



UNIVERSITY OF ALBERTA

MagMod V1.01 USER MANUAL

Any use of this software must refer:

Kravchinsky, V.A, Hnatyshin, D., Lysak, B., Alemie, W., 2019, Computation of Magnetic anomalies Caused by Two-Dimensional Structures of Arbitrary Shape: Derivation and Matlab Implementation. *Geophysical Research Letters* 46, 7345–7351, <https://doi.org/10.1029/2019GL082767>.

Last Update: June 30, 2020

The software is tested for Matlab versions 2015 – 2020.

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Introduction

Characterization of the subsurface is of fundamental importance to both geophysics and geology. Magnetic geophysics is one popular method in providing indirect information of the subsurface geology with both 3D and 2D being common for both academic and exploration studies. To help with the interpretation of magnetic anomaly maps and profiles we have developed a MATLAB based .exe software package (MagMod). This software is designed to allow a user to model arbitrary shaped 2D magnetic objects and compared to profiles obtained in a magnetic survey. The user can vary the number the number of objects as well as the shape to help match the observed profile.

In order to properly interpret magnetic anomalies within a magnetic survey a clear understanding of potential size and shape of their source(s) is required. While simple geometric shapes have relatively simple equations associated with them, modeling arbitrarily shaped magnetic sources efficiently requires extensive computation. Additional complications arise when numerous magnetic objects exist within a magnetic profile, each with its own unique magnetization. To deal with the complications of real world data we have developed a new software tool that is based on re-derived formulas from Talwani (1965). The formulas from Talwani (1965), slightly modified, have been implemented into an easy to use software package that is able to properly calculate the magnetic anomaly associated with any number or arbitrarily shaped objects. Within this software package the user can define each magnetic object by its induced magnetization, remnant magnetization, and magnetic susceptibility.

Intended Use and Limitations:

MagMod is intended to be used by academics, professionals, and students at a post-secondary level with some background in geology, geophysics, or related fields. As such, this document assumes a basic understanding of mathematics and

geophysics. The successful use of the program requires the user to input reasonable geological structures.

The software package was primarily developed to address the following questions:

1) What is the magnetic profile created by an object of a certain shape or size?

This is accomplished by allowing a user to creating a arbitrary shaped polygon through a point and click process or by creating an ellipse a through a click and drag mechanic. MagMod V1.00 with produce the predicted anomaly based on the users imputed magnetic parameters. This can be useful for getting a broad understanding of what sort of profiles different shapes create.

2) How many objects are required to produce a desired magnetic anomaly profile?

A user can import either a 2D magnetic profile or a magnetic anomaly map and then create a 2D transect from the imported map. The loaded profile can then be compared to the user created profile. Adjustments are then made manually in order to match the observed (imported) and predicted magnetic profile.


3) How does remnant magnetization change a magnetic profile?

Remnant magnetization is an often overlooked aspect of modeling magnetic profiles even though remnant magnetization is present in almost all rock and sediments. MagMod V1.00 allows the user to input the strength and direction of the net remnant magnetization for each object. The net magnetic anomaly is produced through the superposition between induced and remnant magnetization.

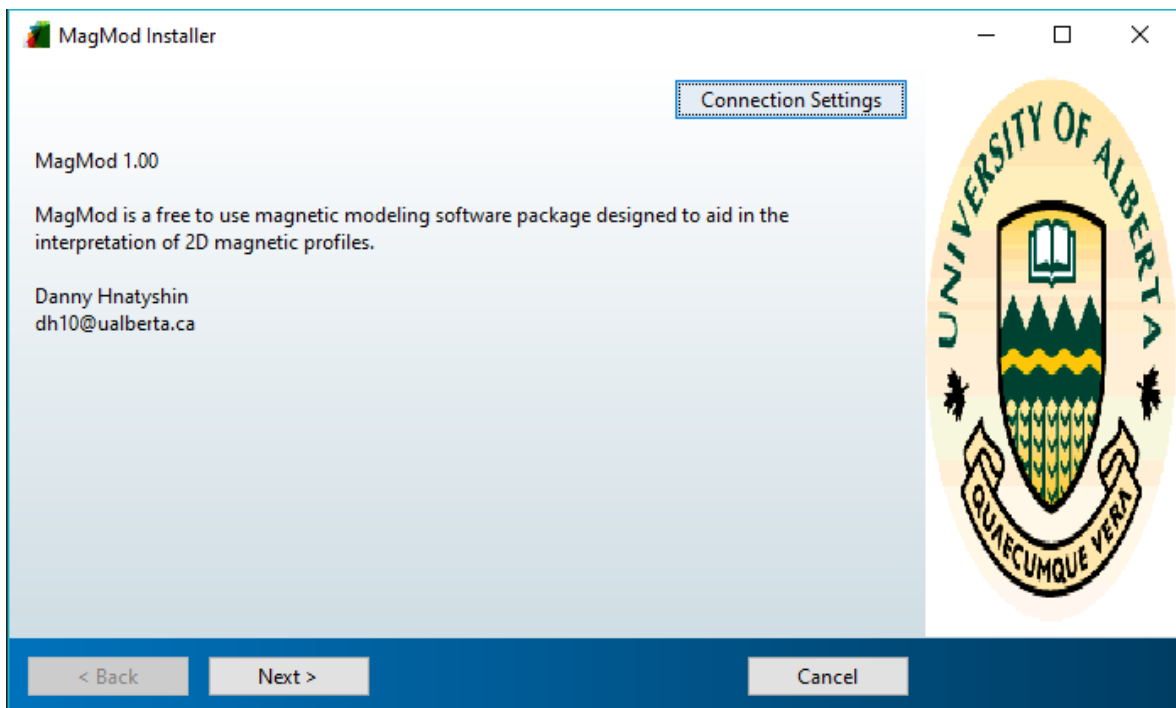
MagMod V1.00 is designed to replicate the magnetic anomalies associated with only 2D objects and therefore will have reduced effectiveness when complex 3D objects exist in the subsurface. However, for simple and relatively symmetric objects (e.g. dikes, kimberlites, spherical ore bodies) the 2D approach should be sufficient.

Installation:

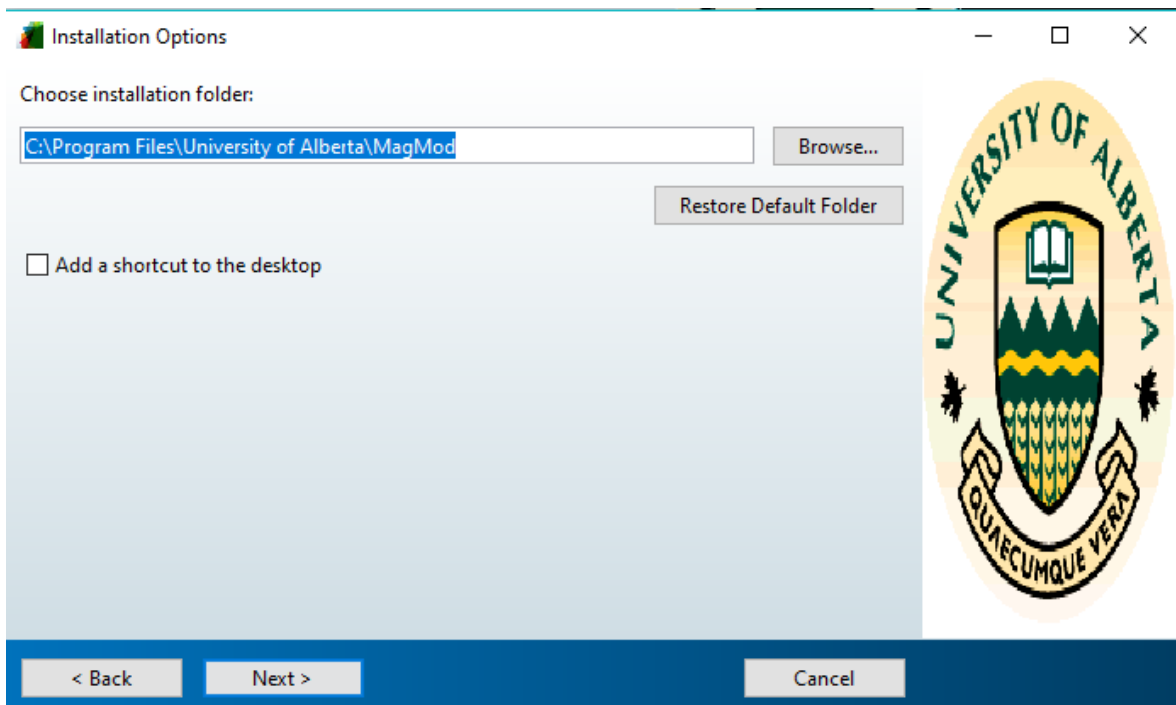
1) To install MagMod V1.00 open the "MyAppInstaller_mcr.exe file

Name	Date modified	Type	Size
 MyAppInstaller_mcr	10/4/2016 11:00 PM	Application	595,237 KB

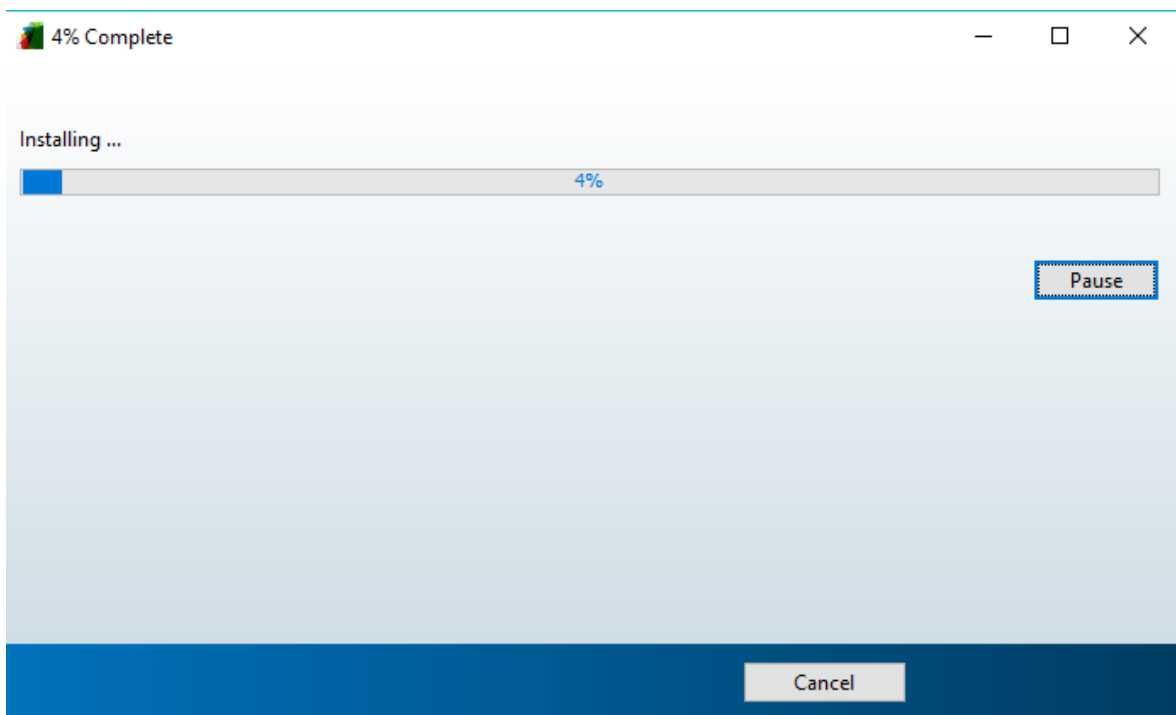
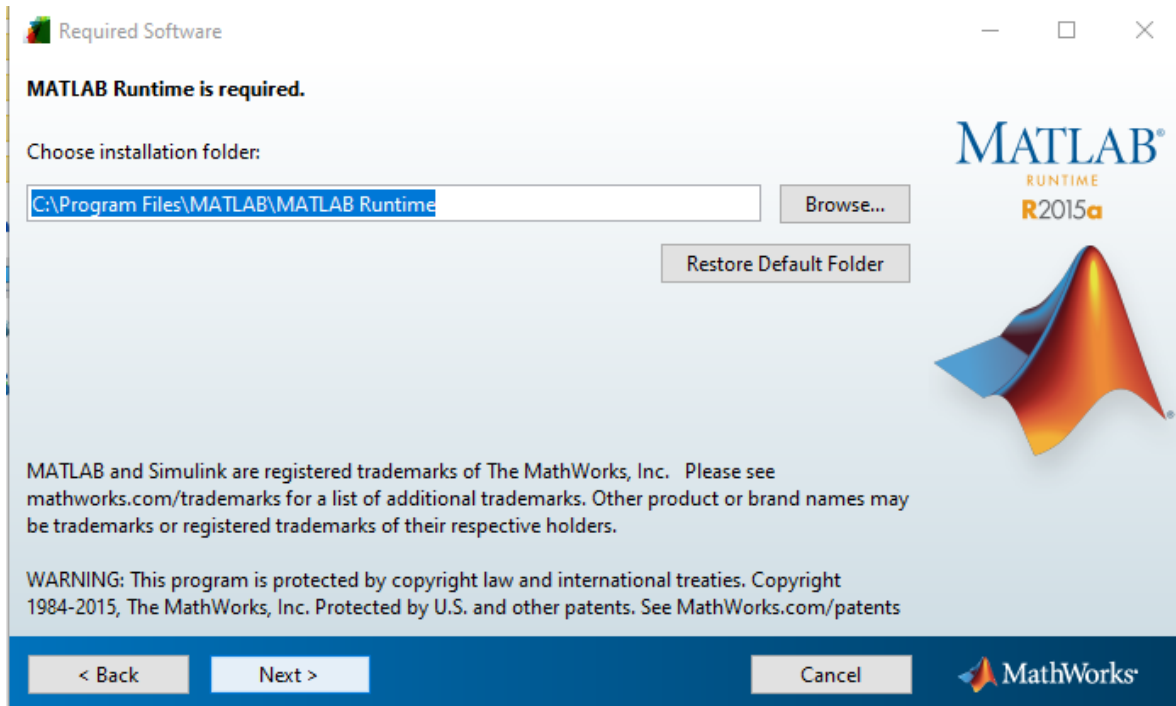
2) This will open up the following screen. Click "Next >"



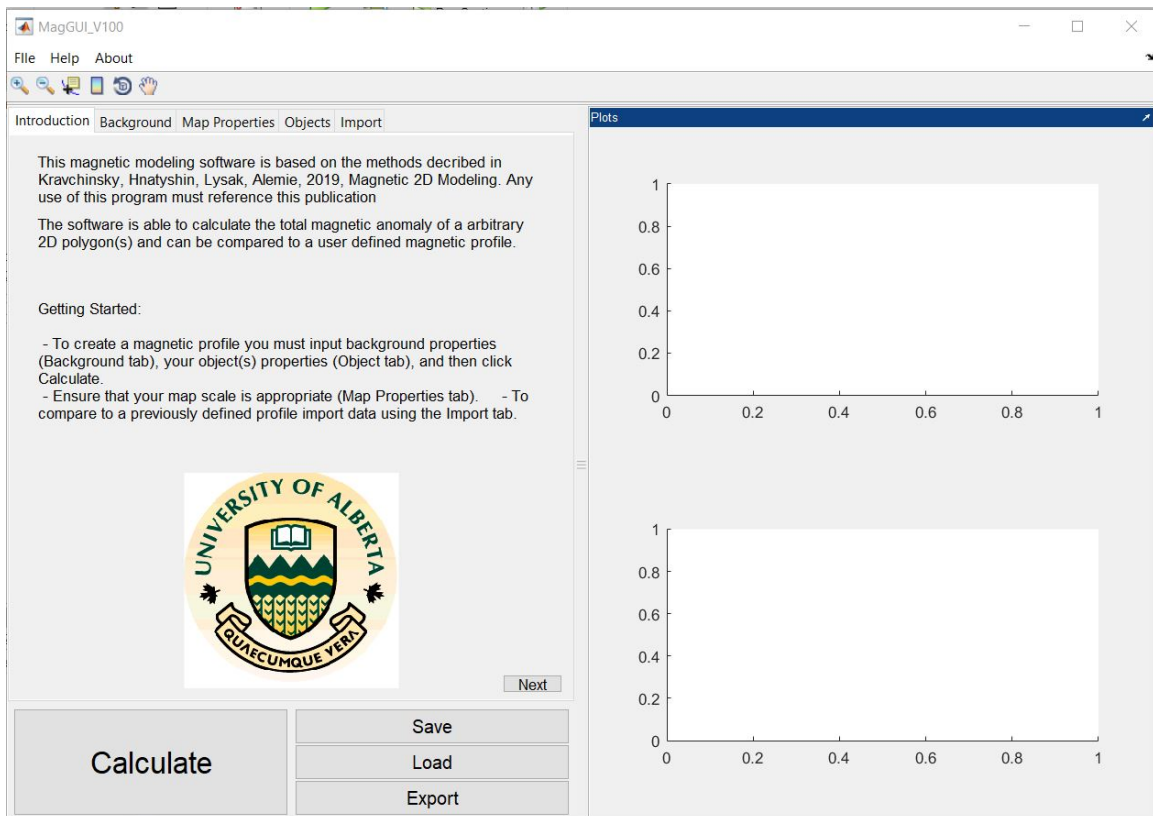
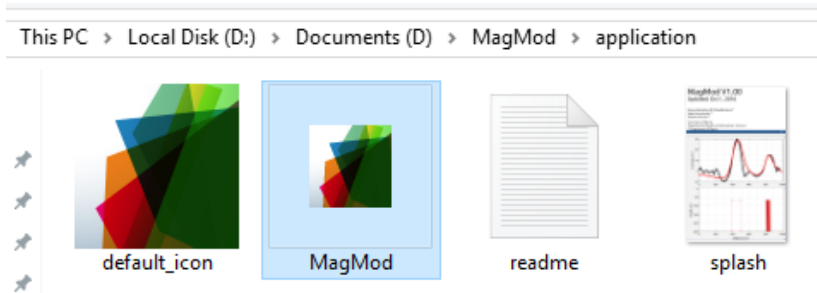
3) Choose the installation folder and click "Next >"



4) To proceed you will need to install MATLAB Runtime if it isn't already installed. If it is not installed the following screen will appear. Click "Next >" through the next few screens to install MATLAB Runtime and MagMod.



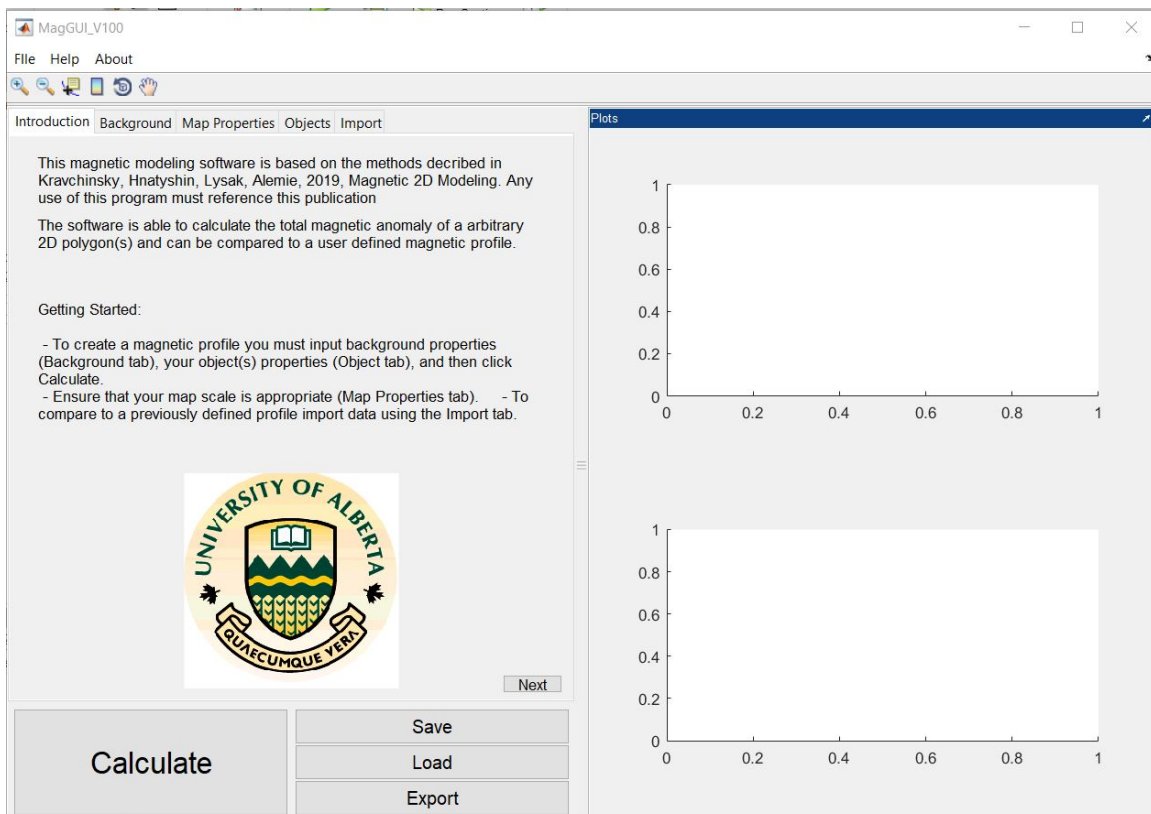
5) To Open MagModV1.00 go into the installation folder and into the application subfolder and open the file called MagMod. This should load the graphical user interface used in MagMod. See the tutorial section on how to use MagMod



Using MagMod V1.00

This section is intended to be an overview and tutorial of the features present in MagMod V1.00. This is a step-by-step guide of how to create and compare magnetic profiles as well as how to save and export any outputs created.

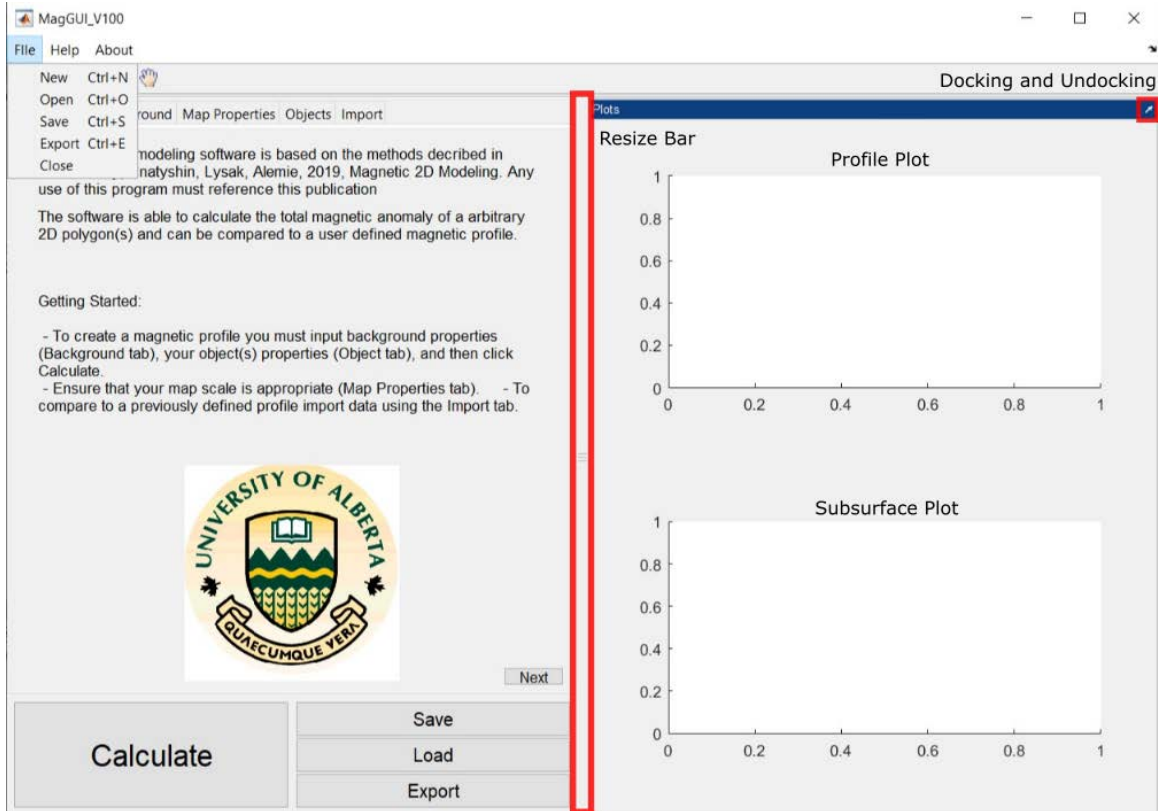
First open up MagModV1.00 and the graphical user interface (GUI) should load.

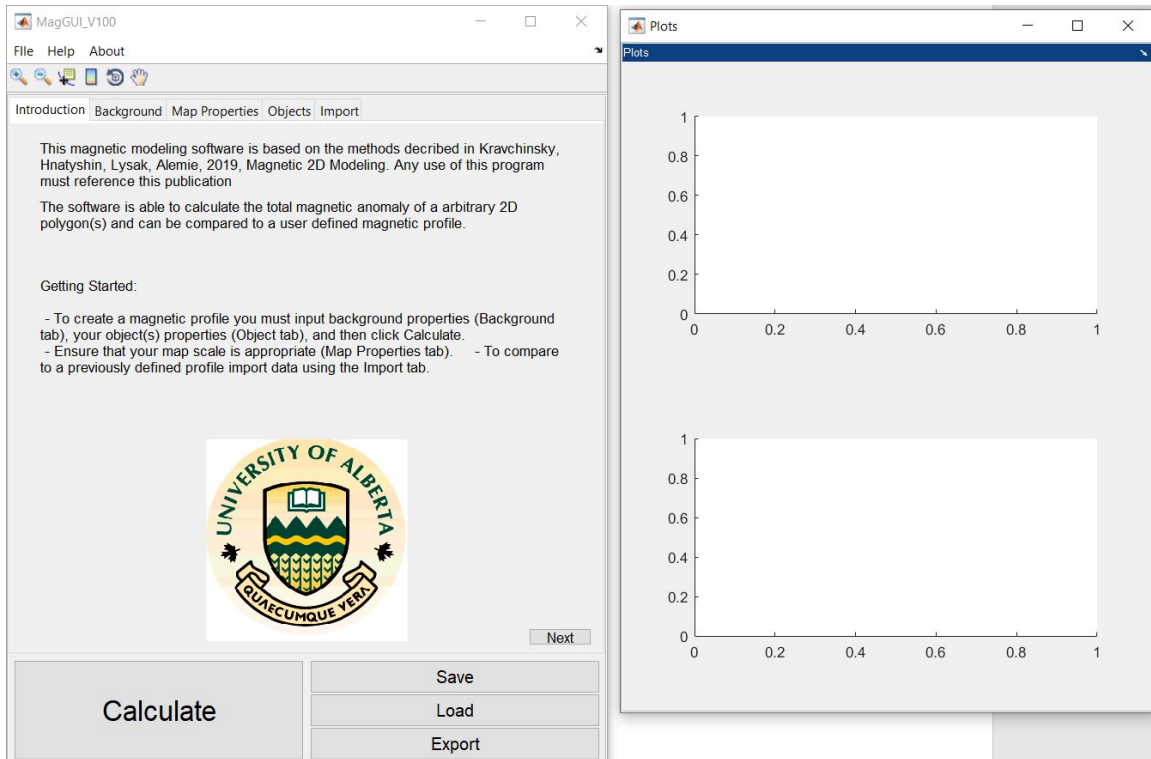


MagMod V1.00 is divided into separate tabs into two sections. The left side contains the Introduction, Background, Map Properties, Options, and Import tabs. While the right side contains plots associated with magnetic profiles and the subsurface.

Undocking and Resizing:

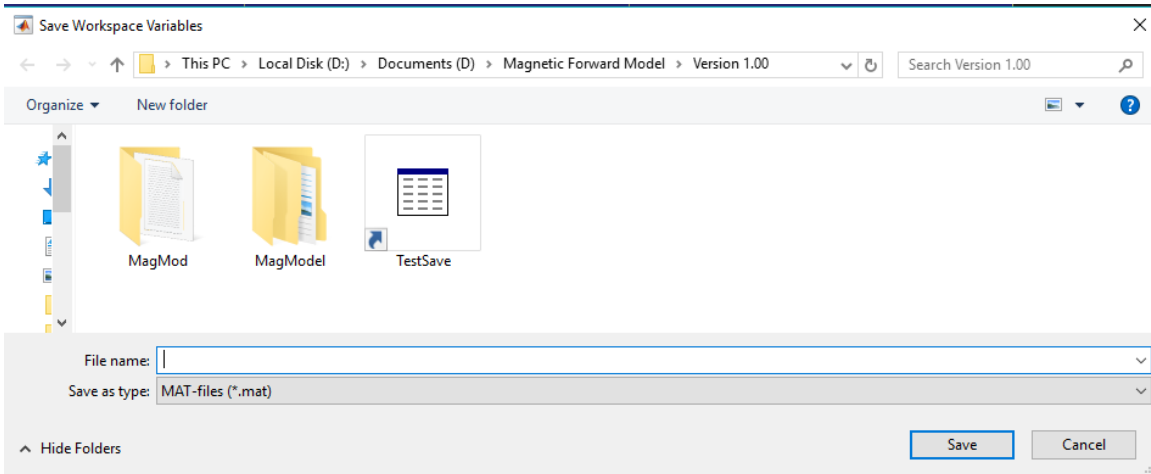
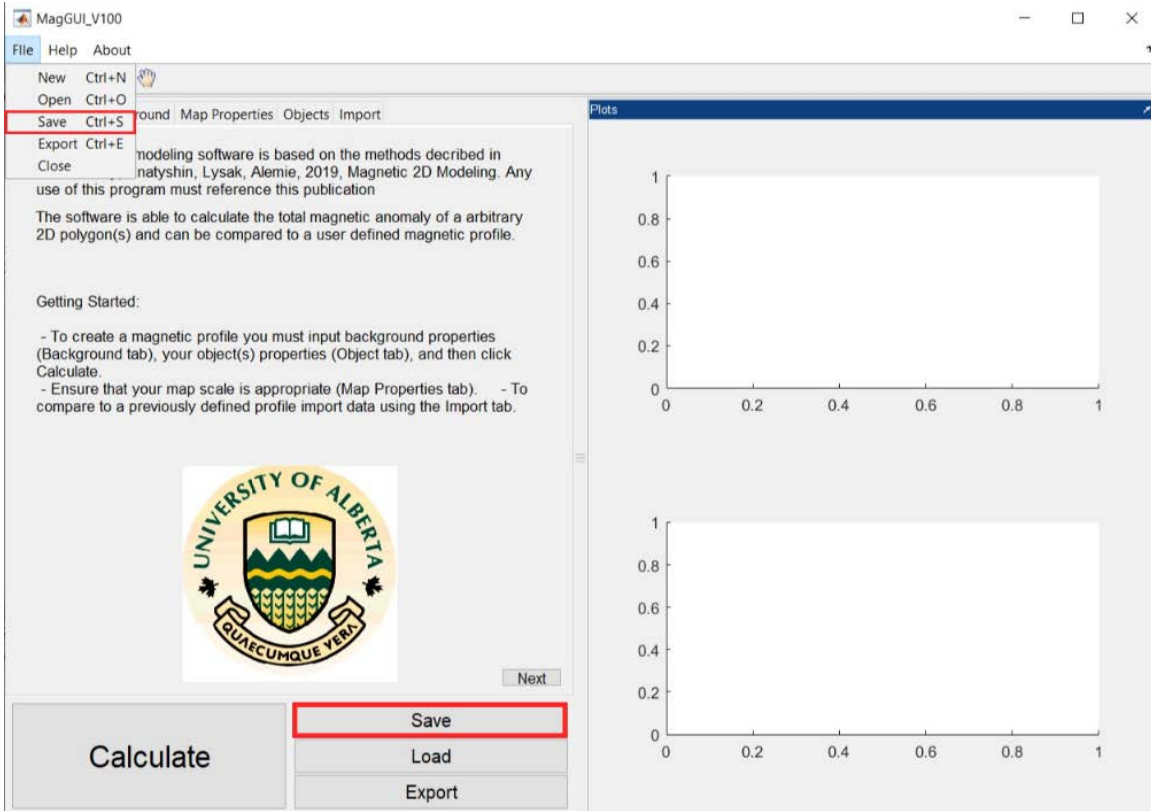
The left side tabs and the right side plots can be undocked from each other by clicking the arrow in the top right side of the GUI. The relative sizing between the tabs and plots can also be adjusted by dragging the divide between them.





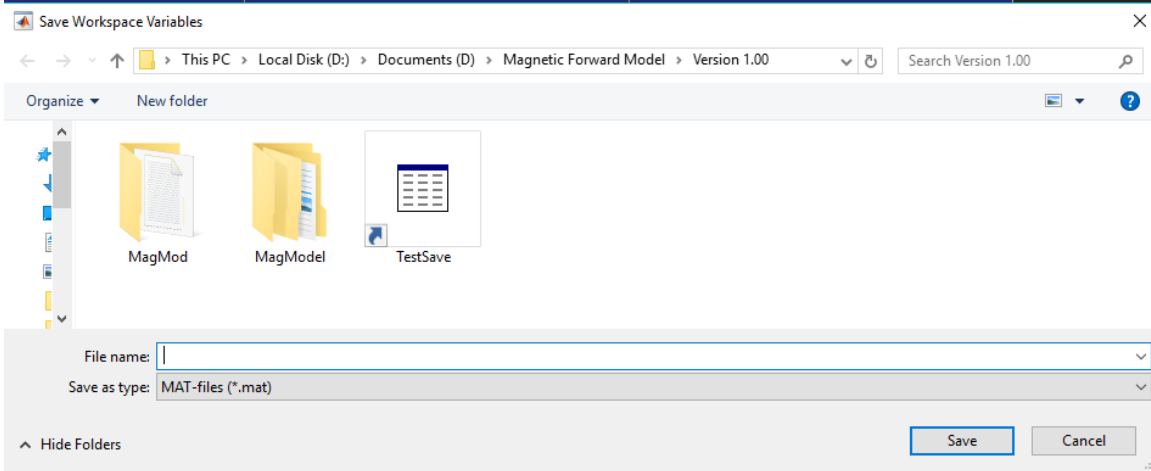
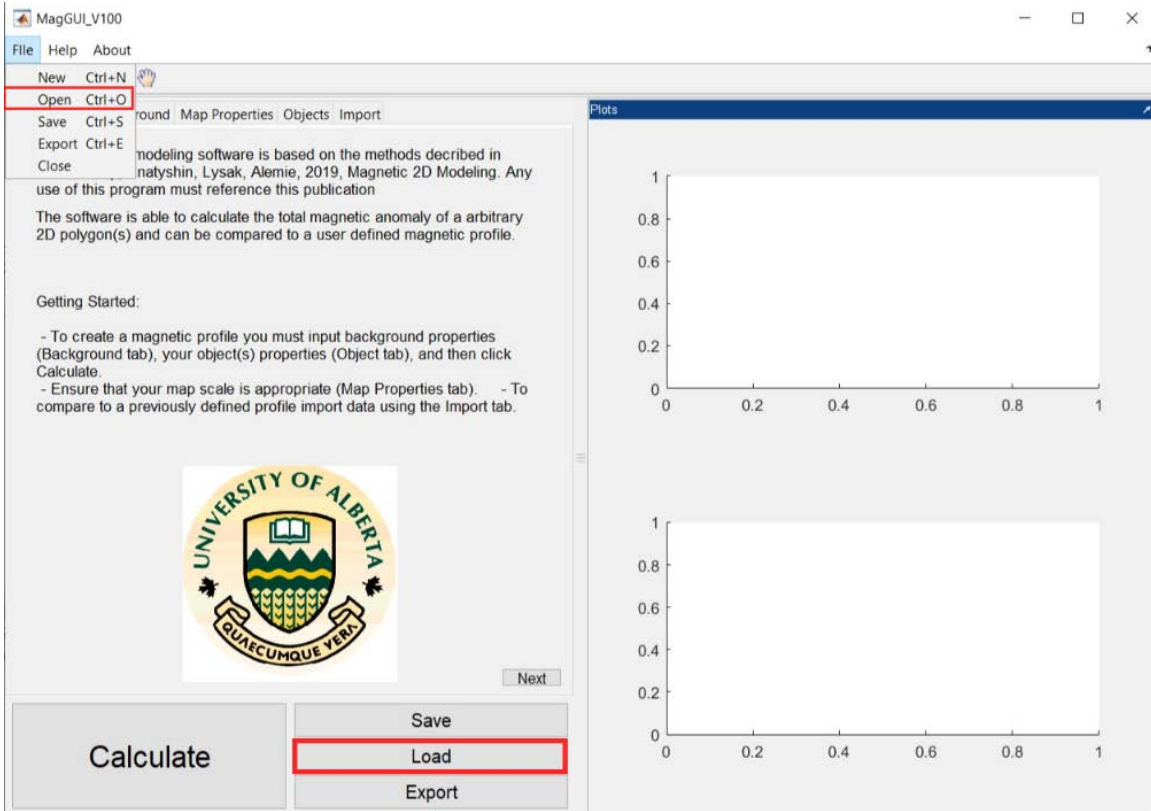
Saving Data:

To save a current project simple click on the "Save" button at the bottom of the GUI or go to File → Save

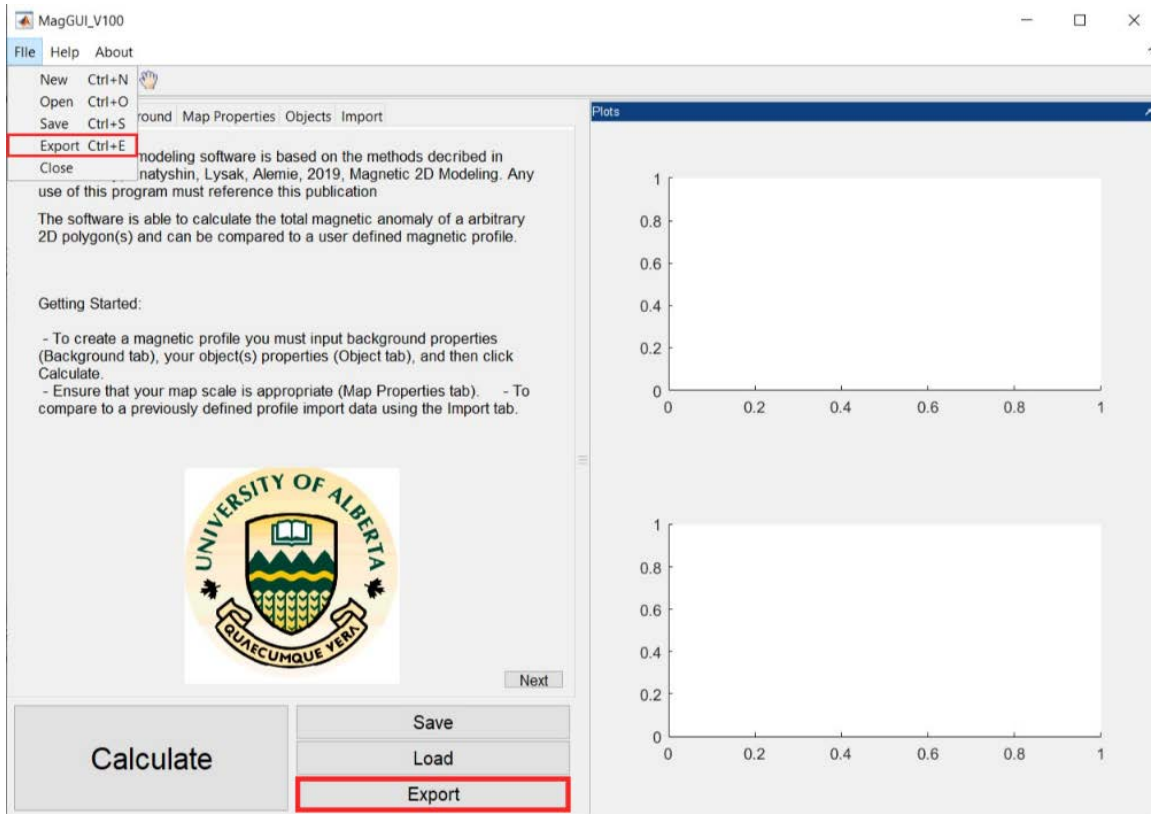


Loading Data

To save a current project simply click on the "Load" button at the bottom of the GUI or go to File → Open. Click on the .mat file that corresponds to the save file you would like to load.



Exporting Data



You can export much of the data you create or load into MagMod V1.00 into an Excel file *.xls file by clicking the "Export" button for by going File → Export.

The following data (when applicable) is exported into separate sheets within the .xls file.

Sheet Name: "Background data"

- Contains all data inputted into the "Background" tab.

Sheet Name: "Map data"

- Contains all data inputted into the "Map" tab.

Sheet Name: "Object data"

- Contain all data inputted into the "Objects" tab.

Sheet Name: "X object's position data"

- Contains the positional data for the user created subsurface object X (created in the "Objects" tab and plotted in the Subsurface Plot). Each object is given its own sheet.

- If the object is a polygon the exported is the vertices of the polygon.

- If the object is a ellipse the exported is the 100 data points used to define the ellipsoidal shape.

Sheet Name: "Map Profile Location"

- If a map profile was imported and a magnetic anomaly profile was created from the map (See tutorial) the start and end x-y coordinates (in m's) of the profile are exported into this sheet.

Sheet Name: "Map Profile Data"

- This is the magnetic profile data (in nT) created by the user defined objects.

Sheet Name: "Imported Profile Data"

- This is the magnetic profile data (in nT) imported into MagMod.

Sheet Name: "Map Data Grid Bounds"

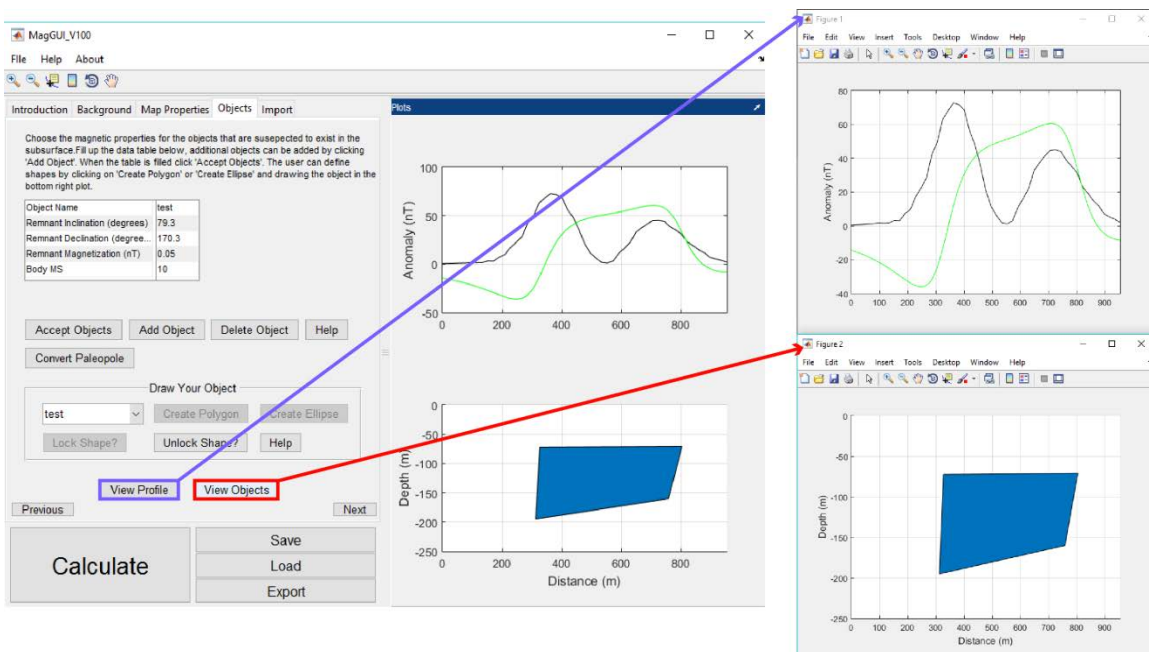
- If a user imported a magnetic anomaly map these are the bounds inputted by the user for this map.

Sheet Name: "Map Data Grid (nT)"

- If a user imported a magnetic anomaly map this is the anomaly data associated with the map in grid format.

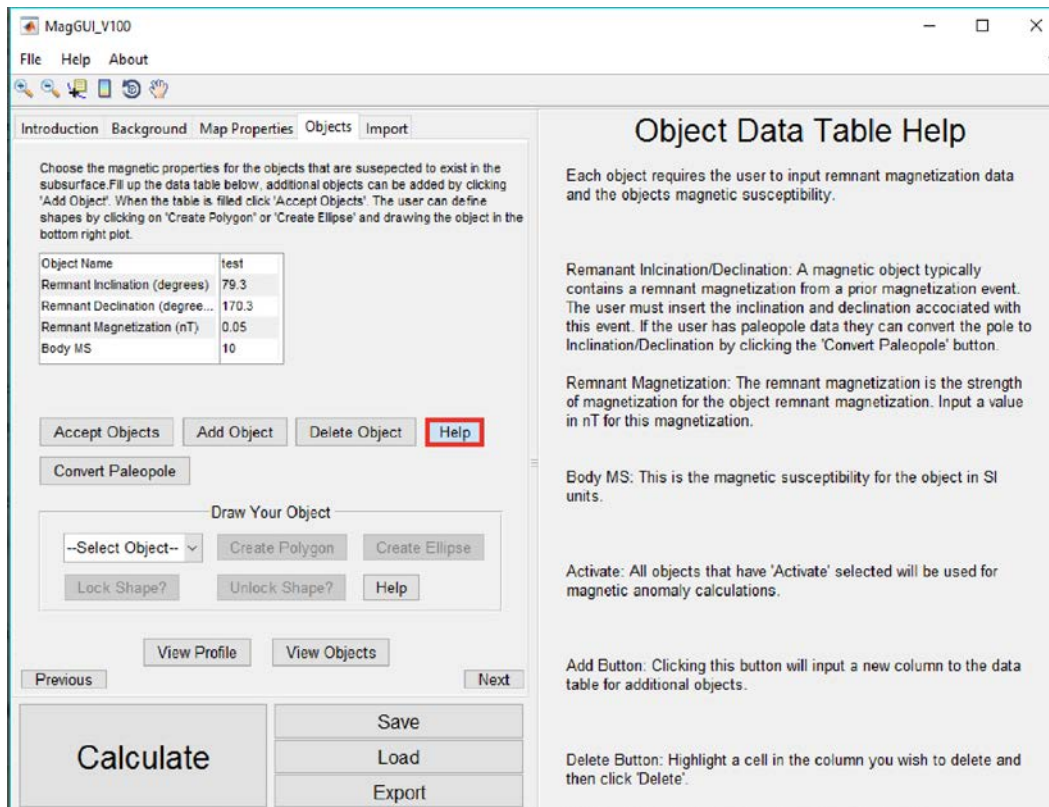
Saving and Modifying Figures

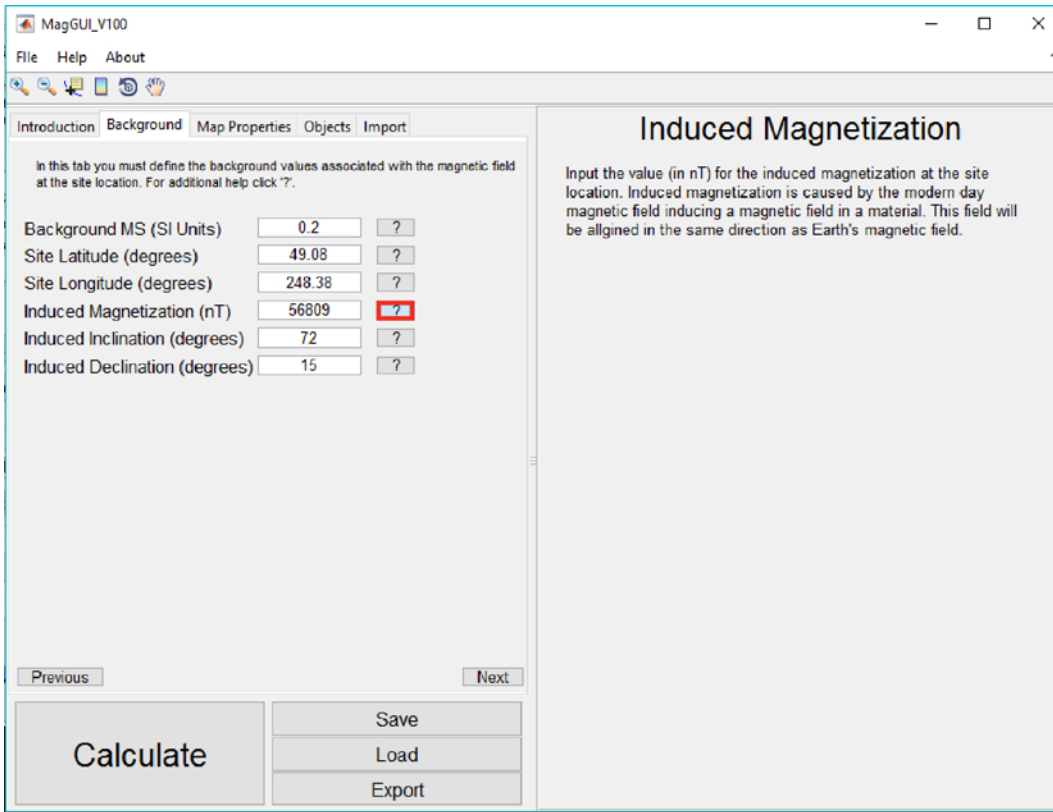
All plots and imported figures can be modified and then saved into a variety of formats (e.g. .pdf, .png, tiff, jpg, ect...) by clicking on the corresponding "View" button. This opens up the figure into a separate window where a variety of options can be modified (e.g. grid lines, colour bars, line width, ect...). The figure can then be save by going to File → Save As.



Help with Function

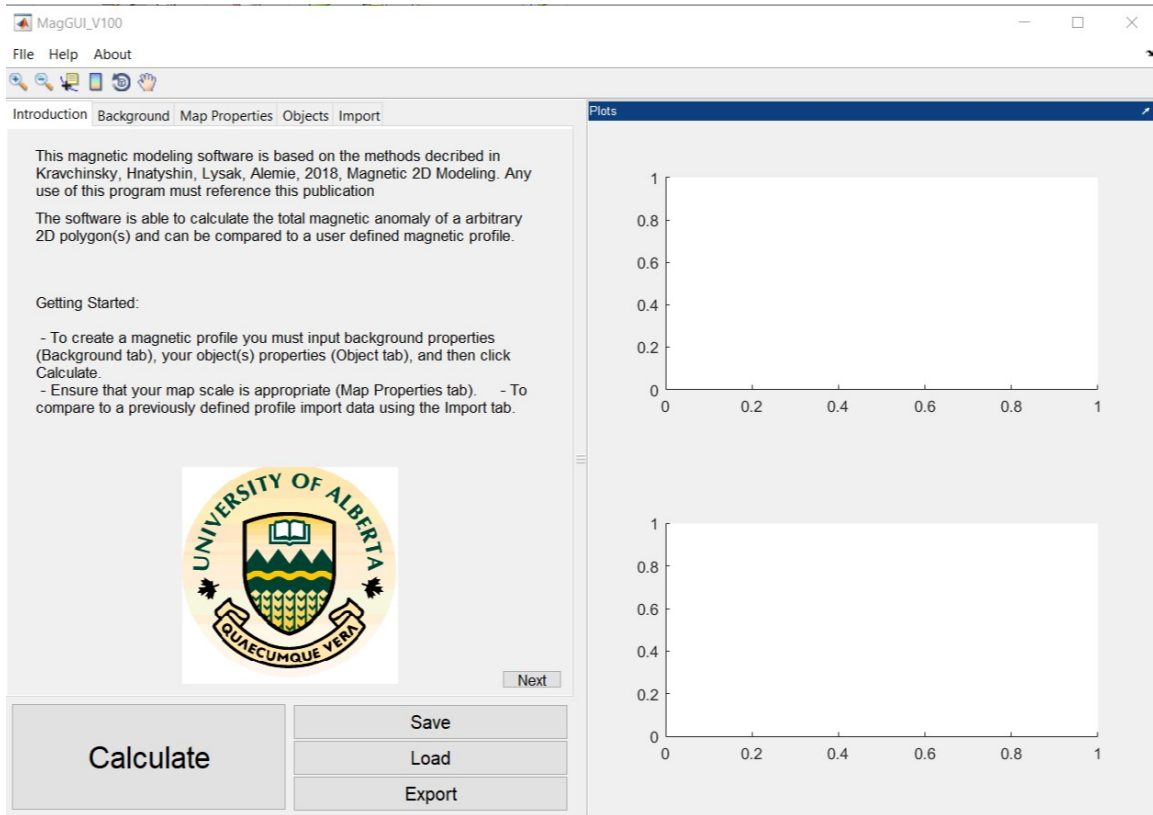
The user can open up the User Manual by going to Help → Export. However, for quick help many functions and tabs have a "Help" or "?" button. By clicking these buttons a side window with a short explanation of the function or variable in question will pop up. Click the button again to close the window.





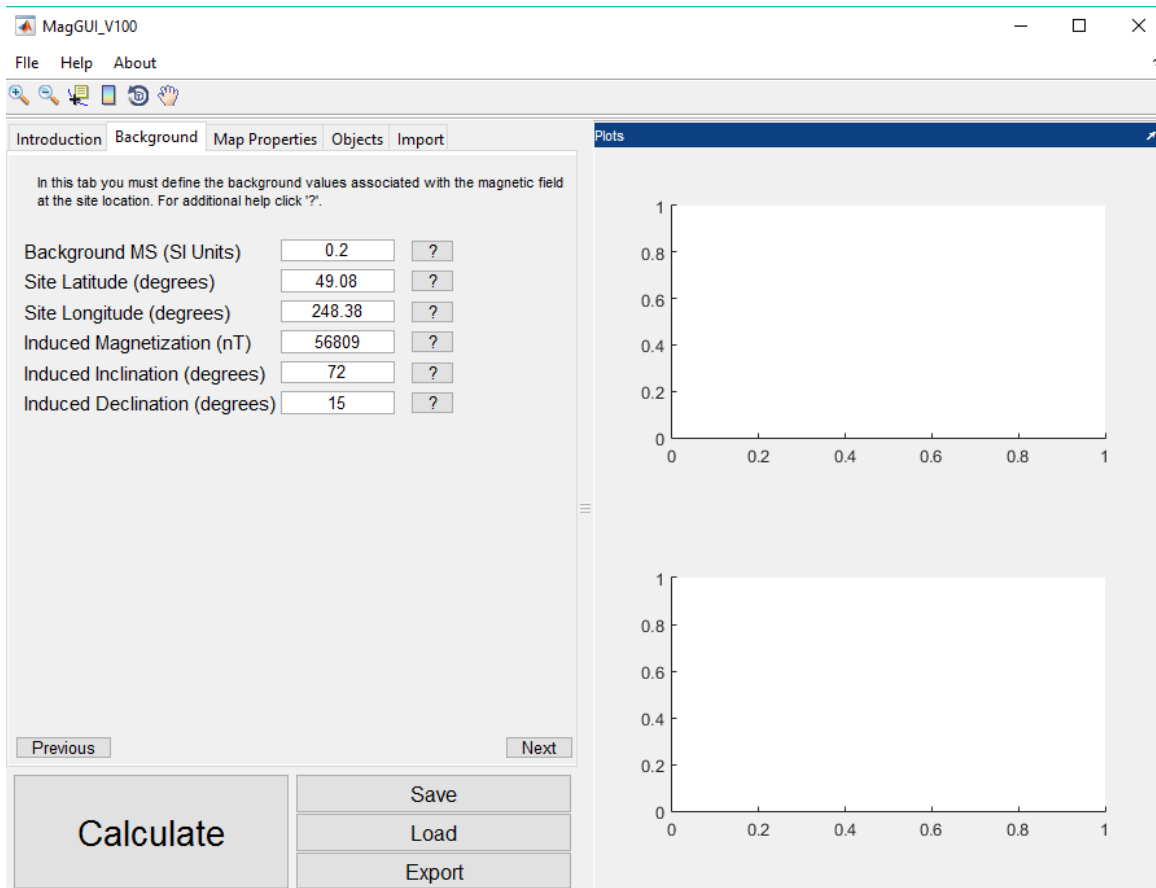
Tab Layout

Introduction Tab:



The "Introduction" tab contains basic information on how to get started. To move to the Background tab either click the tab or click the "Next" button.

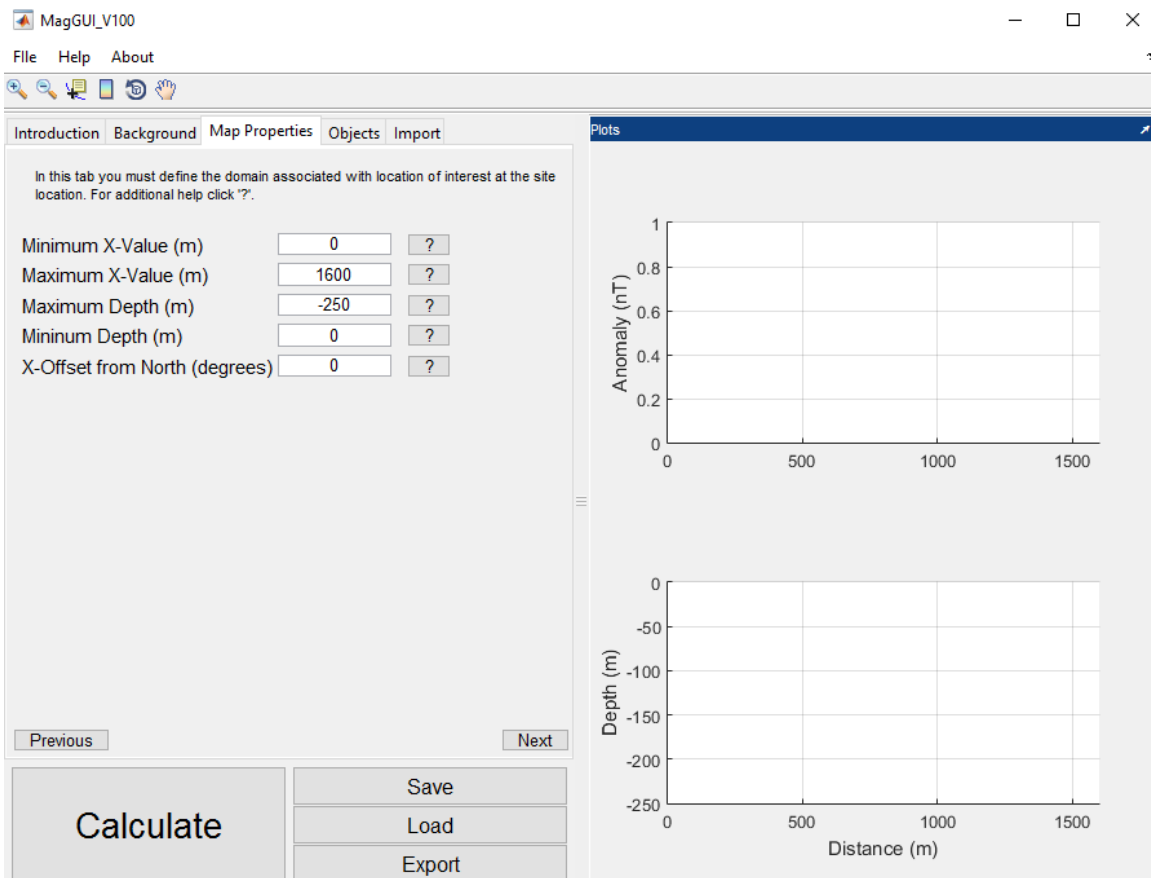
Background Tab:



The "Background" tab contains all the inputs required to describe the location of the survey. This includes the site latitude, site longitude, induced magnetization, inclination, and declination.

The site latitude/longitude should be the value at the center of the profile. The induced magnetization should be the value of the Earth's magnetic field at the site location. The inclination and declination are the values for the site location.

Map Properties Tab:



The "Map Properties" table sets the domain for the profile used in MagMod. Any imported profile will automatically update the "Minimum X-Value", "Maximum X-Value". Map profiles will also adjust the "X-Offset from North" value to the orientation of the loaded profile

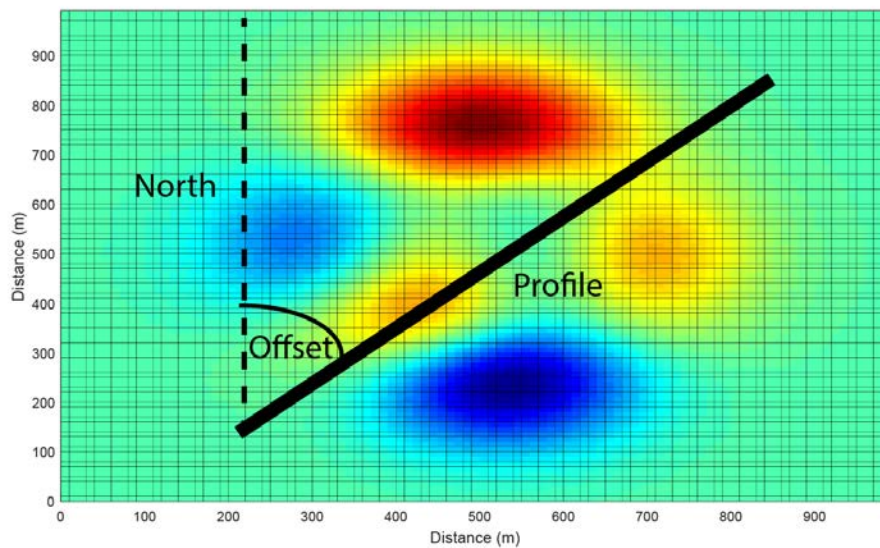
Minimum X-Value: Defines the left boundary for any calculated profile and adjusts both the profile and subsurface plot accordingly.

Maximum X-Value: Defines the right boundary for any calculated profile and adjusts both the profile and subsurface plot accordingly.

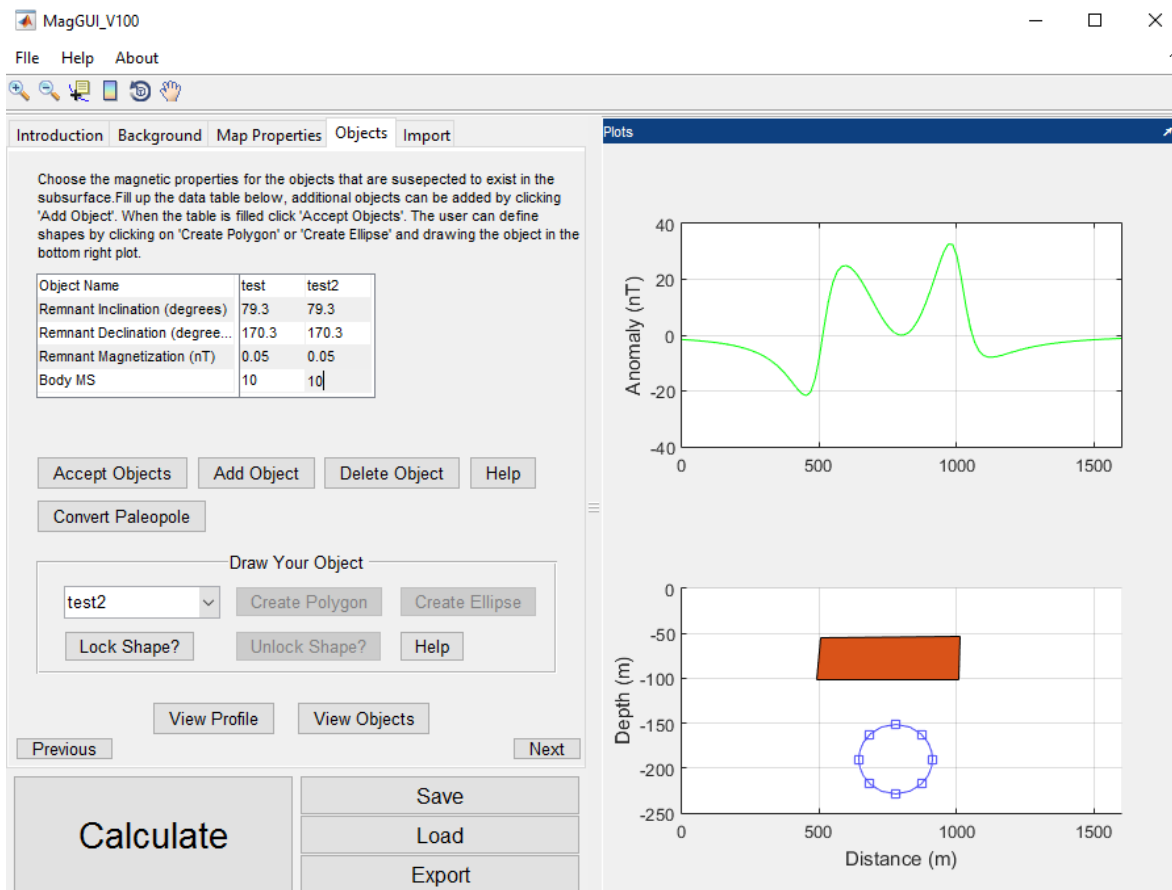
Maximum Depth: Defines the maximum depth shown in the subsurface plot. This should be of sufficient depth to fit any user created objects.

Minimum Depth: Defines the minimum depth shown in the subsurface plot. This should be of sufficient depth to fit any user created objects.

X-Offset from North: This value defines the orientation of the magnetic anomaly profile. For example a S-N orientation should have a offset of 0° while a W-E profile will have a offset of 90° .



Objects Tab:



In the "Objects" tab the user is required to create the magnetic objects responsible for a magnetic anomaly. The user does this by inputting the proper remnant magnetization data for their object(s) into the data table. **The name for each individual object must be unique.**

The user can add additional objects by clicking the "Add Object" button. The user can delete objects by highlighting a cell in the column of the object that they wish to delete and then click the "Delete Object" button.

Once the user is happy with the data table they click "Accept Object" which will populate the popup menu in the "Draw Your Object" panel. For each object the user must either create a polygon or ellipse.

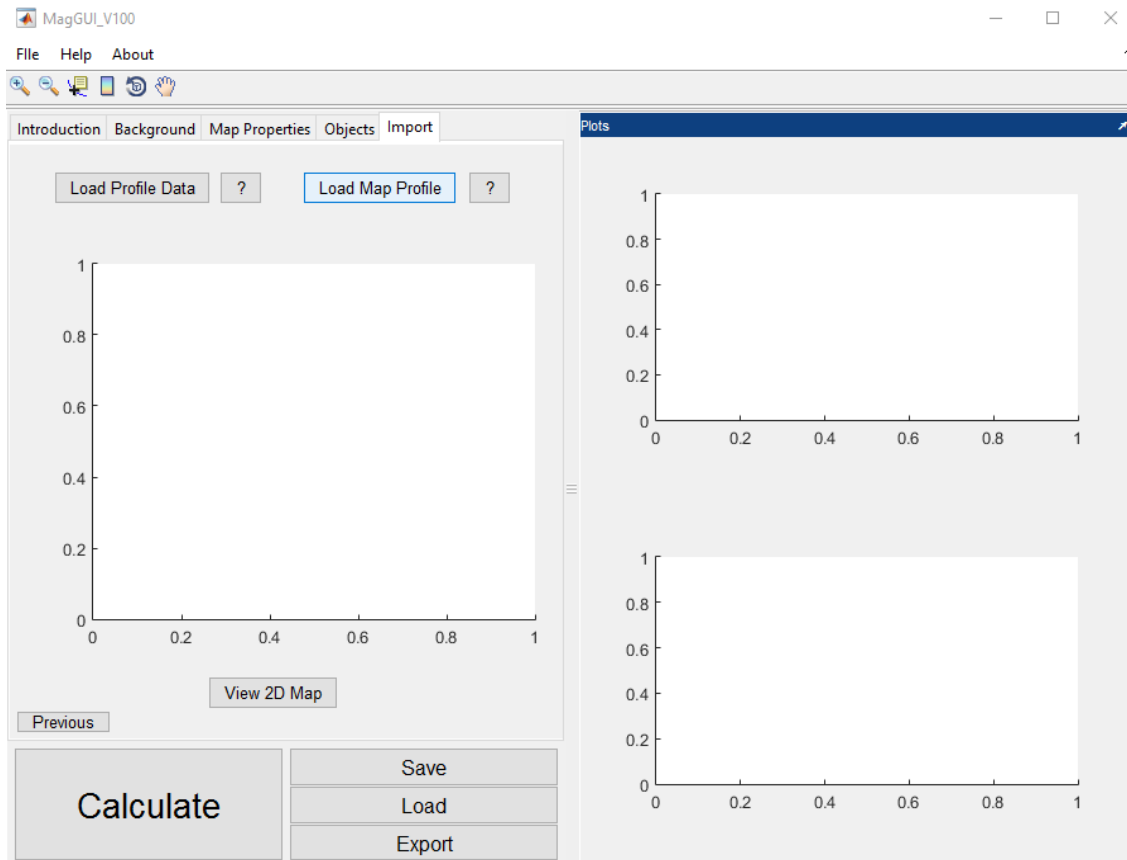
Upon clicking "Create Polygon" or "Create Ellipse" the user will pick a colour for the object (e.g. orange for the rectangle in the above figure). **For a polygon the user clicks in the subsurface plot (bottom plot) at the location of each vertex in a clockwise fashion.** To close the polygon either double click or click the starting vertex a second time. For an ellipse the user will drag the ellipse into the shape and size desired. The created ellipse is defined by 100 data points.

The "Unlock Shape" button allows the user to manipulate their shape after it has been created (e.g. the circle in the previous figure).

The "Lock Shape" button freezes the shape in place (e.g. the orange rectangle in the previous figure).

Clicking "Calculate" will produce the predicted anomaly from the shapes inputted by the user. **Before clicking "Calculate" ensure that you have fill out the data table correctly and have drawn the correct shape for each object!**

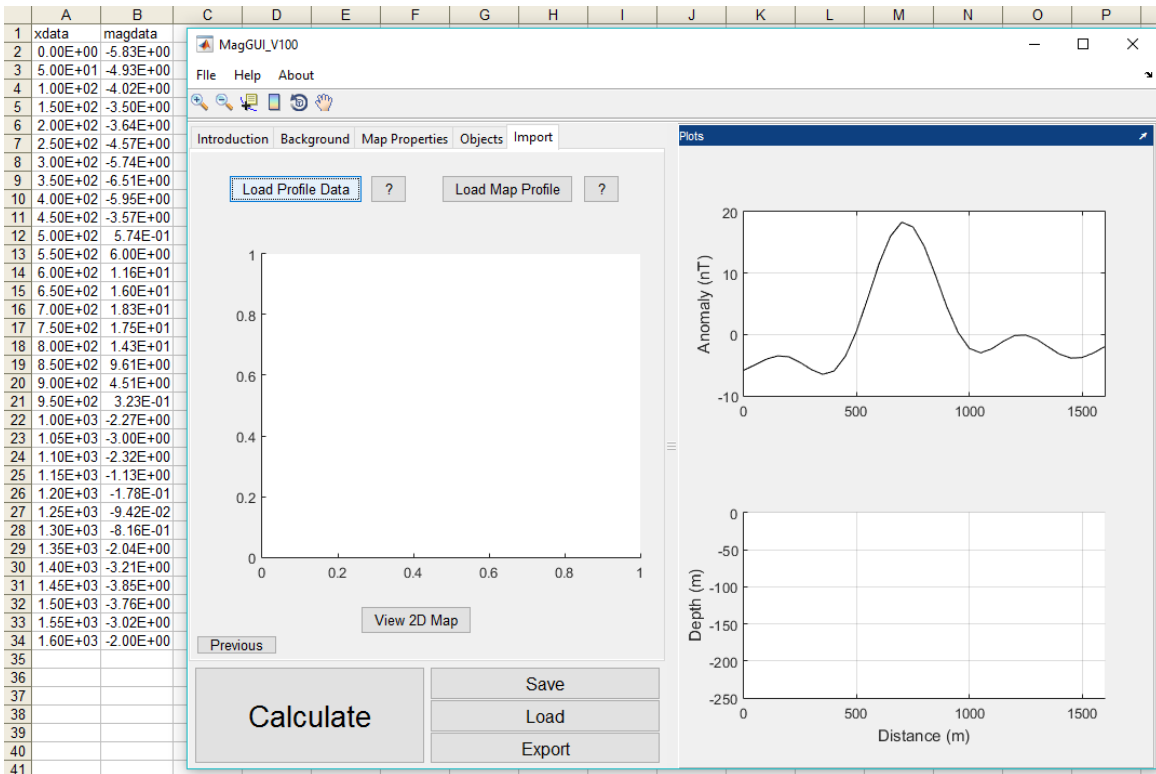
Import Tab:



The "Import" tab allows the user to either load a 2D magnetic profile ("Load Profile Data") into the profile plot or to load a magnetic anomaly map ("Load Map Profile") from which a profile can be created. These profiles must be in a .xls or .xyz format using UTM coordinates (use example spreadsheets as a template or see the figures below) to be loaded properly.

Loading 2D Profiles:

If the user loads a 2D profiles by clicking the "Load Profile Data". The profile is plotted into the profile plot (top plot). See the following figure for the proper .xls template and the output created.



Loading Map Profiles:

If the user has a magnetic anomaly profile map available they can load it into MagMod V1.00. The proper template is as follows (see example map profiles as well). The spreadsheet should contain magnetic anomaly values in nano-tesla to work properly, with each cell corresponding to a data point in x-y space.

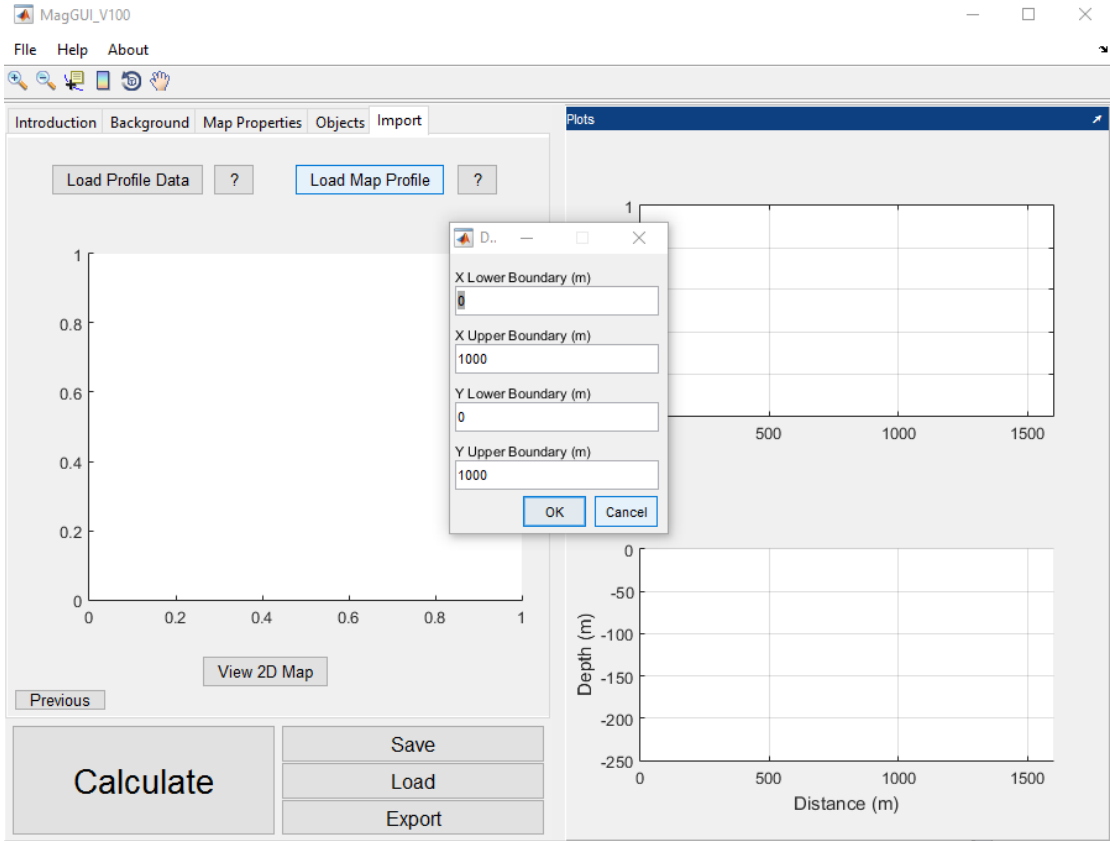
Microsoft Excel - MapExample1

File Edit View Insert Format Tools Data Window Help

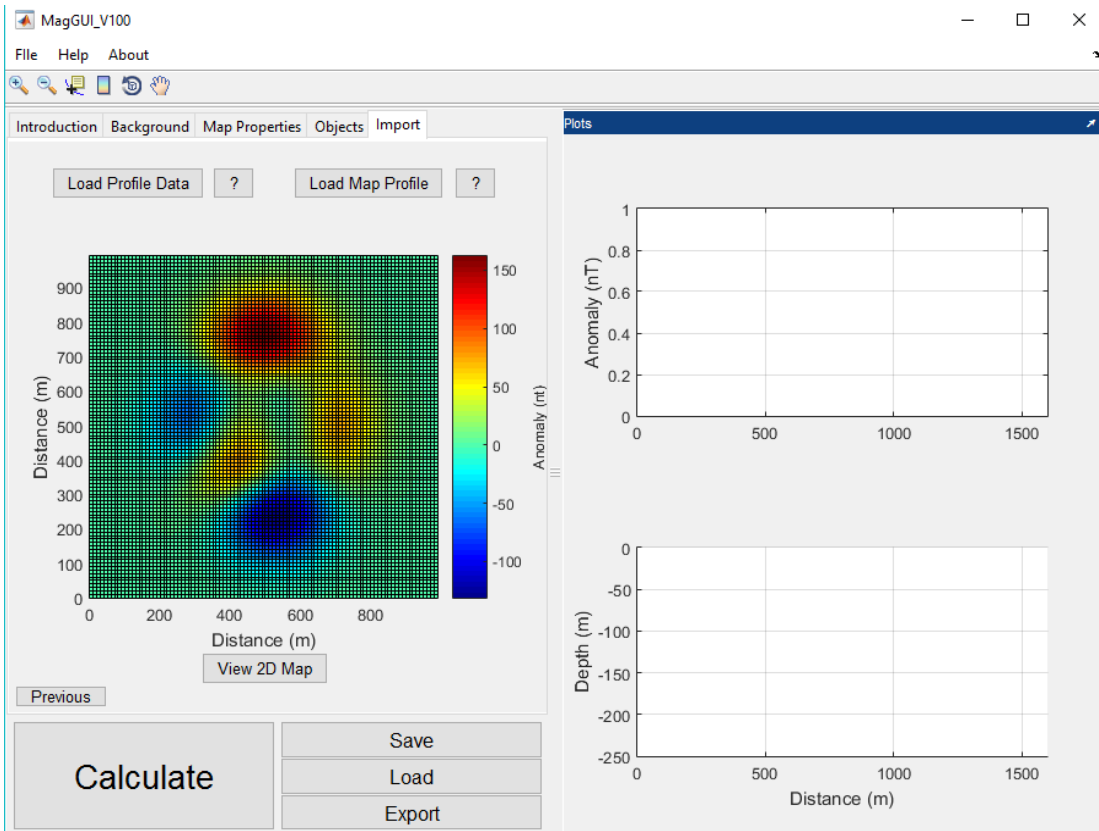
A1 fx 0.00133425605934349

	A	B	C	D	E	F	G	H	I	J	K
1	0.001334	0.001828	0.002483	0.003341	0.004455	0.005885	0.0077	0.009977	0.012801	0.016257	0.02043
2	0.00166	0.002274	0.003088	0.004153	0.005536	0.007308	0.009557	0.012375	0.015864	0.020128	0.025268
3	0.00205	0.002807	0.00381	0.005123	0.006826	0.009008	0.011773	0.015235	0.019516	0.024741	0.031027
4	0.00251	0.003437	0.004664	0.006271	0.008353	0.011019	0.014394	0.018618	0.023834	0.030191	0.037829
5	0.003049	0.004175	0.005666	0.007616	0.010142	0.013376	0.017468	0.022584	0.028896	0.03658	0.045799
6	0.003673	0.005031	0.006827	0.009177	0.01222	0.016114	0.02104	0.027193	0.03478	0.044008	0.055064
7	0.004388	0.006012	0.008159	0.01097	0.014608	0.019264	0.02515	0.032501	0.041561	0.05257	0.06575
8	0.005197	0.007123	0.009671	0.013006	0.017324	0.022849	0.029835	0.038557	0.049303	0.062356	0.077974
9	0.0061	0.008366	0.011364	0.015292	0.020377	0.026886	0.035117	0.045395	0.058058	0.073439	0.091836
10	0.007094	0.009736	0.013236	0.017823	0.023766	0.031376	0.041005	0.053033	0.067857	0.085868	0.107415
11	0.008168	0.011222	0.015273	0.020585	0.027474	0.036304	0.047484	0.061461	0.0787	0.09966	0.12475
12	0.009306	0.012804	0.017449	0.023549	0.031468	0.041631	0.054513	0.070637	0.090546	0.114781	0.143826
13	0.010483	0.01445	0.019725	0.026664	0.035688	0.047285	0.06201	0.080469	0.103299	0.131134	0.164554
14	0.011662	0.016111	0.022042	0.029857	0.040042	0.053159	0.069846	0.090808	0.116789	0.148537	0.186745
15	0.012794	0.017726	0.024317	0.033026	0.044403	0.059093	0.077831	0.101429	0.130757	0.166697	0.210079
16	0.013814	0.019209	0.026442	0.036031	0.048597	0.064874	0.085701	0.112016	0.14483	0.18518	0.234068
17	0.014639	0.020451	0.028277	0.038692	0.052397	0.070216	0.093106	0.122143	0.158496	0.203388	0.25802
18	0.015166	0.021319	0.029645	0.040784	0.055513	0.074757	0.099594	0.131252	0.171082	0.220514	0.28099
19	0.015271	0.021645	0.030332	0.042027	0.057588	0.078041	0.104595	0.13864	0.181724	0.235518	0.30174
20	0.014804	0.021235	0.030078	0.042085	0.058188	0.079516	0.107412	0.143434	0.189349	0.247089	0.318694
21	0.013592	0.019857	0.028579	0.04056	0.056799	0.078523	0.107207	0.144585	0.192649	0.253623	0.329901
22	0.011438	0.017246	0.025486	0.036993	0.052825	0.074295	0.103001	0.140853	0.190076	0.253198	0.333007
23	0.008121	0.013108	0.020405	0.030867	0.045589	0.065954	0.093671	0.130811	0.179831	0.243576	0.325247
24	0.003397	0.007115	0.012903	0.021608	0.034341	0.052527	0.077959	0.112853	0.159882	0.222203	0.30345
25	-0.00299	-0.00108	0.002514	0.008599	0.018267	0.03295	0.054493	0.085217	0.127986	0.18625	0.264072

If the user loads a map profile by clicking the "Load Map Profile" they are asked what the dimensions of the plot are in meters. The X-boundaries correspond to the east-west domain and the Y-boundaries correspond to the north-south domain. This will then set the x-y position for each data point in the loaded from the spreadsheet.

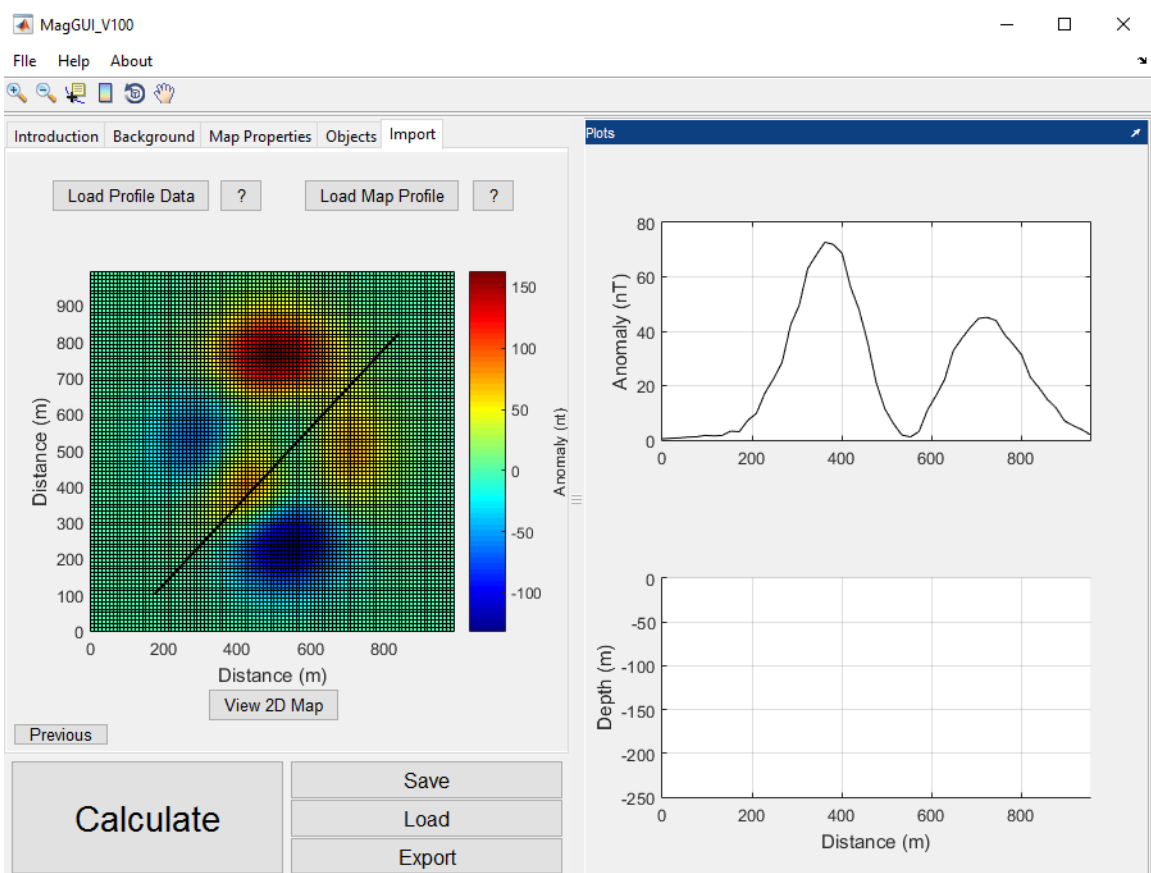


The profile is then loaded into the left-hand panel.



The user clicks and drags across the map profile to get a magnetic anomaly plotted into the profile plot (top plot). If you want S-N profile, the first point on the profile should be the most southern point. Then move the line towards the North. The X-Offset from North will be 0°. If you move your profile from the north to the south (The X-Offset from North will be 180°), then 'drag' the line from the north to the south.

The "Map Properties" are automatically updated when the profile is created.

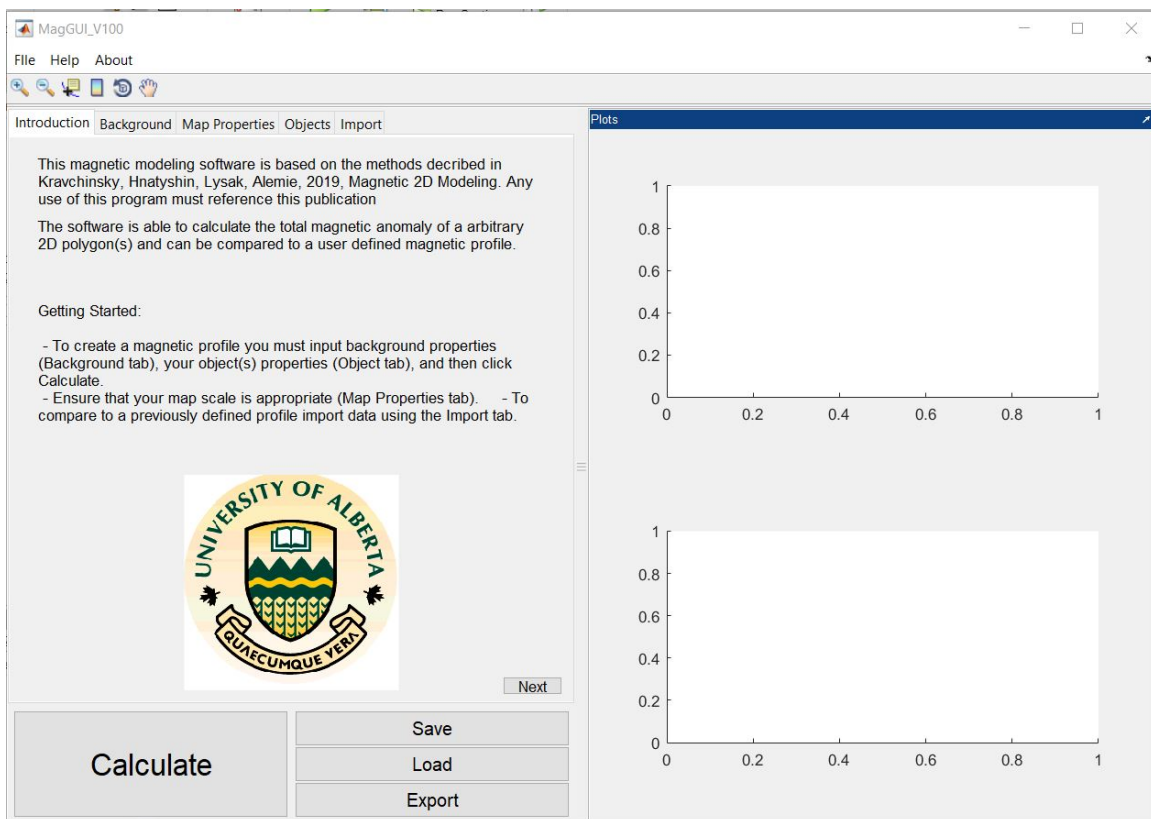


Tutorial

Consider that you have a dataset that contains magnetic anomaly data and you want to determine the shape and location of subsurface objects that are producing the anomaly. The following is a simple tutorial that a user can follow to properly use MagMod V1.00.

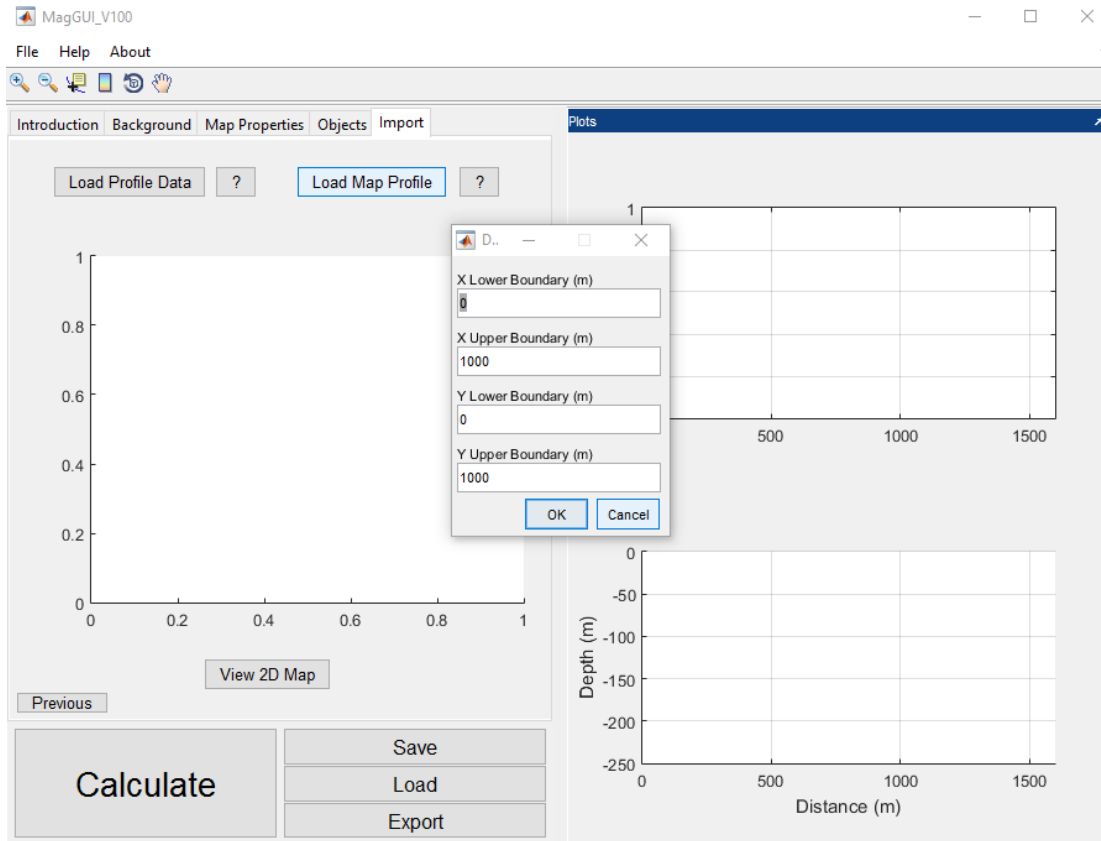
Step 1: Load MagMod V1.00

Load MagMod V.100 by double clicking the icon and it should open the interface.

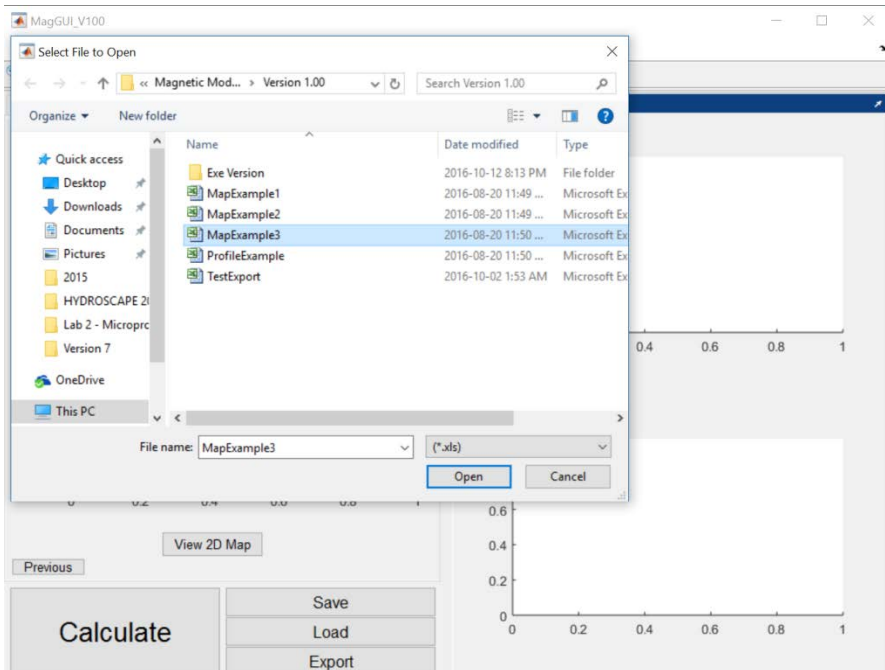


Step 2: Import a profile you wish to model.

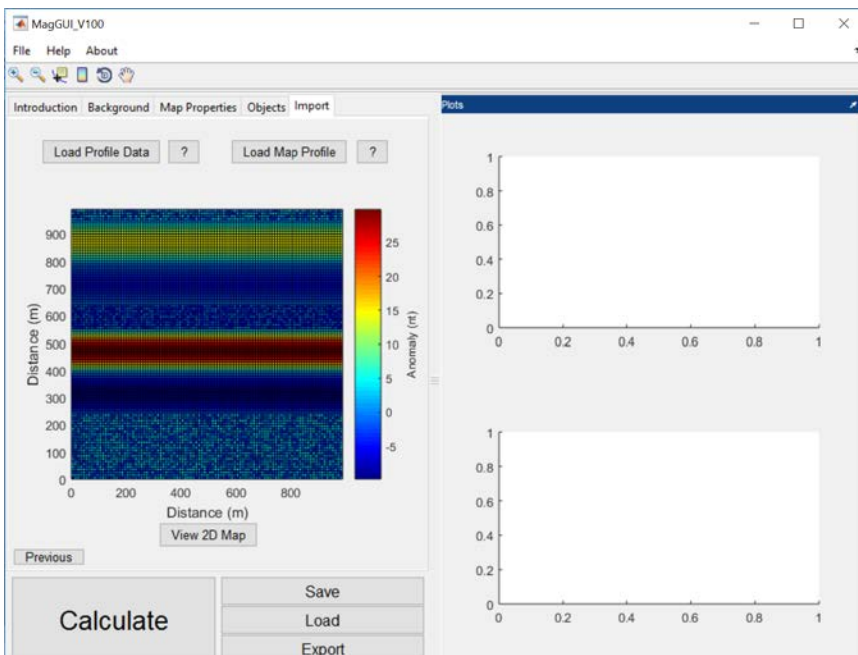
Go to the Import Tab and click either “Load Profile Data” or “Load Map Profile”. In this tutorial we will open a map profile. Once clicked a dialog box will load asking you to input the boundaries for your map.



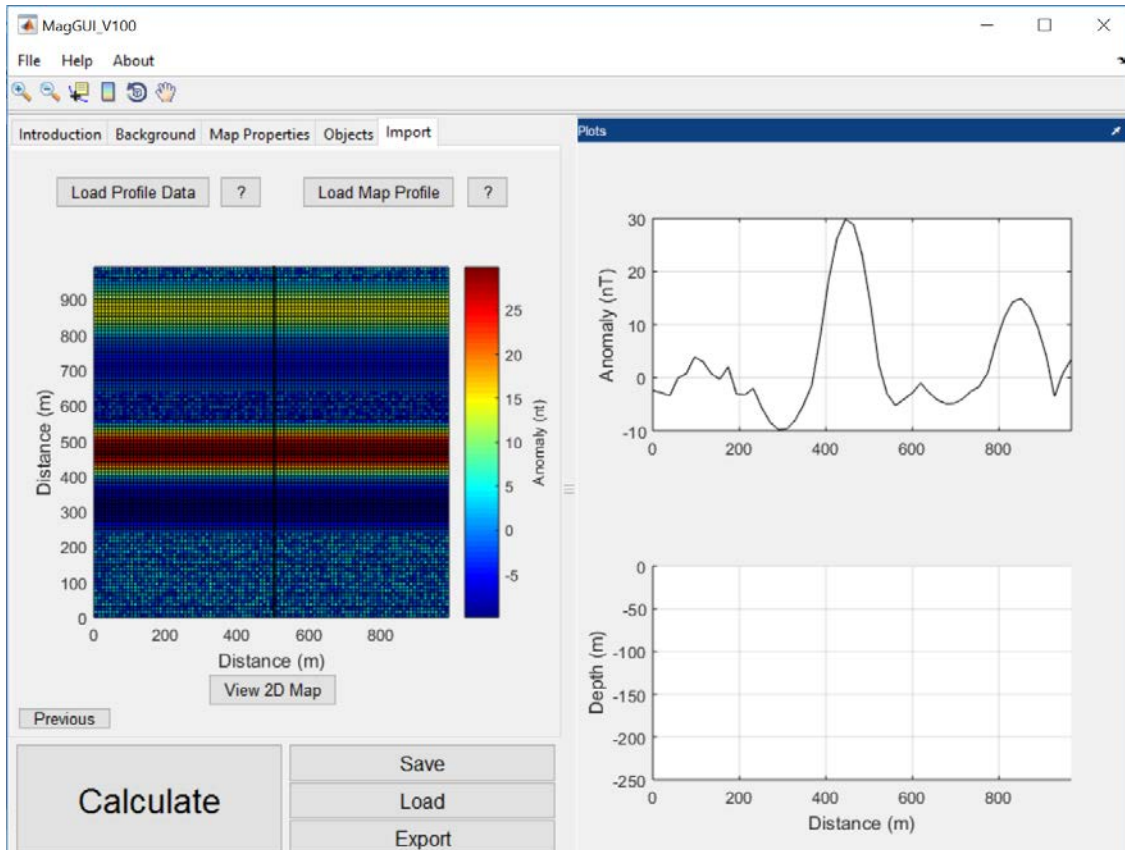
For this tutorial we will input the “X Lower Boundary” and the “Y Lower Boundary” to be 0m. The “X Upper Boundary” and the “Y Upper Boundary” is inputted as 1000m. Click “Ok” and choose the appropriate file to load, in this case MapExample3.xls.



This should load the map into the left side panel.

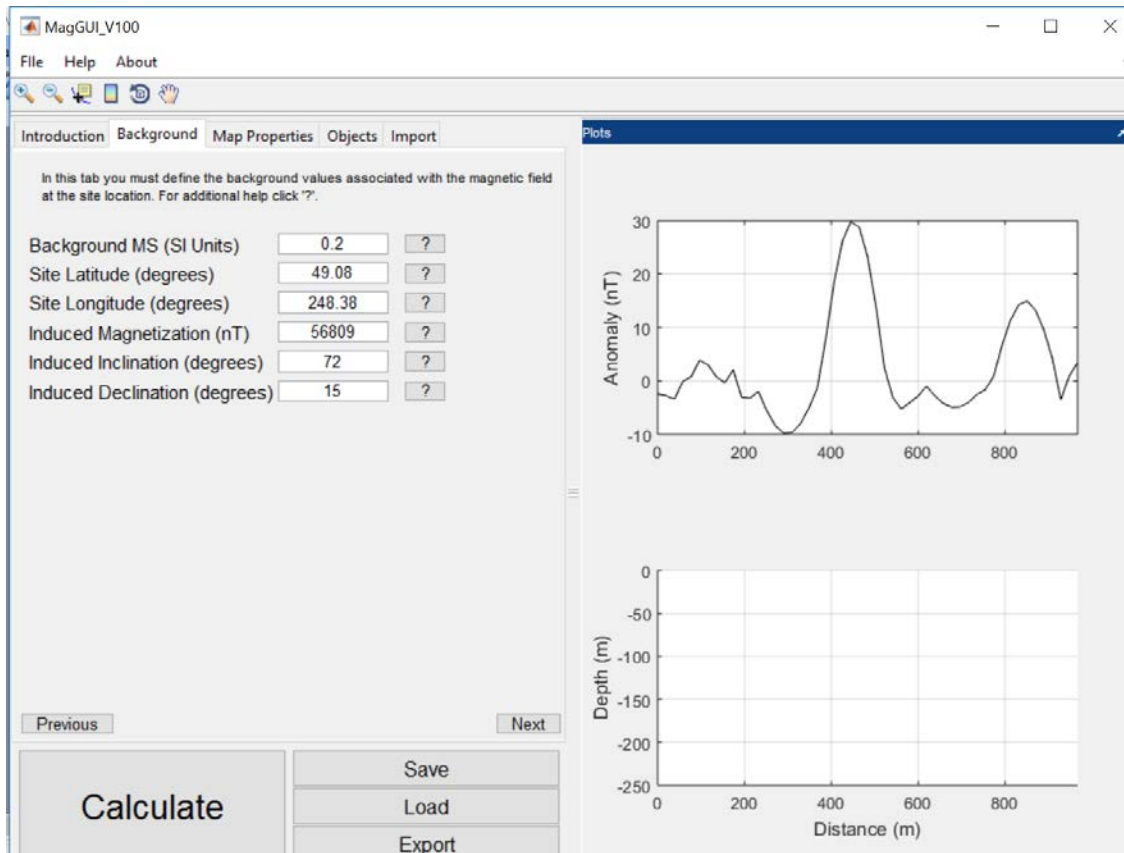


The user then drags a line across the profile. In MapExample3.xls we see that there are 2 symmetric objects in the E-W direction, therefore the most useful profile may be an S-N profile as shown below.



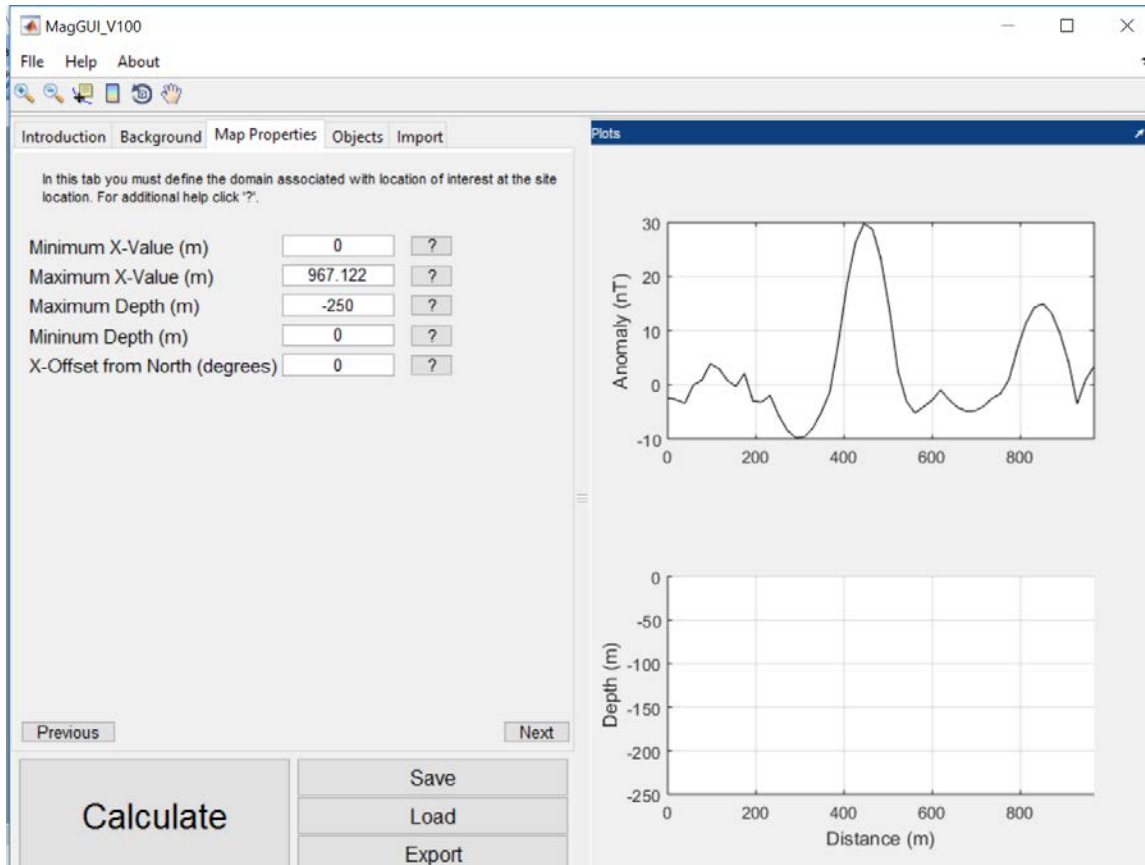
Step 3: Update the Background Tab

The background tab should be updated with the location of the site, and the strength and direction of the local magnetic field. For this example we will keep the default values.



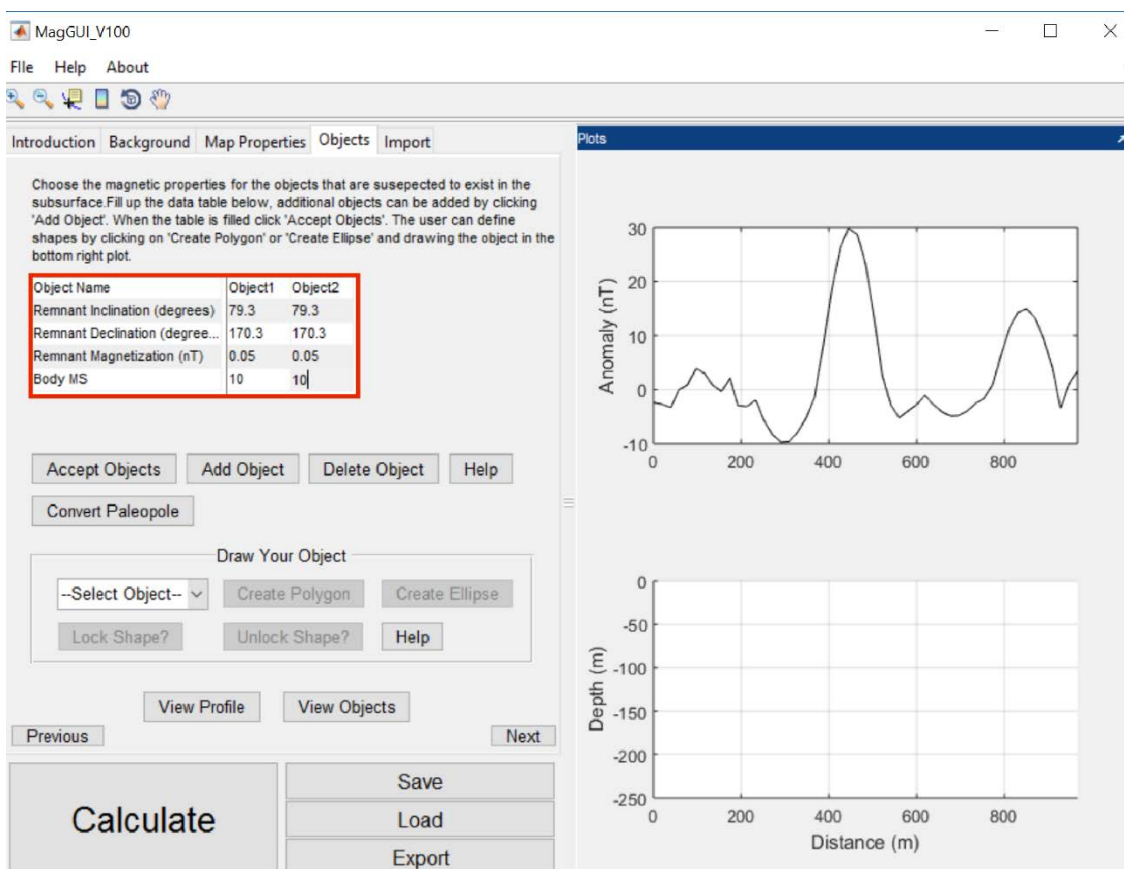
Step 4: Update the Map Properties Tab

Update the map properties to correspond to the domain you wish to model. By default the “Minimum X-Value”, “Maximum X-Value”, and the “X-Offset from North” are matched to the loaded map profile. For this example we will keep the default values.



Step 5: Create Object Properties

For this profile we see that there appears to be two distinct objects. Therefore in the Objects Tab we create will two objects. This is done by clicking the “Add Object” button once which will create two entries into the data table. The data table is then filled each for each individual object (e.g. Object1 and Object2). For this example we will assume both objects have the same magnetic profiles.



The screenshot shows the MagGUI_V100 software interface. The 'Objects' tab is active, displaying a table for defining object properties. The table is as follows:

Object Name	Object1	Object2
Remnant Inclination (degrees)	79.3	79.3
Remnant Declination (degree...	170.3	170.3
Remnant Magnetization (nT)	0.05	0.05
Body MS	10	10

Below the table are buttons for 'Accept Objects', 'Add Object', 'Delete Object', and 'Help'. There is also a 'Convert Paleopole' button. The 'Draw Your Object' section includes a dropdown menu set to '--Select Object--', 'Create Polygon', 'Create Ellipse', 'Lock Shape?', 'Unlock Shape?', and 'Help' buttons. At the bottom of the 'Objects' panel are 'View Profile', 'View Objects', 'Previous', and 'Next' buttons. A large 'Calculate' button is at the bottom left, and 'Save', 'Load', and 'Export' buttons are at the bottom right.

The 'Plots' panel on the right shows two graphs. The top graph plots 'Anomaly (nT)' on the y-axis (ranging from -10 to 30) against 'Distance (m)' on the x-axis (ranging from 0 to 800). The plot shows a magnetic anomaly profile with a prominent peak of approximately 30 nT at a distance of about 450 m, and a secondary peak of about 15 nT at a distance of about 850 m. The bottom graph plots 'Depth (m)' on the y-axis (ranging from 0 to -250) against 'Distance (m)' on the x-axis (ranging from 0 to 800). This graph is currently empty.

Click Accept will update the “Draw Your Object” panel and allow objects to be drawn

MagGUI_V100

File Help About

Introduction Background Map Properties **Objects** Import

Choose the magnetic properties for the objects that are suspected to exist in the subsurface. Fill up the data table below, additional objects can be added by clicking 'Add Object'. When the table is filled click 'Accept Objects'. The user can define shapes by clicking on 'Create Polygon' or 'Create Ellipse' and drawing the object in the bottom right plot.

Object Name	Object1	Object2
Remnant Inclination (degrees)	79.3	79.3
Remnant Declination (degree...	170.3	170.3
Remnant Magnetization (nT)	0.05	0.05
Body MS	10	10

Accept Objects Add Object Delete Object Help

Convert Paleopole

Draw Your Object

Object1 Create Polygon Create Ellipse

Lock Shape? Unlock Shape? Help

View Profile View Objects

Previous Next

Calculate Save Load Export

Plots

Anomaly (nT)

Depth (m)

Distance (m)

Step 6: Draw the Object(s)

In the popup menu choose the object you wish to draw (e.g. Object1) and then click either “Create Polygon” or “Create Ellipse”. In this example “Create Polygon” was chosen, which brings up a colour menu which allows the user to choose the colour of the object.

The screenshot shows the MagGUI_V100 software interface. The 'Objects' tab is active, displaying a table of magnetic properties for two objects. A 'Color' dialog box is open, allowing the user to select a color for the object. The 'Create Polygon' button is highlighted in the 'Draw Your Object' section. The 'Plots' panel on the right shows two graphs: a line graph of Anomaly (nT) vs. Distance (m) and a blank graph of Depth (m) vs. Distance (m).

Object Name	Object1	Object2
Remnant Inclination (degrees)	79.3	79.3
Remnant Declination (degree...)	170.3	170.3
Remnant Magnetization (nT)	0.05	0.05
Body MS	10	10

Color selection dialog options:

- More Colors...
- OK
- Cancel

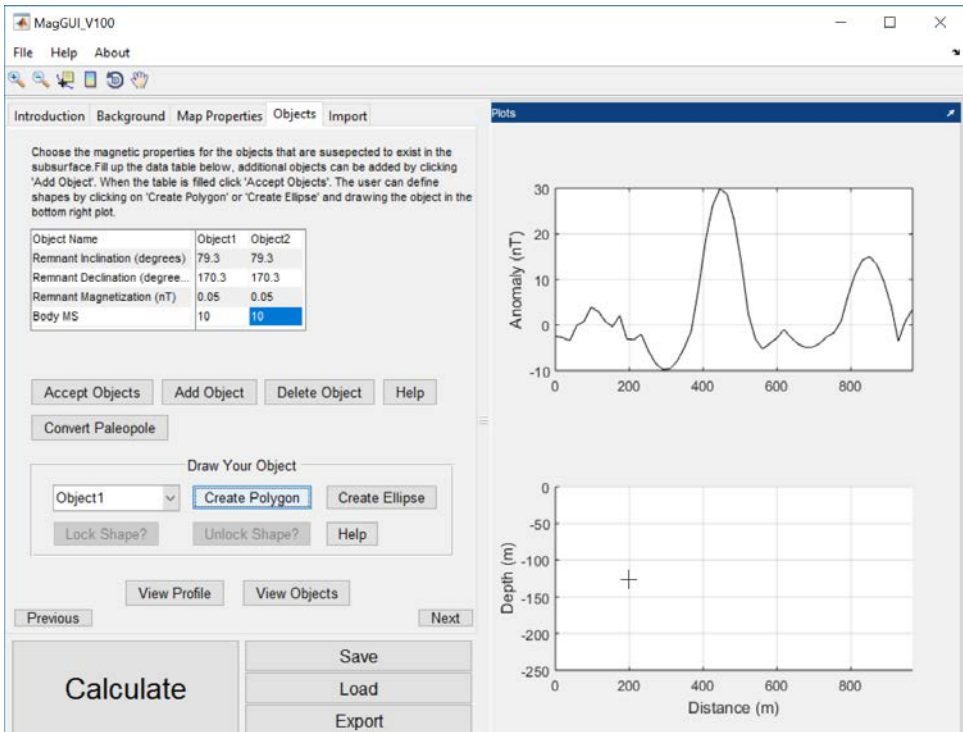
Draw Your Object options:

- Object1 (selected)
- Create Polygon (highlighted)
- Create Ellipse
- Lock Shape?
- Unlock Shape?
- Help

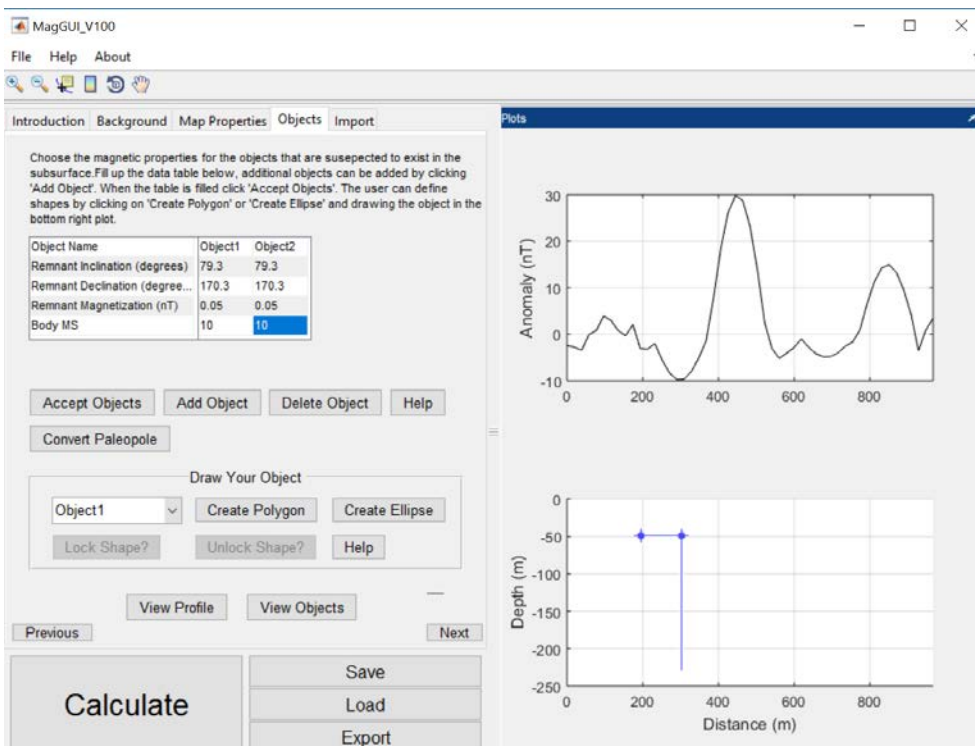
Navigation and Action buttons:

- Previous
- Next
- View Profile
- View Objects
- Calculate
- Save
- Load
- Export

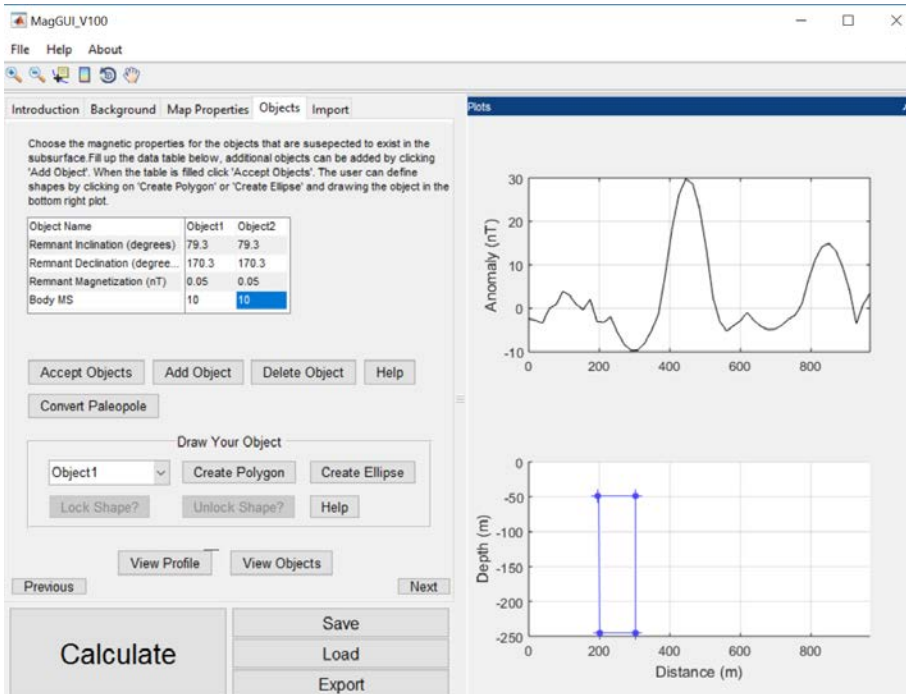
Once the colour has been select the mouse cursor is brought to the bottom right plotting area where a crosshair should be visible.



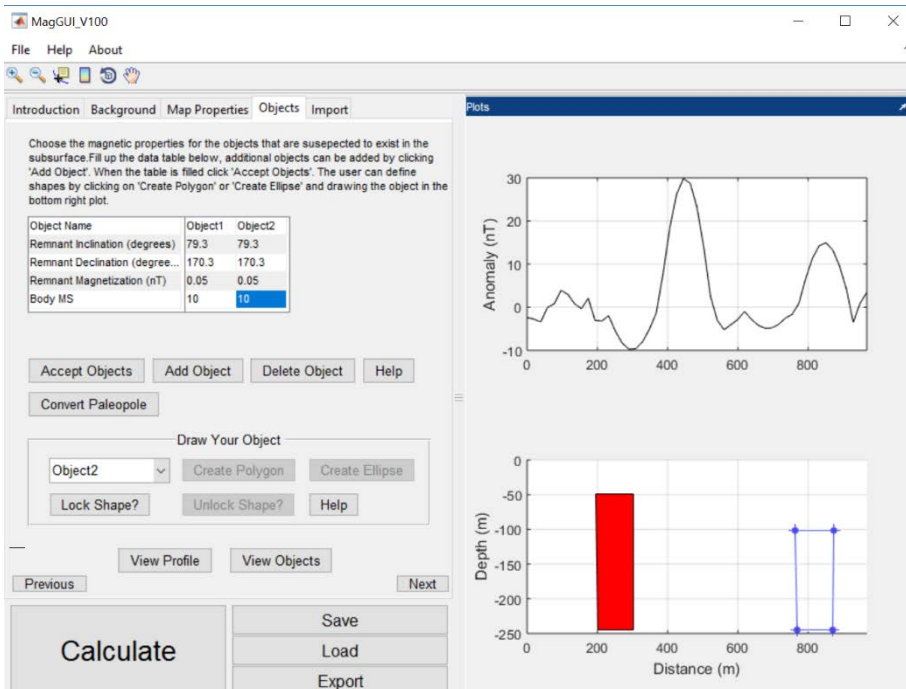
The user then click to create a vertex for the polygon. **Additional vertices need to be place in a clockwise fashion.**



To close the polygon the last vertex can either overlap with the first vertex or the user can double click.

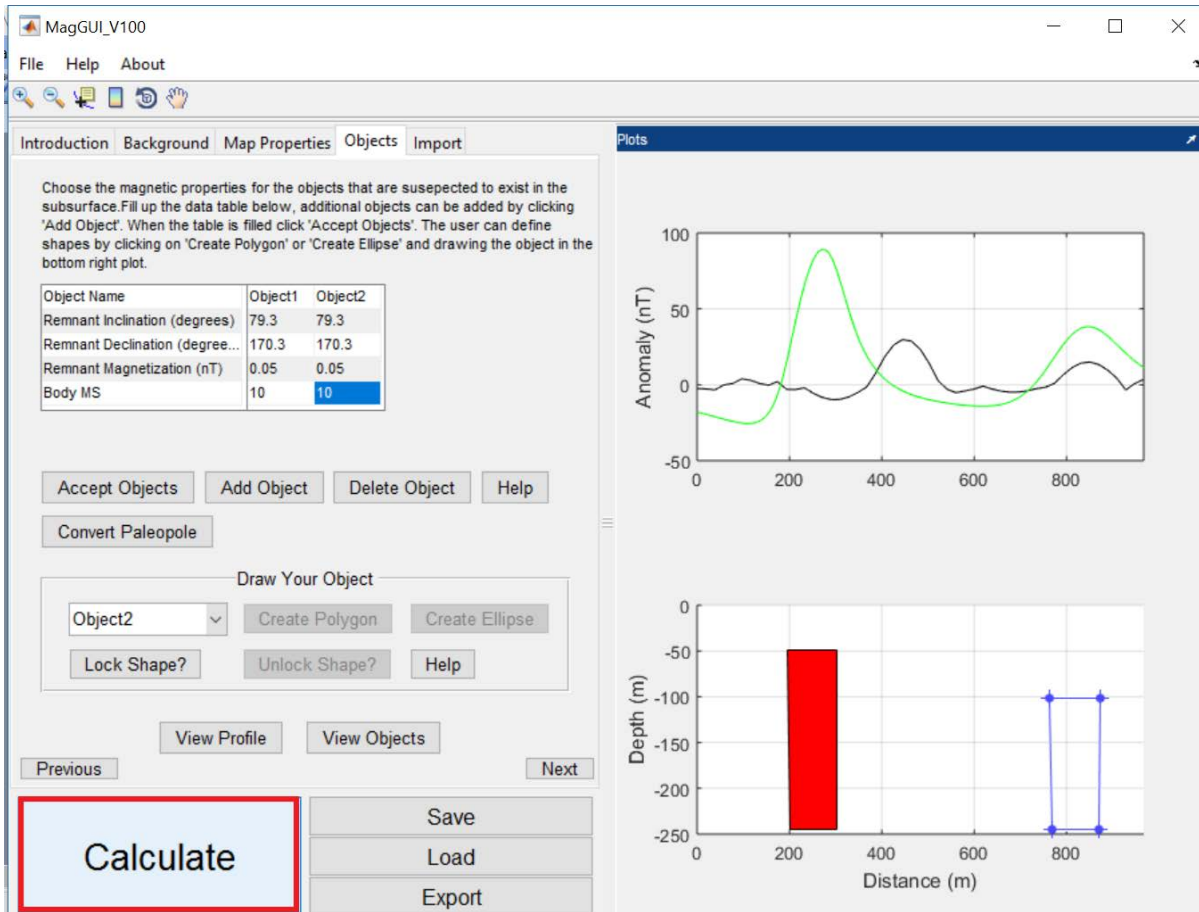


After the first object is finished other objects can then be created in a similar fashion.



Step 7: Calculate Profile

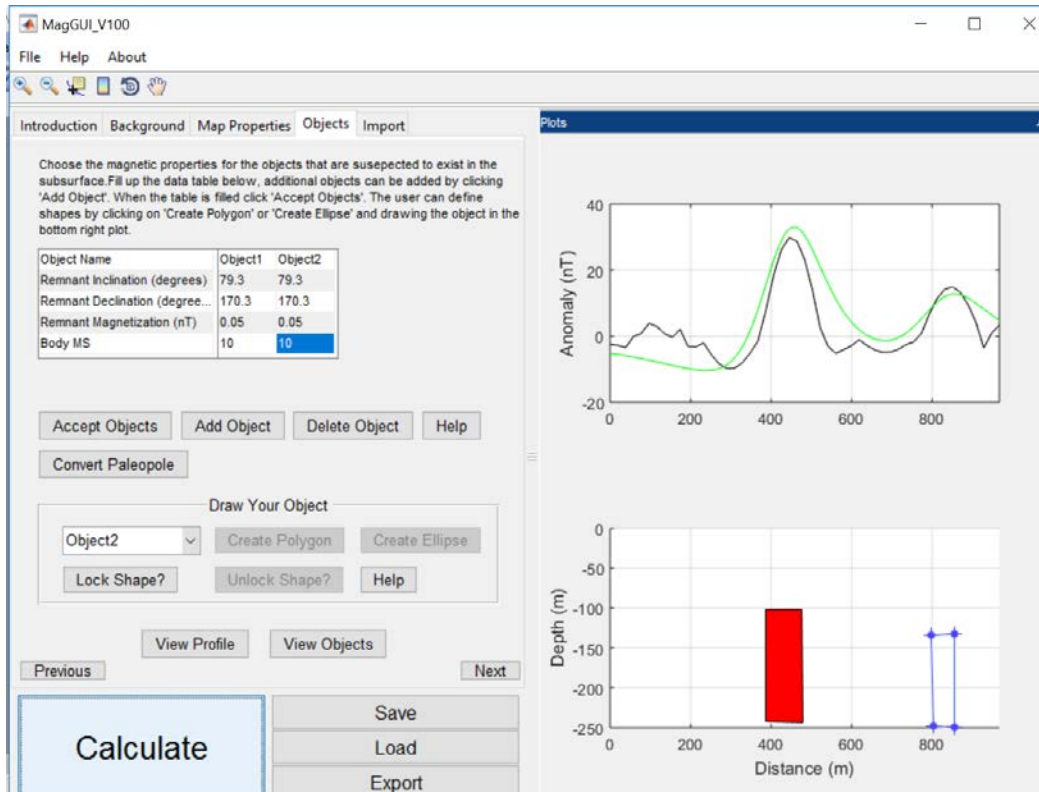
Once the objects have been created the magnetic anomaly profile that they create is produced by clicking "Calculate".



Step 8: Modifying Objects

If the two profiles do not match the objects can be tweaked in shape/depth by unlocking ("Unlock Shape?" button) the current shape (if isn't already unlocked). The user can reposition each individual vertex by clicking the vertex and dragging to

a new point. The user can also drag the shape to a new location. Alternatively the user can modify the data table. If the user modifies the data table they must click “Accept Objects” again.



Step 9: Interpretation

In the example we have two rectangular objects that create a profile similar to the observed map profile. Since the objects are symmetric in the E-W direction we may suggest the following interpretation in cross section and map view. **However, it is important to realize that these are non-unique solutions!**

