Geosoft Technical Note
Depth to Basement Methods

Introduction

This technical note describes how to use the **montaj Depth to Basement** extension to determine the position (distance along the profile and depth), dip (orientation) and intensity (susceptibility) of magnetic source bodies for a magnetic profile. With large, distinct density contrasts, the extension can also be used on gravity profiles to determine the position of gravity source bodies.

This extension includes three different Profile Depth to Basement (PDepth) techniques; *Werner Deconvolution*, *Analytic Signal* and *Extended Euler Deconvolution*. Each Depth to Basement function uses a different accepted technique for determining the depth to the source. Each method has advantages in particular geologic situations. Applying multiple methods to the same anomaly profile greatly improves the reliability of results.

Solutions are saved in a new Geosoft GDB (database), enabling you to immediately view the results in profile, edit the solutions, and plot the solutions to 2D and 3D maps. Additional functions also enable you to cluster solutions, export solutions to GM-SYS models, and generate starting GM-SYS models from data profiles.

Using the Depth to Basement Methods

The Depth to Basement methods will operate on all selected lines in the current database. Simply select one of the methods to use. Adjust the method-specific parameters to control the number of solutions generated by the calculations. Note that Depth to Basement methods recreate the output database each time a method is run, so previous solutions may be overwritten.

TO USE THE DEPTH TO BASEMENT METHODS:

1   From the *GX* menu, select *Load Menu*. The *Load Menu* dialog is displayed.

2   Select the **pdepth.omn** file and click **[Open]**. The *Pdepth* menu will be added to the **Oasis montaj** menu bar.

3   Make sure the database you want to analyse is set as the current (selected) database.

4   From the *PDepth* menu, select the method you would like to use. For further information about each method, refer to the solution specific sections below:

- Werner solutions
- Analytic Signal solutions
- Extended Euler solutions

5   Fill in the necessary fields to generate the solution.

6   Click **[OK]**.

Data Requirements for All Depth to Basement Methods

Each method requires X, Y, elevation, topography and anomaly channels for the input profiles. Topography may be all dummies. The difference between elevation and topography channels is subtracted from the solution depths to generate the channel containing the depth of the solutions relative to sea level, Depth_sl. All channels containing distance units are assumed to use the same units.

All methods require minimum and maximum depths, in the same distance units, that define the solution space. Solutions shallower than the minimum depth or deeper than the maximum depth will be discarded.

Depth to Basement methods are designed primarily for use with total-field magnetic data. For each method, you must set the magnetic field parameters to those appropriate to the magnetic survey. However, mathematically the magnetic response is equivalent to the derivative of the gravity response, so it is possible to use Depth to Basement methods on gravity profiles by using either the horizontal or vertical derivative of gravity as the input anomaly profile, rather than total-field magnetic data. When using the vertical derivative, set the *Inclination* to 90 degrees and the *Declination* to 0. For the horizontal derivative, set the *Inclination* to 0, and the *Declination* to the profile azimuth.
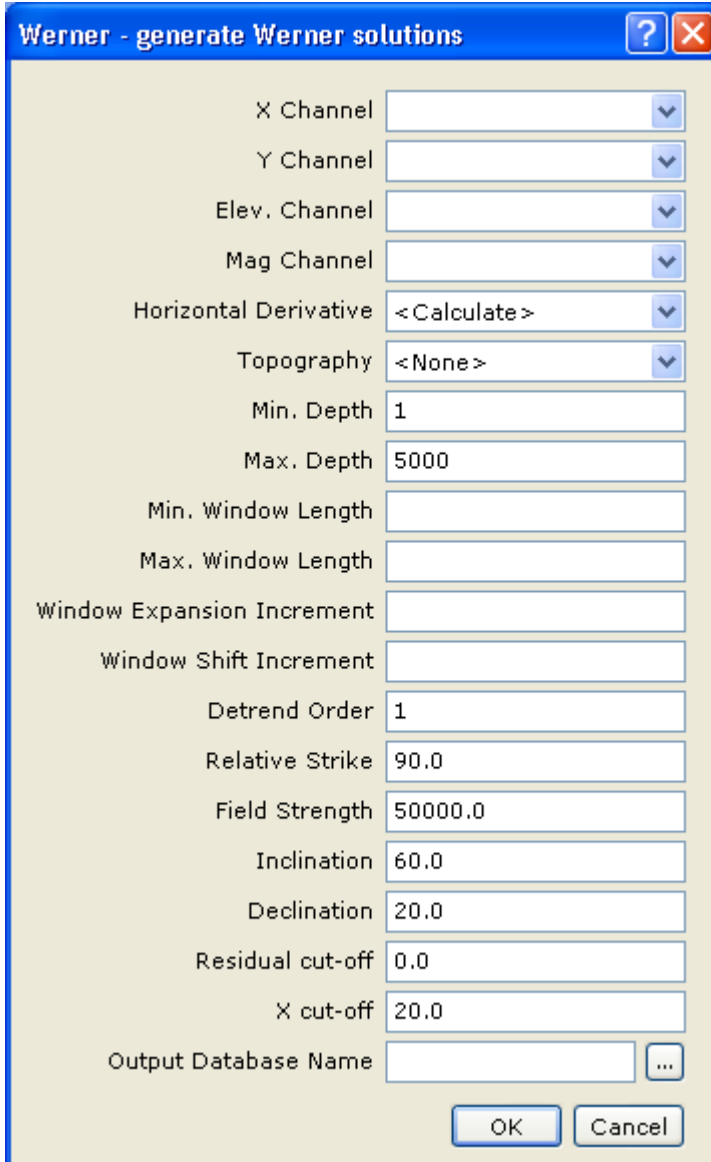
Setting the *Field Strength* to 10 seems to give the best conversion of susceptibilities to densities. However, remember that the susceptibilities calculated for dike solutions are really effective susceptibilities (i.e., susceptibility * width). Also remember that the contact solutions are calculated from the 2nd derivative of the gravity profile. Unless the original gravity profile is especially clean, the 2nd derivative will tend to be noisy, so the density contrasts calculated are often not very accurate.

The methods use horizontal and vertical derivatives in the calculations. You may either specify existing derivative channels to use, or have one or more derivatives calculated from the input channel. If your input profiles are noisy, you can improve the performance of Depth to Basement methods significantly by low-pass filtering or smoothing the anomaly profiles prior to running the methods. This is especially true in the case of gravity profiles, where the derivatives are really 2nd derivatives. The calculated susceptibilities and densities will be less accurate with noisy data.

All of the methods assume that the anomaly profile is perpendicular to the geologic structure generating the field. Set the *Relative Strike* parameter to reflect the clockwise difference between the profile azimuth and the geologic strike.

Generating Werner Solutions

Each Werner Deconvolution calculation operates on a segment of the anomaly profile referred to as a window, and may produce a single solution. Starting at the beginning of the profile using the smallest window size, the window moves along the profile to the end. Then the window size is incremented and the entire profile is processed again.

You may elect to have a trend removed from each window as part of the calculation. In the *Detrend Order* parameter, specify 0-order, 1st-order, or 2nd-order trend removal.

Several parameters in the dialog control the number of solutions generated by Werner:

- *Min. Window Length* sets the minimum lengths of the Werner operator.
- *Max. Window Length* set the maximum lengths of the Werner operator.
- *Window Expansion Increment* determines the number and size of steps between the minimum and maximum.
- *Window Shift Increment* sets the distance the Werner operator is moved along the profile between calculations.
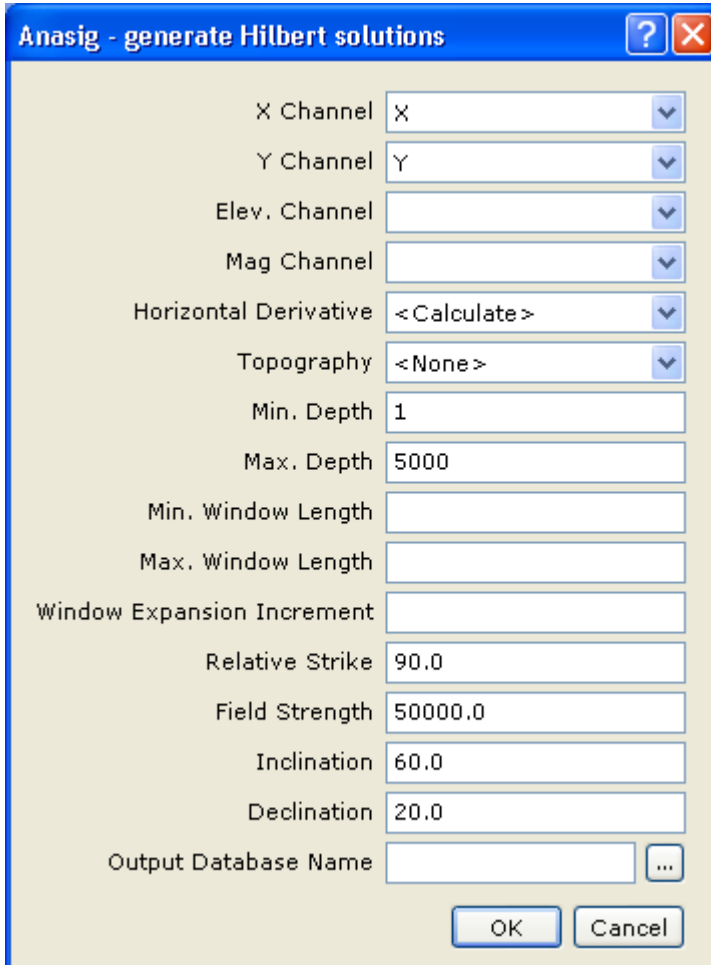
These four parameters are specified in distance units. Smaller values of *Window Expansion Increment* and *Window Shift Increment* generate more calculations and hence more solutions.

Each Werner calculation potentially generates one solution. Two input parameters determine whether a calculated solution will be saved in the output database: *Residual cut-off* sets an amplitude threshold for anomalies (in nT units) and allows you to eliminate solutions caused by noise in the input profile. Larger values of *Residual cut-off* eliminate more solutions. *X cut-off* sets a horizontal distance threshold (in fiducials units) for solutions relative to the center of the Werner operator. When *X cut-off* is decreased, more solutions are eliminated. Values of X cut-off greater than 2, combined with small values of *Window Shift Increment*, generate the spray patterns seen in some examples in the literature.

The Werner Deconvolution method will not find many valid solutions at depths shallower than the input data spacing or deeper than the window length.

Generating Analytic Signal Solutions

When using Analytic Signal method on gravity profiles use the horizontal derivative of gravity as the input profile rather than total-field magnetics. If the "Field Strength" is set to "1", "Inclination" set to "90", and the "Declination" set to zero the "Susc" output channel will be the calculated density contrast. Note that the "Contact" solutions are computed from the 2nd horizontal derivative in the gravity case, so some low-pass filtering is often required.

Three parameters in the dialog control the number of solutions generated by the Analytic Signal (Anasig) method.

- *Min. Window Length* sets the minimum lengths of the analytic signal operator.
- *Max. Window Length* set the maximum lengths of the analytic signal operator.
- *Window Expansion Increment* determines the number and size of steps between the minimum and maximum.
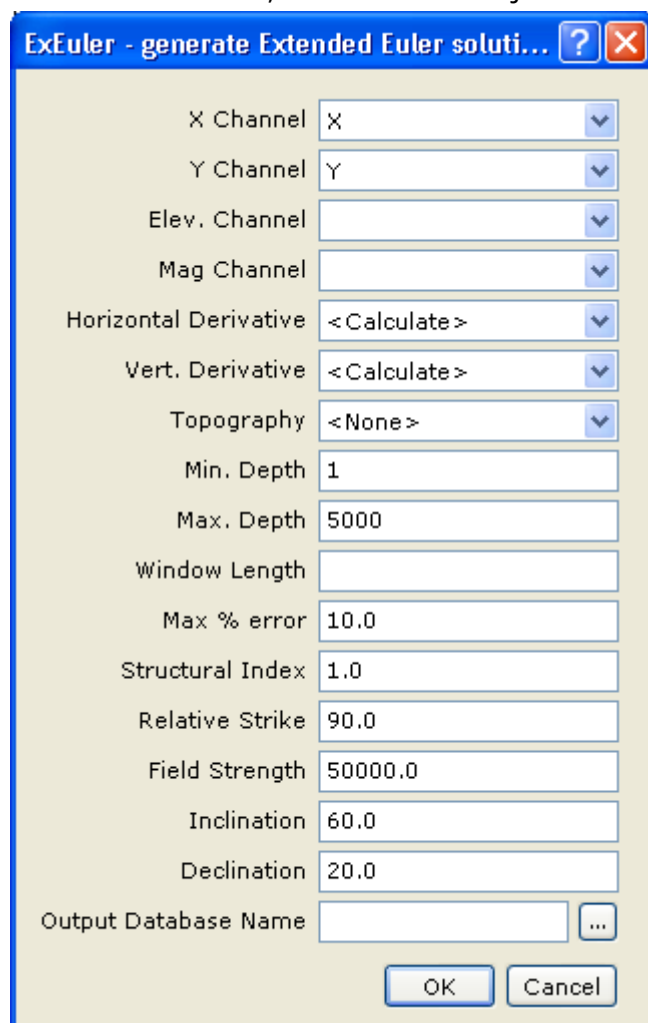
These three parameters are specified in distance units. The distance units in the input parameters are always the same as those for the X and Y input channels. For example, if the X, Y channels are in meters, all the distance, depth inputs and

outputs will be in meters. Smaller values of *Window Expansion Increment* and *Window Shift Increment* generate more calculations and hence more solutions.

Each analytic signal calculation may generate a single solution. After a local peak is detected in the anomaly profile, operators that vary from *Min. Window Length* to *Max. Window Length* are used to calculate an interpolated location for the peak and a depth.

Generating Extended Euler Solutions

The Extended Euler algorithm used in this method was provided by GETECH and is based on the paper from 2001 by Mushayandebvu et al. This approach calculates solutions using both the conventional Euler equation (Reid et al, 1990) and the rotational constraint equation from extended Euler. Solving both equations jointly (extended Euler) gives distance, depth, dip, and susceptibility, assuming there is no remnant magnetization. Using conventional Euler Deconvolution gives a second estimate for distance and depth. If the relative difference in depth for the two estimates is less than the maximum percentage error given by the user, the solution is retained; otherwise it is rejected.

Four parameters in the dialog control the number of solutions generated by the extended Euler (ExEuler) operator:

- *Min. Depth* sets the minimum depth cut-off.
- *Max. Depth* sets the maximum depth cut-off.
- *Window Length* sets the length of the ExEuler operator, which is moved across the profile and is used for each calculation.
- *Max % error* is used to filter out solutions that differ in depth by more than this stated percentage when calculated by both Euler and Extended Euler calculations.
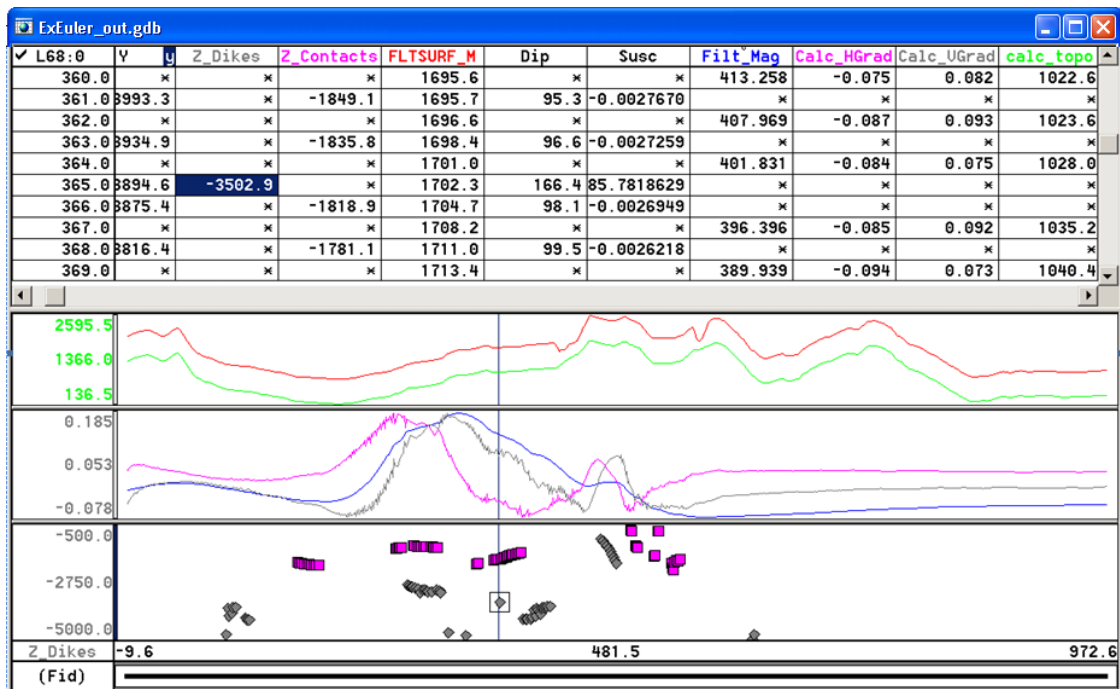
The minimum and maximum depths, as well as the window length parameter are specified in distance units. The distance units in the input parameters are always the same as those for the X and Y input channels. For example, if the X and Y channels are in meters, all the distance, depth inputs and outputs will be in meters.

The Extended Euler method (ExEuler) will not find many valid solutions at depths shallower than the input data spacing or deeper than the window length. ExEuler always makes two passes through the data. The first pass always uses a Structural Index (SI) of zero to calculate contact solutions. The second pass uses the SI given by the user in the dialog entry for Dike Structural Index. The results of the second pass are always flagged as dike solutions regardless of the SI used.

Displaying Results in Oasis montaj

The solutions are written to the separate *Output Database* specified by the user. Solutions are sorted by distance-along-the-line, referenced to the first point in the input profile. The channel, *Z_Dikes* contains the dike solution depths relative to the flight elevation. The channel, *Z_Contacts* contains the contact solution elevations relative to the flight elevation. All of the solutions are also in a 3rd channel named *Z_Both*. The channel *Depth_sl* contains the elevations of all solutions relative to sea level, calculated using the input "Elev" channel if it was non-dummy. *Dike0_Cont1* contains a flag identifying the solution as a dike (**0**) or a contact (**1**) solution. The sign of the Z-axis is negative down (elevations) for all output channels (*Z_Dikes*, *Z_contacts*, *Z_Both*, *Flt_Elev*, *Topography*, and *Depth_sl*) to facilitate convenient profile plots.

In addition to the calculated solutions, each method samples the input channels "Elev", "Topography", "Mag", "Vertical Derivative", and "Horizontal Derivative" at the location of each solution and copies them into the output database. As shown below, the *Z_Dikes* and *Z_Contacts* channels are plotted as symbols in the bottom panel. The middle panel shows the input magnetic profile and the vertical and horizontal derivatives (either input or calculated). The top panel shows the input flight "elevation" and "topography".

L68:0	Y	y	Z_Dikes	Z_Contacts	FLTSURF_M	Dip	Susc	Filt_Mag	Calc_HGrad	Calc_UGrad	calc_topo
360.0			×	×	1695.6	×	×	413.258	-0.075	0.082	1022.6
361.0	3993.3		×	-1849.1	1695.7	95.3	-0.0027670	×	×	×	×
362.0			×	×	1696.6	×	×	407.969	-0.087	0.093	1023.6
363.0	3934.9		×	-1835.8	1698.4	96.6	-0.0027259	×	×	×	×
364.0			×	×	1701.0	×	×	401.831	-0.084	0.075	1028.0
365.0	3894.6		-3502.9	×	1702.3	166.4	85.7818629	×	×	×	×
366.0	3875.4		×	-1818.9	1704.7	98.1	-0.0026949	×	×	×	×
367.0			×	×	1708.2	×	×	396.396	-0.085	0.092	1035.2
368.0	3816.4		×	-1781.1	1711.0	99.5	-0.0026218	×	×	×	×
369.0			×	×	1713.4	×	×	389.939	-0.094	0.073	1040.4

Solutions derived from the total field profile are designated as dike solutions and solutions derived from the horizontal gradient are designated as contact solutions. Dike and contact solutions are flagged in the *Dyke0_Cont1* channel by a "0" or "1" respectively. (Note that the flag values my conflict with the SI designation in the ExEuler method, but is consistent with the other methods in Depth to Basement. To separate dike and contact solutions (in the *Depth_sl* channel for example), select *Simple windowing* from the *PDepth* menu and use **0 - 0** for dike solutions or **1 - 1** for contact solutions. From there, select *Build solution channel* from the *PDepth* menu to generate a channel containing just dike solutions or just contact solutions.
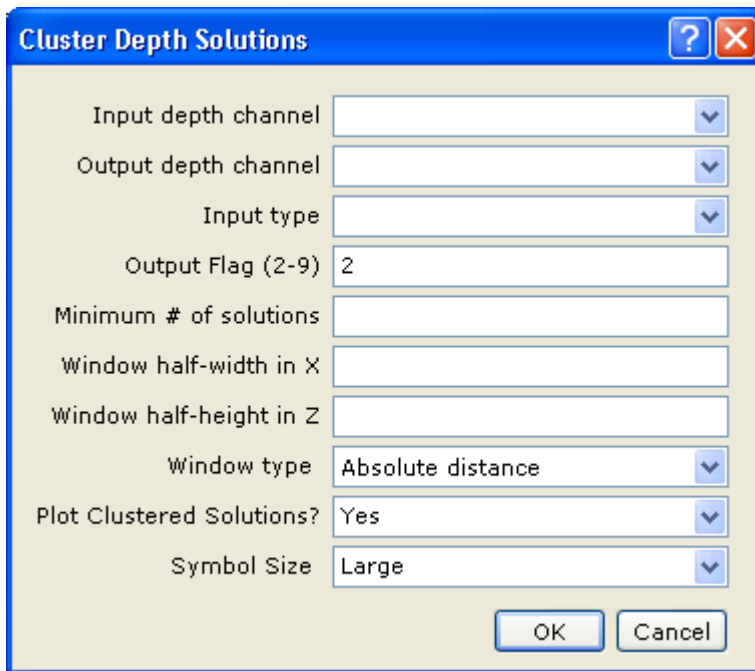
Clustering Solutions

The Depth to Basement methods usually generates a spray of solutions around the real solution due to multiple passes with different window lengths. It is often useful to collapse these groups of solutions into single, average solutions for plotting on maps or in cross sections.

TO CLUSTER SOLUTIONS:

1   From the *PDepth* menu, select *Cluster solutions*. The *Cluster Depth Solutions* dialog is displayed.

The clustered solutions are appended to the end of each selected line in the current database. The *Output Flag* parameter sets a new flag value for the clustered solutions. Existing solutions with the new flag value are deleted before the new clusters are generated. Assigning different output flag values can save more than one cluster run.

Set the *Minimum # of solutions* parameter to indicate how many solutions must be present within the window to generate a clustered solution.

Dike solutions and contact solutions must be clustered in separate runs. The user specifies a rectangular window around a solution by specifying the *Window half-width in* X and *Window half-width in Z*. The *Window type* parameter specifies whether these parameters are given in absolute distance units (e.g., meters or kilometres) or as a percentage of depth. The percentage of depth mode provides a mechanism for expanding the window for deeper solutions. The user also specifies a minimum number of solutions in the window to qualify as a valid cluster.

If you wish to plot the clustered solutions automatically in the database profiles, you may select "Yes" for the *Plot Clustered Solutions* parameter. You may also select the plotted *Symbol Size* parameter.
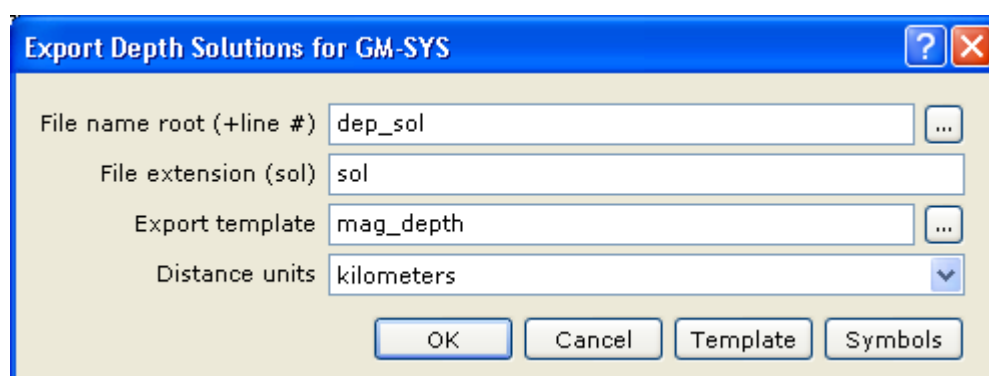
The number of solutions collapsed to form each cluster is saved in the *Window_Width* channel. Note that you can work with any distance unit (e.g., meters, kilometres, feet, etc.) as long as you are consistent. The X, Y, distance, and depth channels need to be in the same units. The input solution depth channel needs to be specified because there are two choices:

- *Depth_sl* - the depth referenced to sea level
- *Z_both* - the depth relative to the flight elevation

If you plan to export the solutions to GM-SYS, we suggest that you use *Depth_sl*.

Displaying Results in GM-SYS

To generate symbol files suitable for loading into GM-SYS models, make the solution database active and select *Export solutions to GM-SYS* from the *PDepth* menu.   This will generate a separate symbol file for each selected line in the solution database. You must enter a base file name and path. You may enter a file extension other than the default *.sol.

The line name is appended to the base file name. Note that the depths exported are those in the *Depth_sl* channel by default. If you want the clustered solutions exported, they need to be copied into the *Depth_sl* channel or you may make changes to the export template (the default template **mag_depth.o0** can be found in "*../Geosoft/Oasis montaj/etc/*") to output the appropriate channel.

TO GENERATE **GM-SYS** MODELS FROM THE PROFILE DATABASE:

1   From the *PDepth* menu, select *Export profiles to GM-SYS*. The *Create a GM-SYS models from all selected lines* dialog will be displayed.

Make sure the anomaly (not solution) database is the current database. This dialog will generate a separate GM-SYS model for each selected line in the database with the magnetic, topography, and gravity profiles. GM-SYS Profile will not be started automatically.

2   Open the imported model in GM-SYS.

You need to load the symbol file generated in the first step after opening the model in GM-SYS.

3   From the *Symbol* menu, select *Load/Config Symbols*.

Why Some Calculated Susceptibilities Are Large

If the *Field Strength* input is in nT units, the calculated susceptibilities for contact sources will be in cgs units. However, the susceptibilities calculated for the dike sources are effective susceptibility which is the cgs susceptibility multiplied by the dike width (in the input x,y length units).

For example, if you build a GM-SYS Profile model of a dike that is 100 meters wide, the effective susceptibility calculated by ExEuler will be 100 X the actual susceptibility if the distance units are in meters and 0.1 X the actual susceptibility if the distance units are in kilometres.

The interpreter can use the large susceptibility values for dike solutions in conjunction with the susceptibilities of nearby contact solutions as an indication of the width of dike-like features.   Unfortunately, using SI values for the Field Strength does not yield correct values for susceptibilities.

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References

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