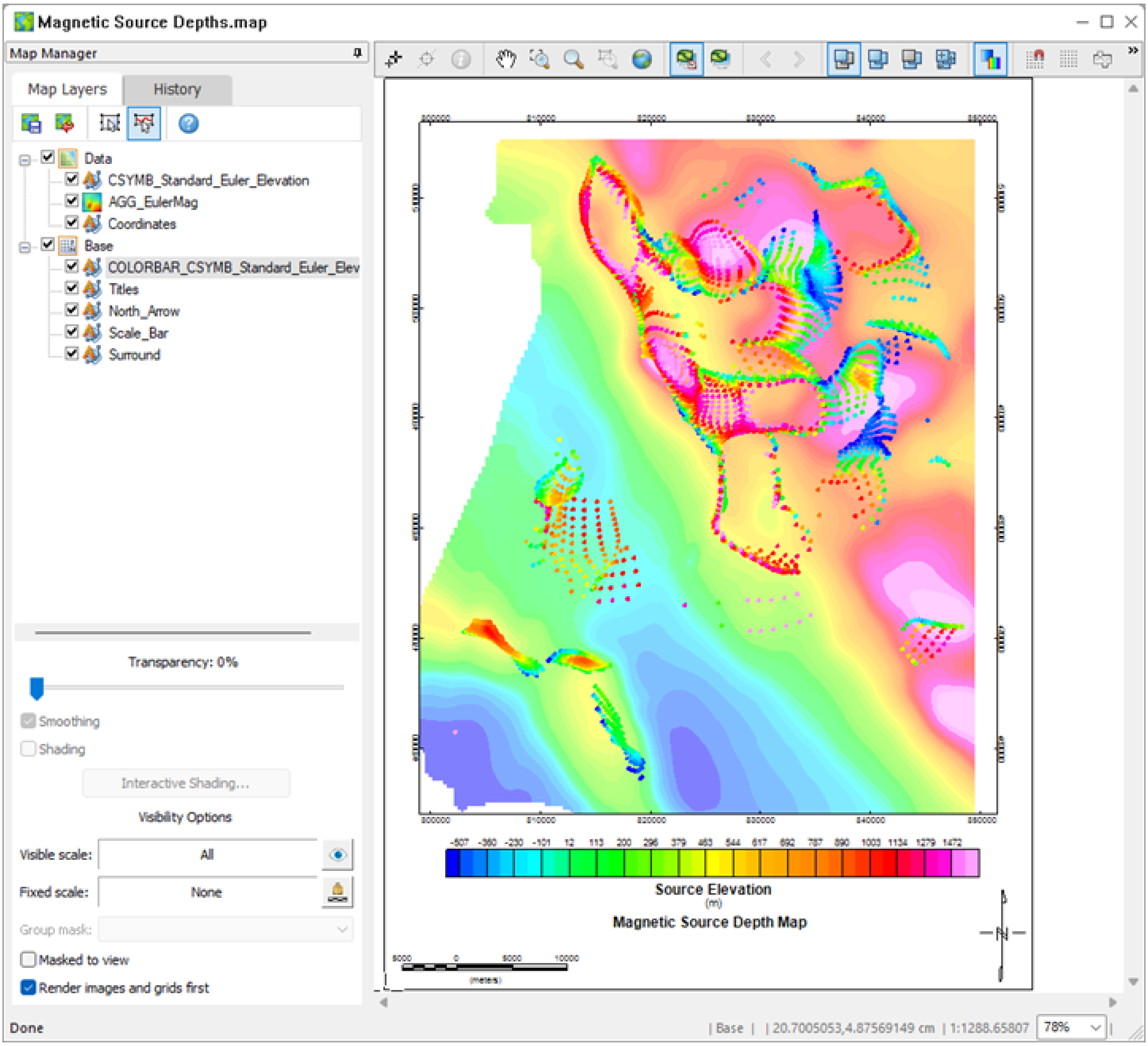
1. For the *Data layer*, click on the drop down and select **Data\CSYMB_Standard_Euler_Elevation** from the list.
2. The *Second data layer* can be left blank.

> The second data layer is optional. It is used to add shading to the colour bar for a shaded-colour image.

3. Specify the *Title* as **Source Elevation** and the *Sub-title 1* as **(m)**. The *Sub-title 2* field can be left blank.
4. Set the Bar orientation option to **Horizontal**.
5. Click the **More** button to display further *Size definition* and *Annotations* options.



6. Set the *Label decimals* to **0**, the *Maximum bar length* to **150** mm and then click on the **Less** button to close these options.
7. Click on the **Locate** button to locate the bottom left corner of the colour bar on the map. You will be prompted to click on the map; **click** somewhere in the area above and to the left of the map title, using the image below as a guide.
8. Click **OK** to plot the colour bar. Then map should now look like what is shown below.



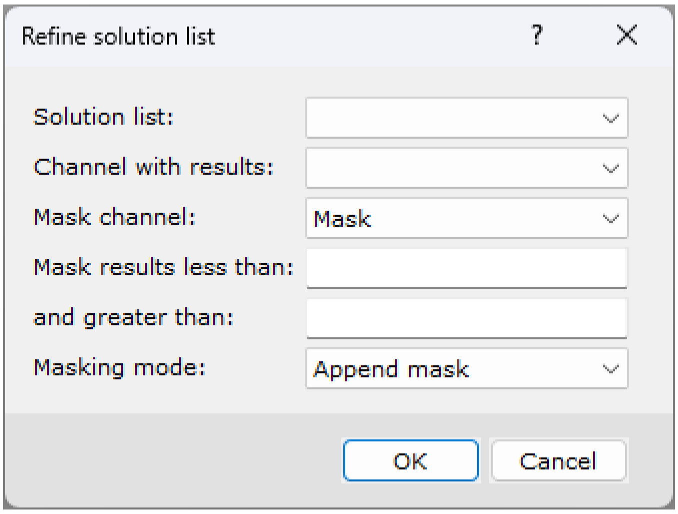
The solutions range from elevations of ~1500 m above sea level to about ~500 m below it. There are many linear clusters of solutions, which one expects when using an SI of 1 to represent dyke like sources. There is however also a lot of scatter and variability in the solutions which could be reduced by windowing the data.

In the process of running Euler deconvolution, we rejected soltuions where the depth uncertainty (dZ) > 15% and solution that are offset > 3200 m from the center of the search window. We will now conduct further windowing based on the following criteria:

- Window soultions using a harsher dZ cutoff of 7%
- Window solutions using a locational uncertainty (dXY) of 15%
- Window solutions that are offset > 2000 m from the window center in either X or Y directions

To Window Euler Solutions

1. Select the **Standard_Euler** database.
2. Open the *Euler 3D* menu, select *Window Results* and then select **Window Solution List**. The *Refine Solution List* dialog appears.



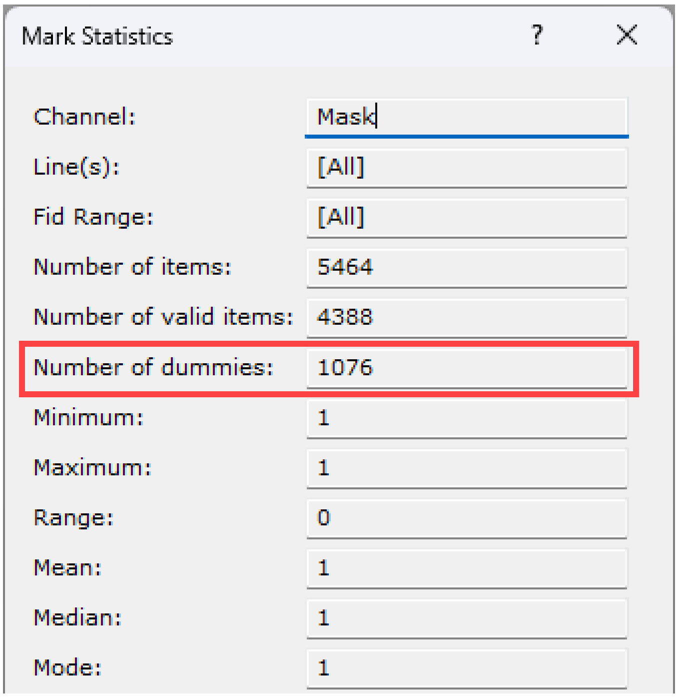
3. Click on the *Solution list* drop down and select **SI_1** from the list.
4. Click on the *Channel with results* drop down and select **dZ** from the list.
5. The *Mask channel* should be set to **Mask**.
6. For the *Mask results less than*parameter, specify a value of **0** and for the *and greater than* parameter, specify a value of **7**.

Solutions with a depth uncertainty that is outside this range will be masked out.

7. Specify the *Masking mode* as **Append mask**.

The *Append* mask mode ensures that existing values in a Mask channel are only overwritten if the specified window criteria are met. The *Preset* mode resets all Mask channel values to 1 prior to windowing.

8. Click the **OK** button. The *Mask* channel of the Standard_Euler database is updated. Below we show the current statistics of the *Mask* channel, which demonstrate that windowing on dZ has excluded a further 1076 solutions from the list.



9. Repeat steps 2-8 above to apply several more passes of windowing the solutions, according to the criteria shown in the table below:

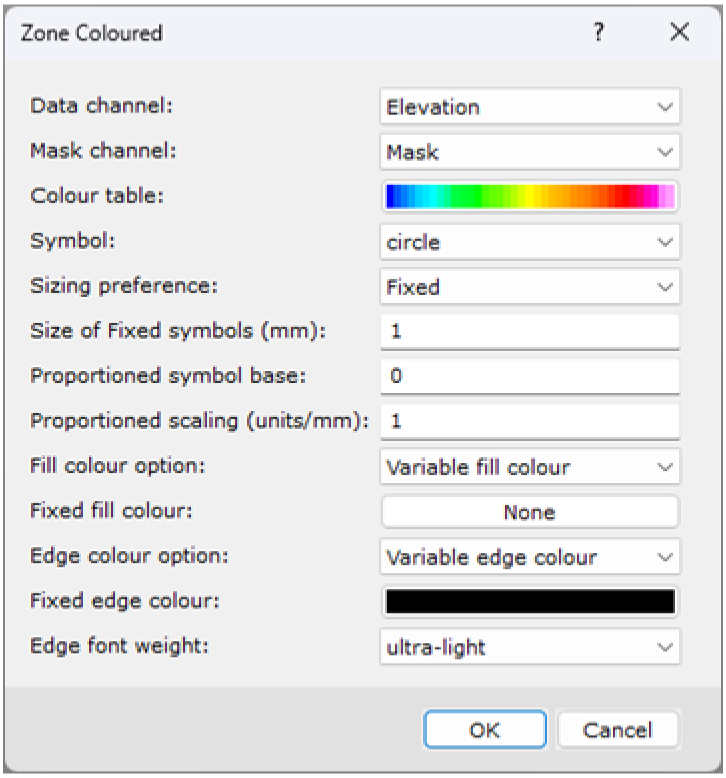
Channel	Mask results less than...	...and greater than
dXY	0	15
X_offset	-2000	2000
Y_offset	-2000	2000

You should find that these further passes of windowing mask out a further 700-800 solutions. We will not replot and compare the results.

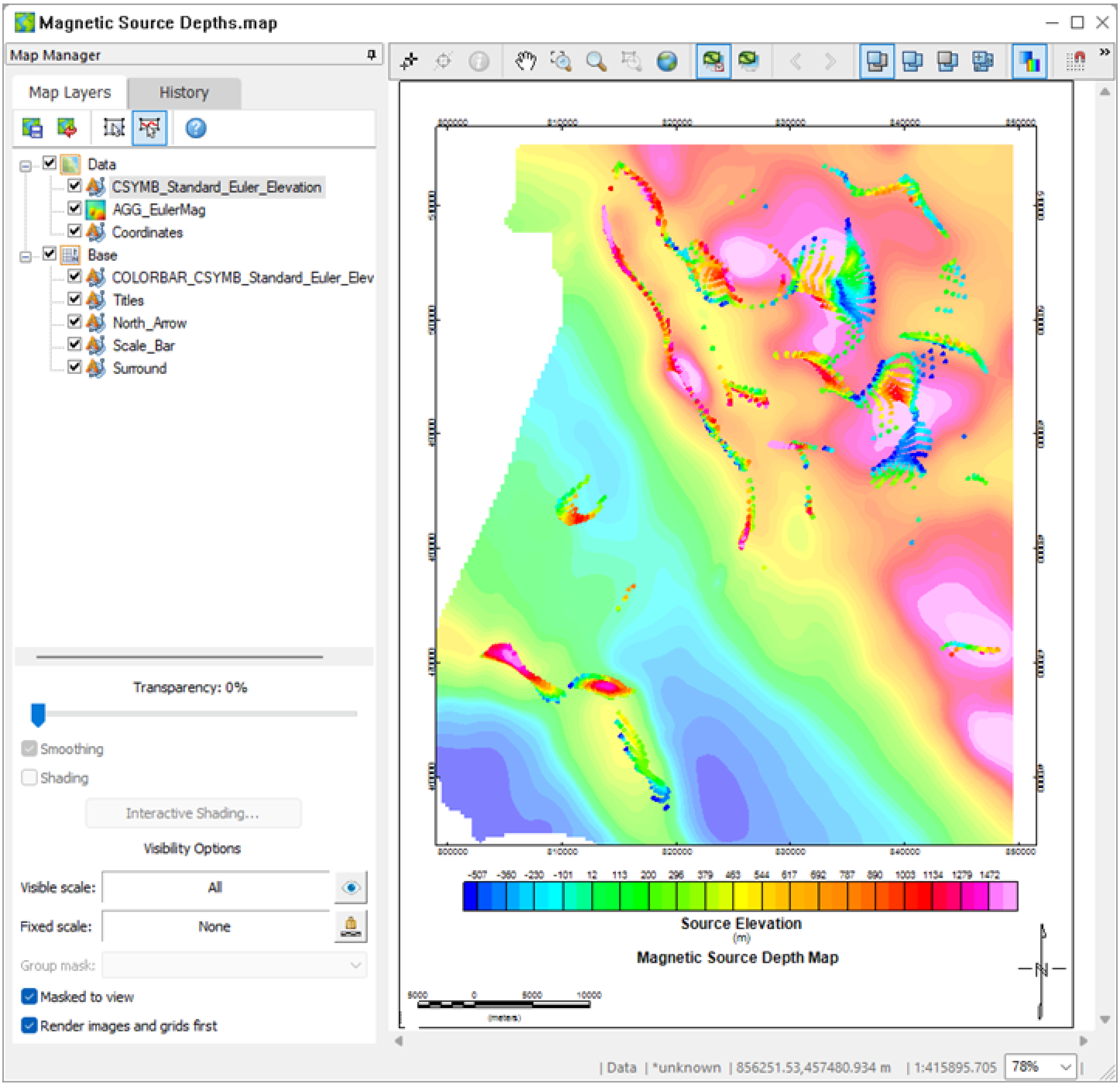
To Replot Solutions

1. Make sure that the **Magnetic Source Depths** map and the **Standard_Euler** database are open and selected.

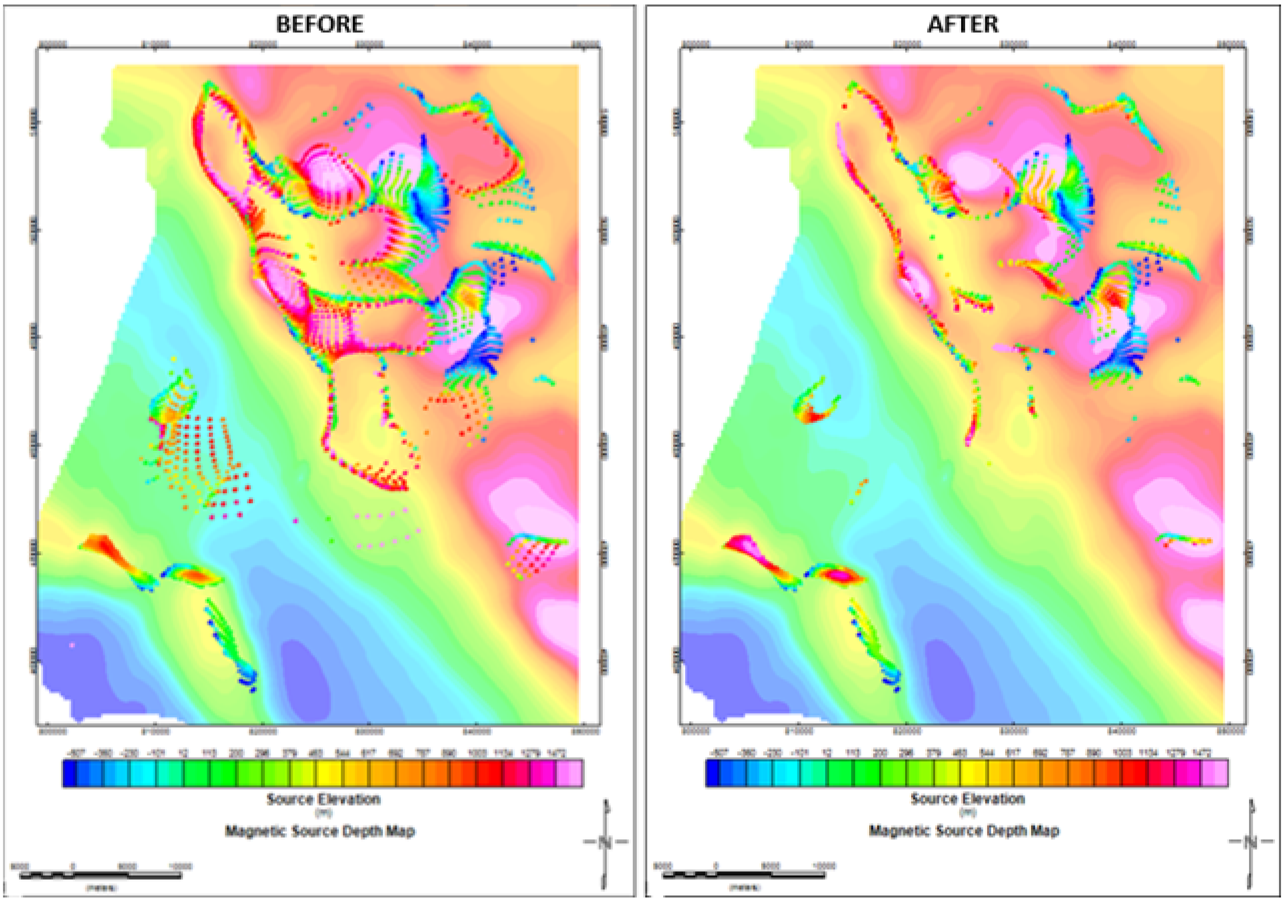
2. Open the *Euler 3D* menu, select *Plot Solution Symbols* and then select **Zone Coloured**. The *Zone Coloured* dialog appears.



3. The dialog retains all the chosen parameters and settings from when it was last used. Click **OK**. The windowed solutions are plotted.

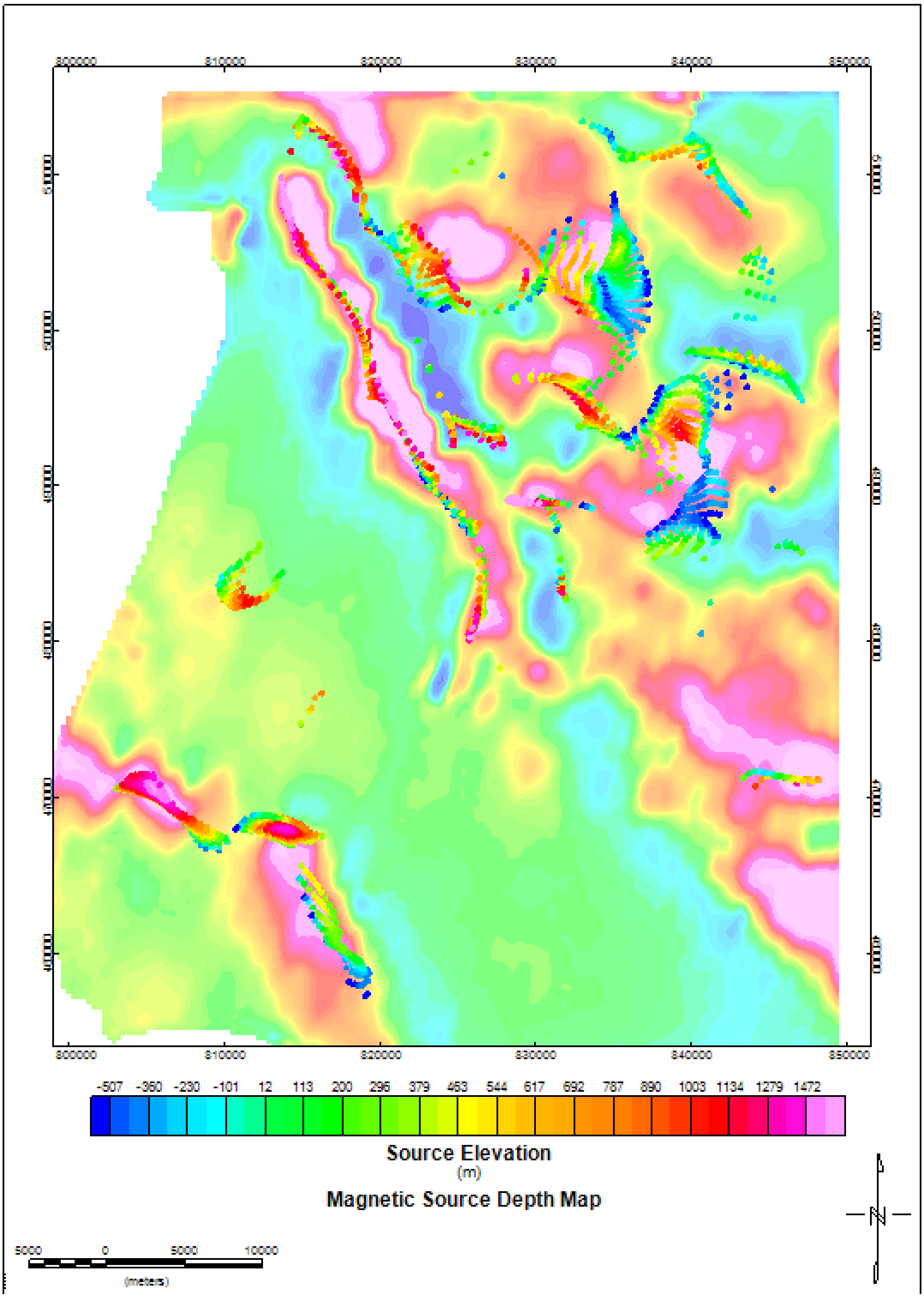


Below we compare the results before and after windowing.



Windowing the data has removed a great number of 'scattered' solutions, although many still remain. Scattered solutions that remain might be attributed to (mathematically) viable solutions being found for SI = 1 over anomalies that are likely caused by sources with geometry that is not dyke-like, such as within the north-eastern sector of the map. These sources could be contacts (SI = 0 for magnetic data) rather than dykes, so in practice, running further passes of Euler deconvolution on this data using SI = 0 would be a good idea.

When assessing how solutions that have SI = 1 relate to the input data, it can be difficult to distinguish dyke like geometries from total field data, particularly in areas that contain broader, high-ampltiude anomalies such as the sample data. In these cases in can be good to view the sources alongside the vertical (dZ) and/or horizontal derivative grids, as shown below, where we have plotted the windowed solutions over the dz.grd, which has been coloured using a Normal distribution.



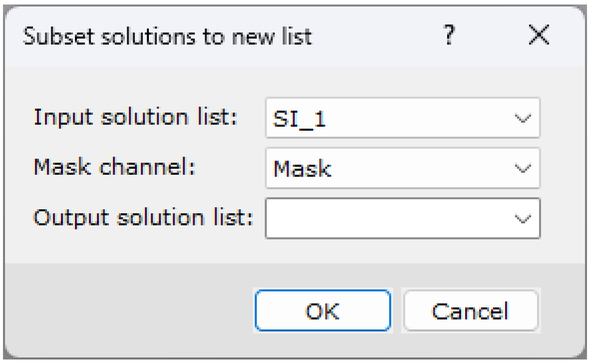
This makes it easier to see which clusters of solutions are associated with the correct structure type, or otherwise; linear clusters of solutions in the north-eastern sector of the map may be caused by contacts rather than dykes.

Creating a Subset Solution List

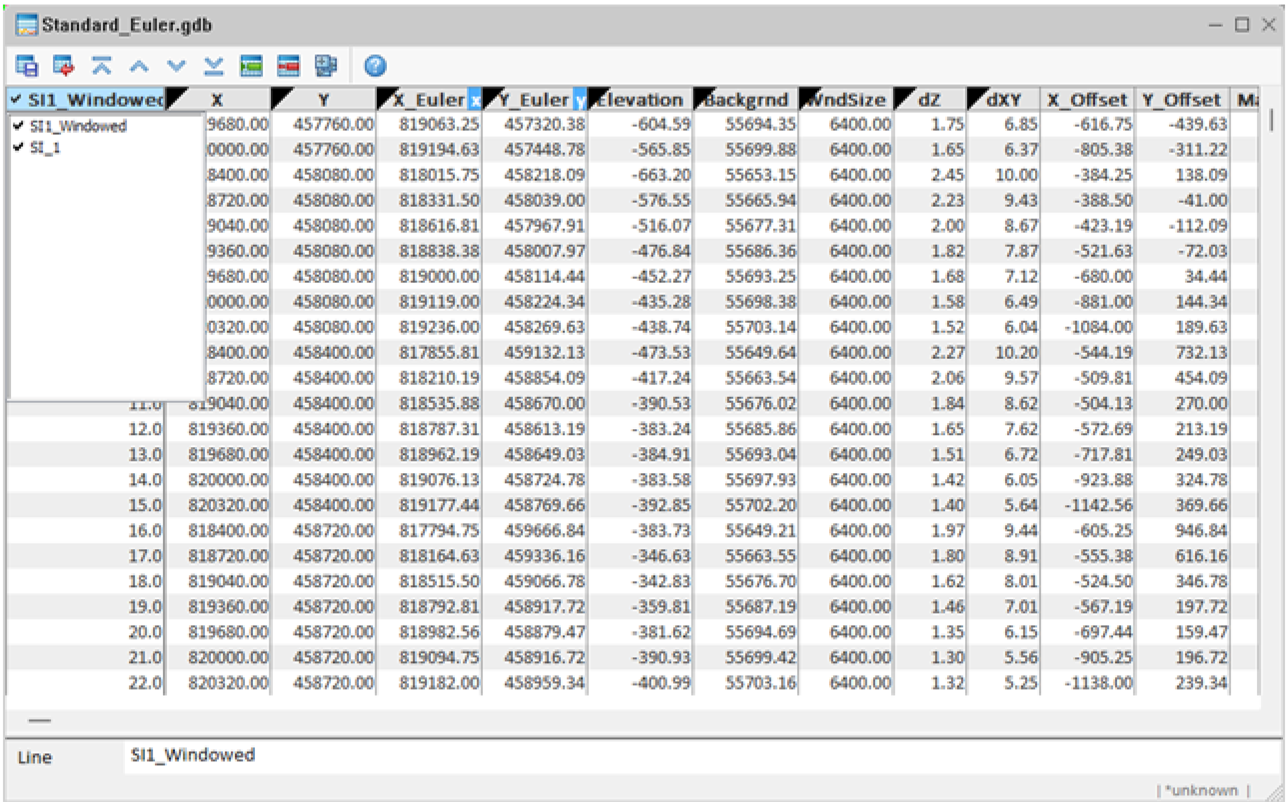
Once you have windowed a set of solutions and are happy with your selection, you may want to store the windowed subset in a new, separate group/line within database. We will now demonstrate how to do this, using the *Subset Solution List* menu option.

To Create a Subset Solution List

1. Open the *Euler 3D* menu, select *Window Results* and then select **Subset Solution List**. The *Subset solutions to new list* dialog appears.



2. The *Input solution list* should be set to **SI_1**.
3. The *Mask channel* should be set to **Mask**.
4. Specify the name of the *Output solution list* as **SI1_Windowed**.
5. Click the **OK** button. The group is added to the database.



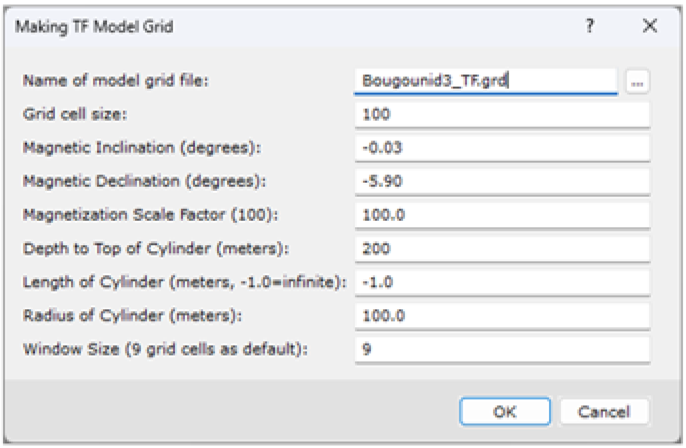
Specialized Source Depth Estimation Tools

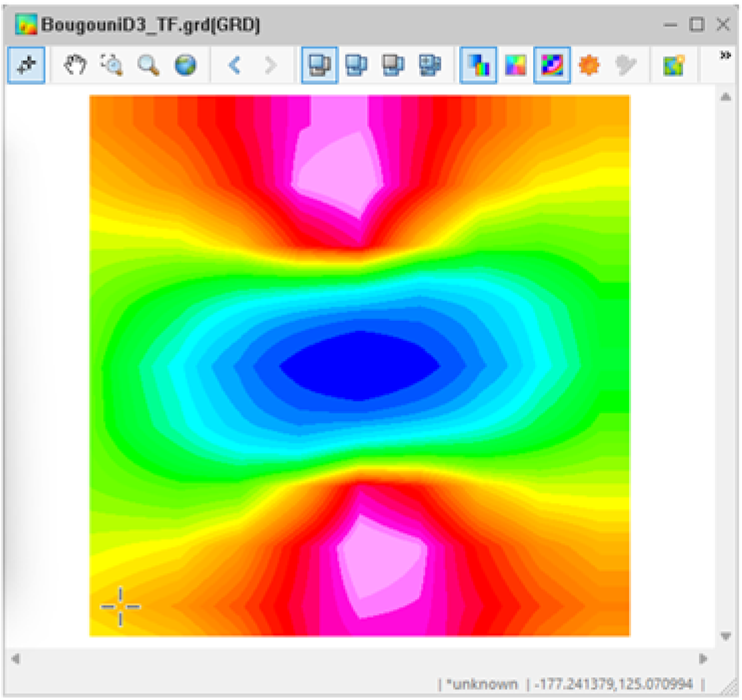
The Grav/Mag Interpretation extension includes several additional specialized source depth estimation tools for working with gravity and magnetic data, including the *Kimberlite*, *Source Edge Detection (SED)*, and *Source Parameter Imaging (SPI)*.

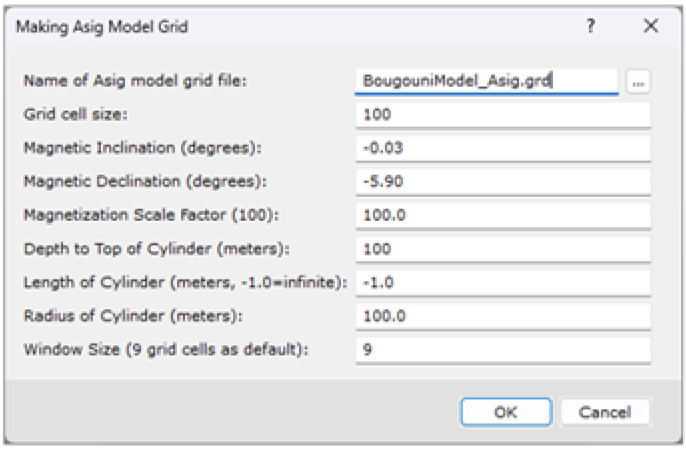
Kimberlite (Keating Magnetic Correlation Coefficients) Tool

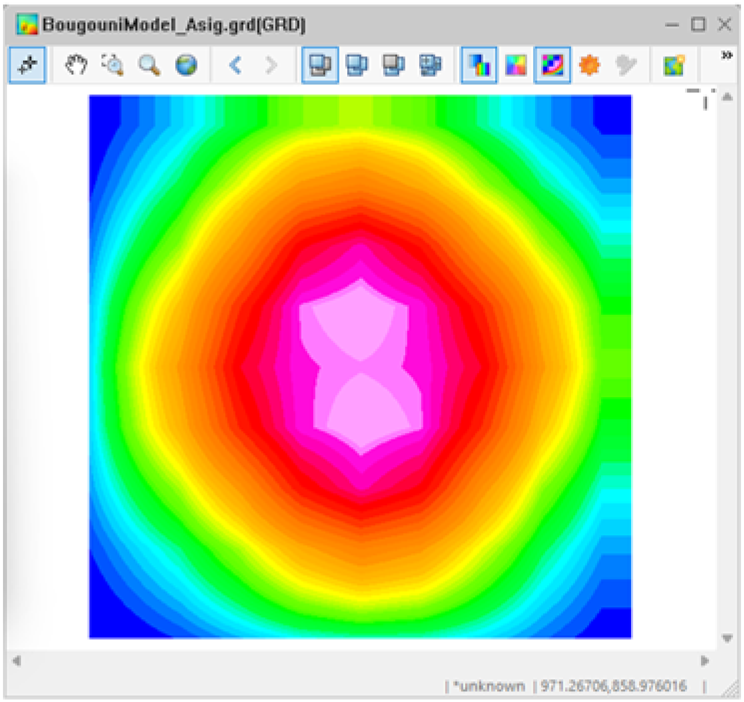
The *Kimberlite* tool uses a simple pattern recognition technique to locate magnetic anomalies that resemble the response of a Kimberlite pipe (Keating and Sailhac, 2004) from gridded residual total field or Analytic Signal data.

The workflow involves first creating a grid of the magnetic (total field or Analytic Signal) response of a dipping vertical cylinder. Examples of both are shown below.



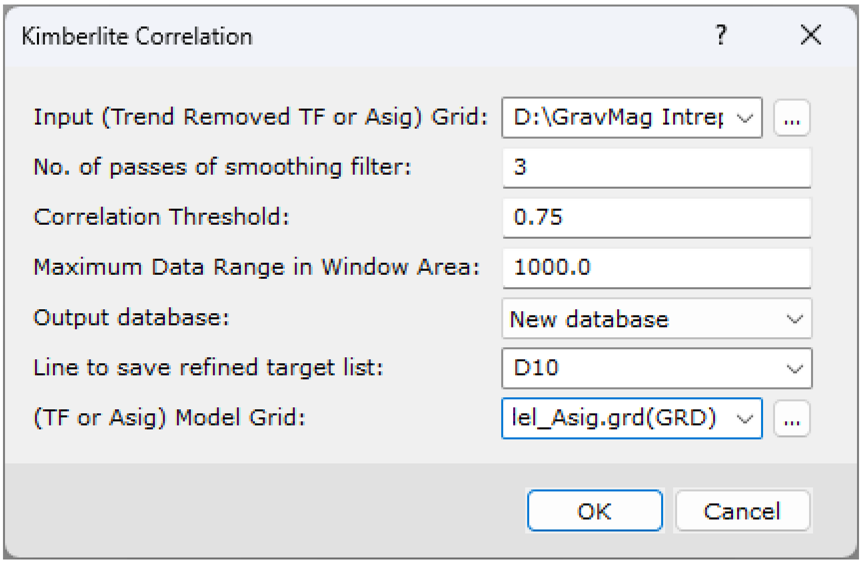




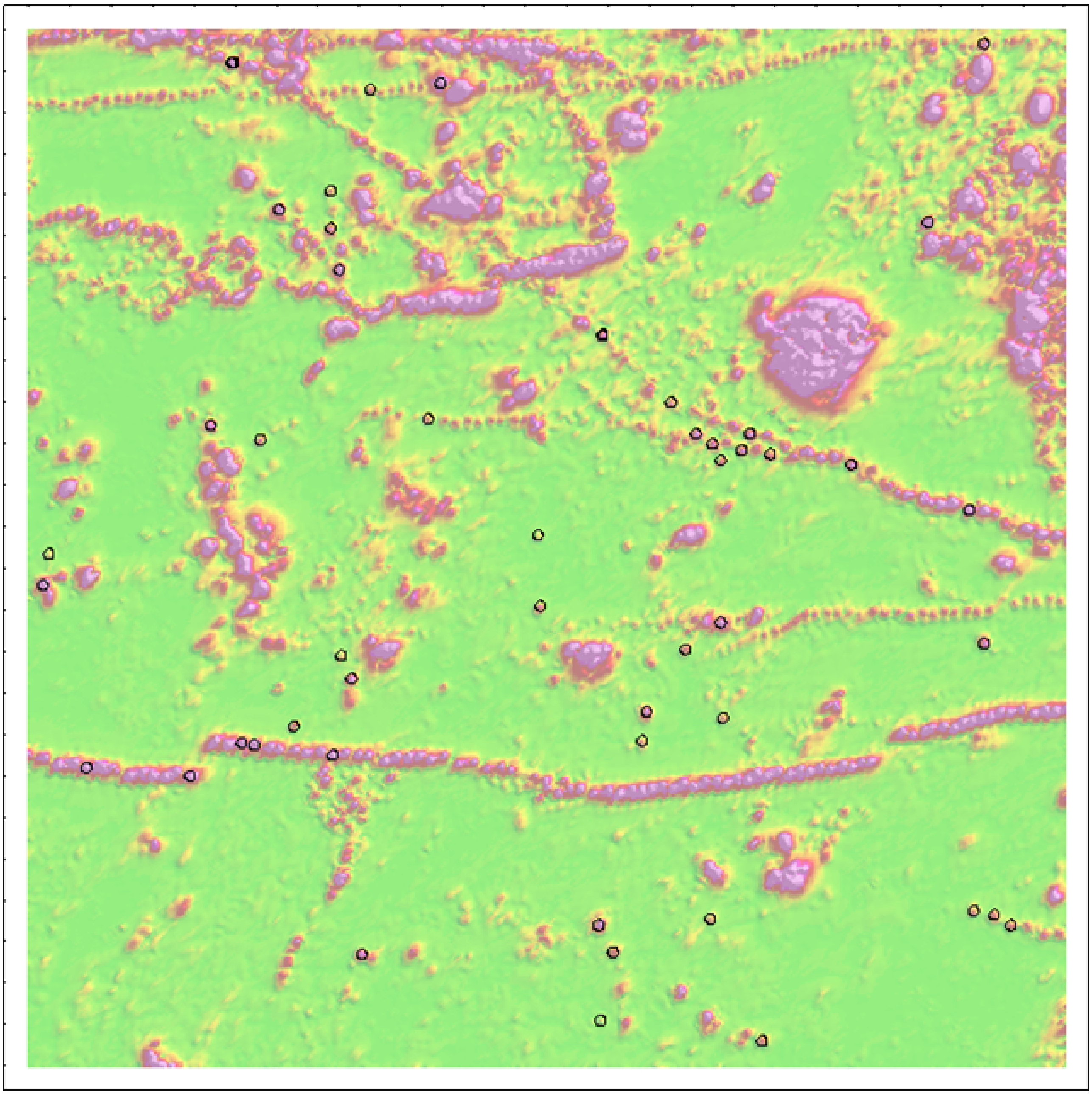


It is recommended to use the Analytic Signal instead of the Total Field in areas where anomalies are distorted due to non-inducing field magnetization. The depth to top, radius, length and magnetization of the model can be varied. For a model of finite length, the response for two models are computed, using depths to the top and bottom of the cylinder, with the resultant response being the difference between the two.

The computed model grid is then used to calculate the Keating correlation coefficients for kimberlite pipe targets at each grid node:



Solutions with correlation coefficients that exceed a specified threshold are retained for interpretation. an example of Kimberlite solutions derived from Analytic Signal data is shown below.



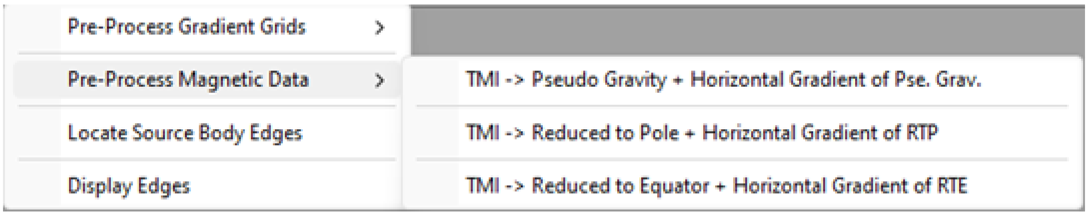
Here are some important things to consider when using this tool:

- The cell size for the model response grid must be as same as the grid cell size of the grid which will be used to locate Kimberlite target solutions
- The depth-to-top parameter is the depth below the magnetic sensor. It accounts for the terrain clearance of the magnetometer and the anticipated depth of burial to the top of the Kimberlite pipe
- The window size should be large enough to fully represent the response of the model. For example, a deeply buried cylinder requires a larger window in order to capture its magnetic response). Conversely, the window size should not be so large that it incorporates neighboring anomalies

Source Edge Detection Tool

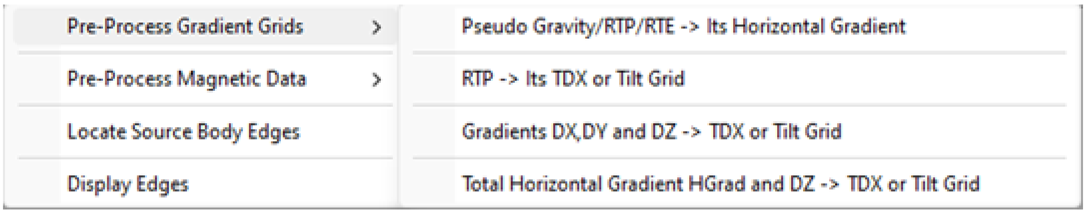
The *Source Edge Detection (SED)* technique of Cordell and Grauch (1982, 1987) can estimate the location of both peaks and abrupt lateral changes in magnetization or mass density of upper crustal rocks, using maxima from gridded horizontal gradient data. The workflow consists of the following steps:

1. Pseudogravity (PG), Reduction to the Pole (RTP) or Recuction to the Equator (RTE) transforms. This step is only required for magnetic field data:

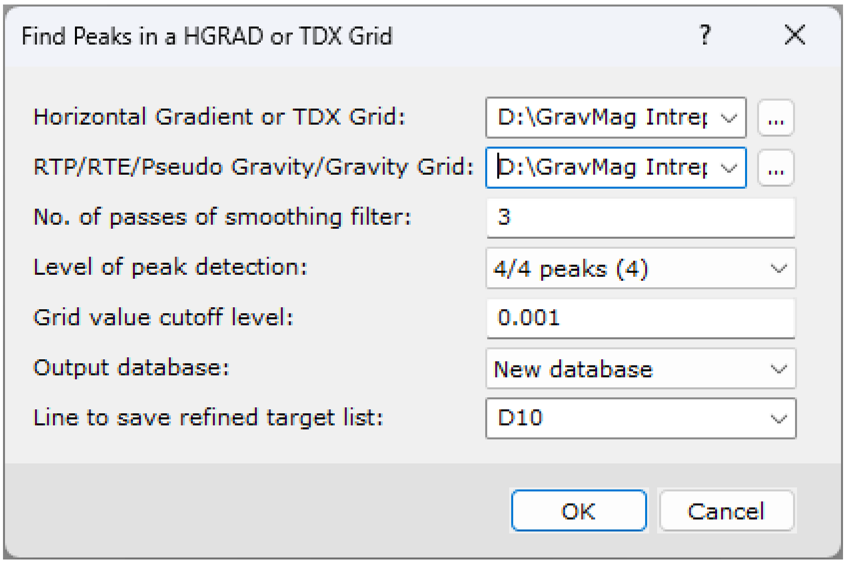


RTP, RTE or PG transformations are required for magnetic data to remove the effects of the geomagnetic field when locating the source edges. The RTE may prove more effective than RTP at low magnetic latitudes. The PG transformation will suppress the shorter wavelength anomalies (i.e. near-surface sources), and is therefore suited to locating regional-scale features.

2. Compute the gradient grids:



3. Identify edges or peaks from gradient data:



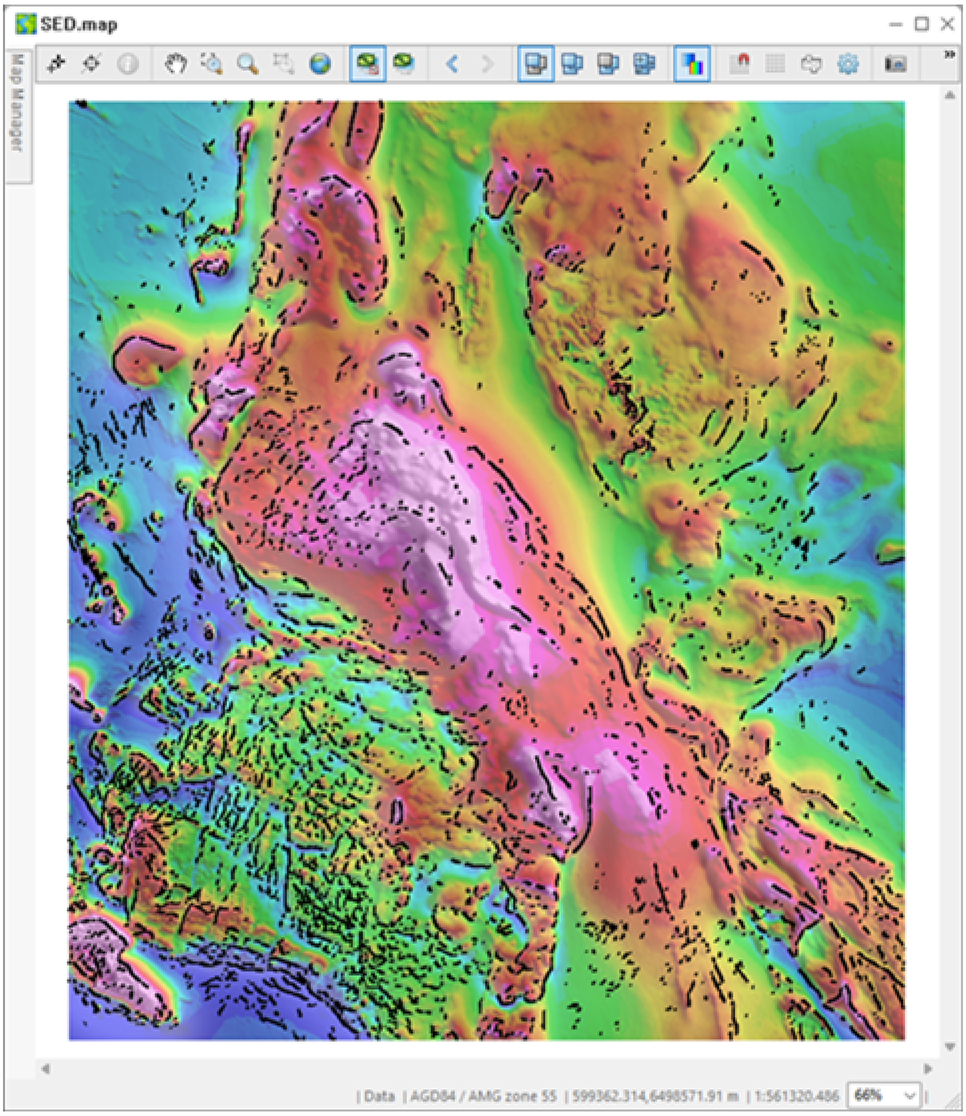
A Hanning smoothing filter is provided to damp noise that is commonly associated with gradient data. The *Level of peak detection* is the same parameter as used during Located Euler deconvolution and can be used to include or exclude anomalies based on their "quality", which is a function of how/whether the field falls off moving away from the anomaly centre in each cardinal direction.

> A *Level of peak detection* value of 2 or 3 has been observed to work best for SED.

The *Grid value cutoff level* can be used to exclude results that may be derived from noise. A value of 0 (zero) can be specifed to find all source edges.

> A reasonable cutoff level can be determined by examining the horizontal gradient grid for a "background" value using the Grid value tool, which can be launched by right-clicking within any grid window.

4. Plot results. An example is shown below, with source edge locations shown in black over a composite image of TMI with the horizontal gradient of the TMI pseudogravity used for shading.



In summary, to use this tool to detect edges:

1. Apply SED to the TDX of your RTP anomaly
2. Apply SED to the horizontal gradient of the pseudo gravity

If you want to use this tool to find peak locations:

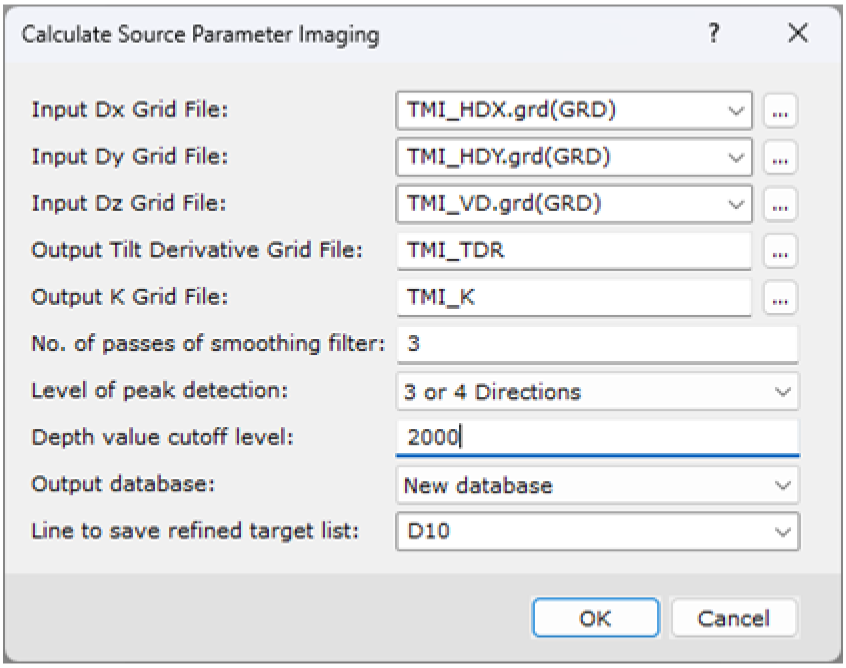
1. Apply SED to the 1VD of the RTP anomaly
2. Apply SED to the 2VD of the RTP anomaly

3. Apply SED to the RTP-tilt derivative

Source Parameter Imaging

The *Source Parameter Imaging (SPI)* tool (Smith et al. 1998) offers the most straightforward of all of the magnetic source depth estimation methods. It uses the Complex Analytic Signal to estimate source depth, so the depth estimate is independent of the magnetic inclination, declination, dip, strike and any remanent magnetization. The method assumes that the causative body is a 2D contact, thin sheet or horizontal cylinder.

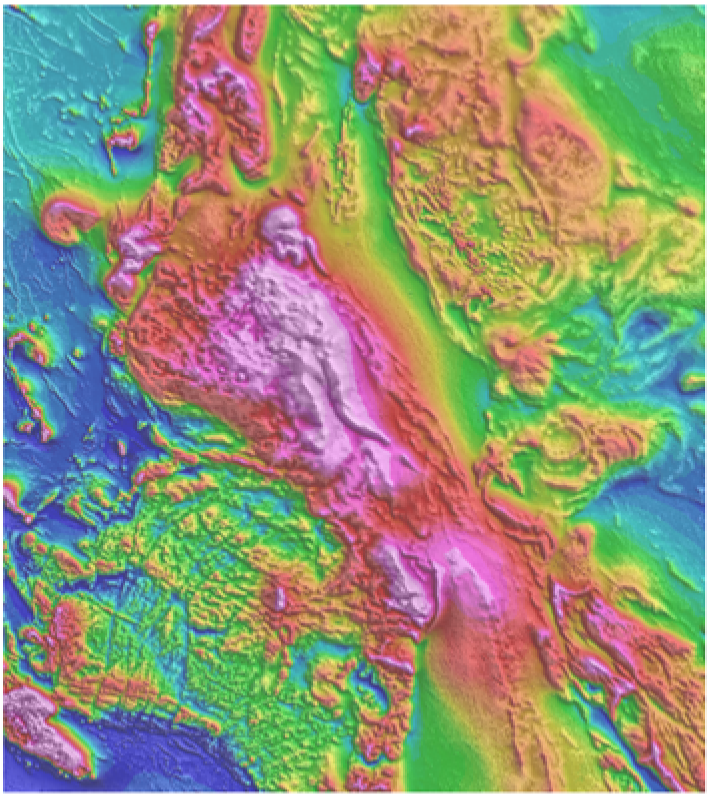
The biggest advantage of this method is that the user does not have to choose a Structural Index, nor do they have to run multiple passes for each SI that they think might be present in the area of interest. The results do not requrie windowing and are amenable to being gridded.



The tool requires input (X and Y) horizontal derivative grids and a vertical derivative grid. The *Source Parameter Imaging* menu offers the ability to generate the two horizontal derivative grids from TMI data using convolution filters, and the first vertical derivative grid using a FFT filter. However, the user may compute these grids separately if desired.

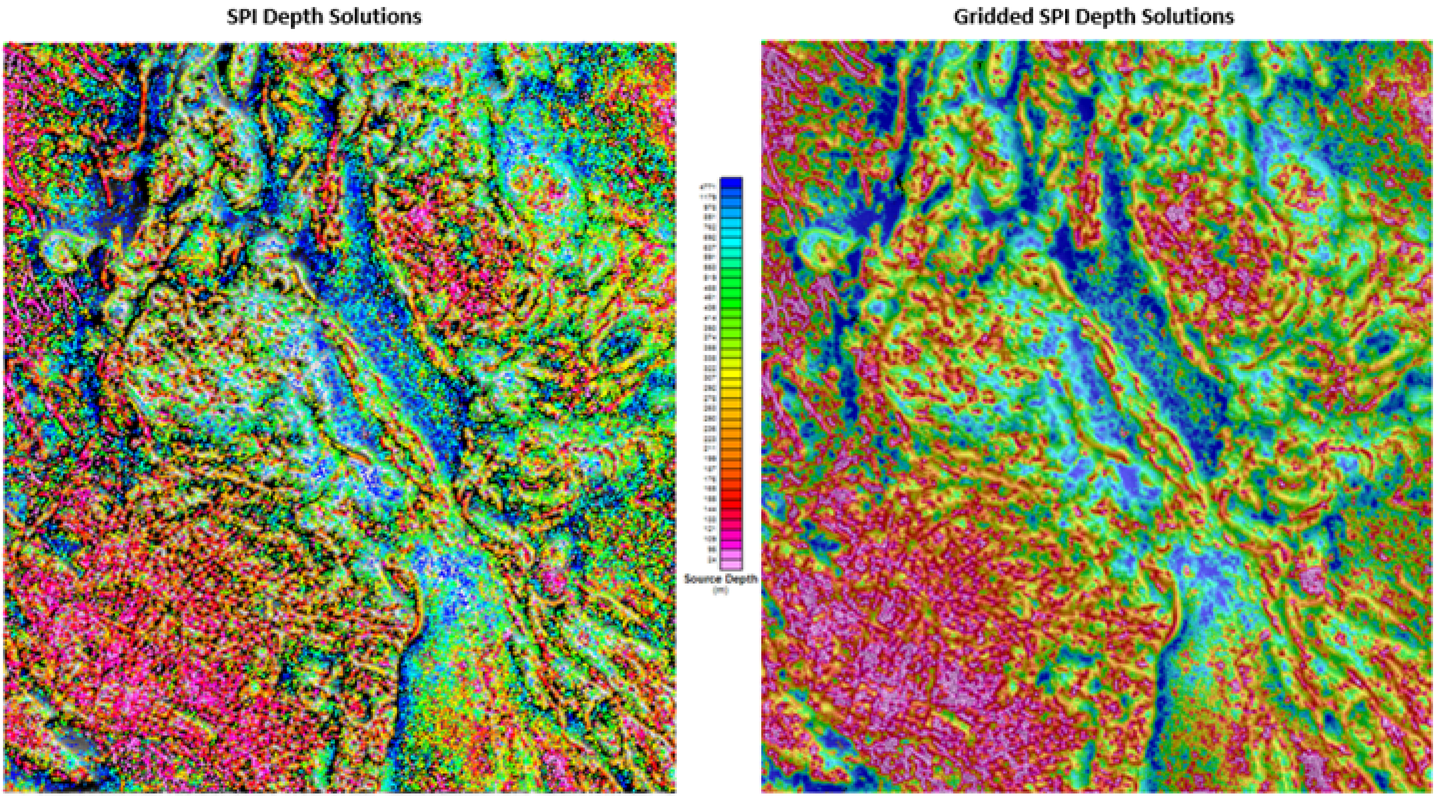
The application of 1-3 passes of a smoothing (Hanning) filter is offered and recommended in order to damp near surface and cultural "noise". More passes tend to reduce the number of shallow solutions found. The tool uses the same Blakely peak detection method that SED and Located Euler use; in the case of SPI, a peak detection value of 3 usually works best, but 4 or 2 may be better for some data sets, depending on the geological responses and the noise levels.

TMI Grid



Tilt Derivative Grid

One output of SPI is a grid of the tilt derivative, which some prefer to use for interpretation over vertical derivative grids. Such a grid is shown above. SPI produces depth solutions that are spread evenly over the area of interest meaning that they can easily be gridded. Below we show the depth solution symbols for the area shown above, overlain on the tilt derivative grid shown above. Next to this we show a grid of the same depth solutions, overlain on the same tilt derivative grid. The grid was created using Minimum curvature gridding.



The accuracy of SPI source depth estimates has been demonstrated to be +/- 20% in tests on real data sets with drillhole control. This accuracy is similar to that of Euler deconvolution, however SPI has the advantage that it produces a more complete set of coherent solution points and is easier to use.

References

Blakely, R. J. and Simpson, R. W., 1986, Approximating edges of source bodies from magnetic and gravity anomalies, Geophysics, vol. 61, p. 1494-1498

Cordell, L. and Grauch, V. J. S., 1982, Mapping basement magnetization zones from aeromagnetic data in the San Juan Basin, New Mexico, 52nd Annual International Meeting, SEG Expanded Abstracts, p. 246-247.

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