SenGRSP USER GUIDE

SenGRSP is a MATLAB-based graphical user interface (GUI) designed for the inversion of gravity and self-potential (SP) datasets using a variety of iterative methods. This tool is highly practical and flexible, providing an effective solution for geophysical modeling and parameter estimation. The software employs several iterative techniques, including Fixed Point, Bisection, Regula-Falsi, Secant, and Steffensen's methods. This variety enables users to evaluate the performance of each approach and select the one that minimizes the root-mean-square (RMS) error, ensuring the best model fit.

In addition to its inversion capabilities, SenGRSP also facilitates forward modeling, enabling users to simulate and analyze anomalies under various noise levels. The ability to add customizable Gaussian noise provides valuable insights into the sensitivity and reliability of the model, helping users assess the robustness of parameter estimates. With its user-friendly interface, SenGRSP minimizes the learning curve, facilitating seamless interaction and sophisticated data interpretation.

- This user guide provides detailed instructions for using SenGRSP for both forward and inverse modeling of gravity and self-potential anomalies (For more detailed information, Özyalın et al., 2025).

Main Interface

The main interface features three buttons: **FORWARD MODELING**, **INVERSE MODELING,** and **EXIT** (Fig. 1).

- ✓ **FORWARD MODELING** provides the user interface for calculating gravity or self-potential model anomalies with or without noise.
- ✓ **INVERSE MODELING** offers the user interface for interpreting gravity or self-potential data.
- ✓ **EXIT** terminates the program.

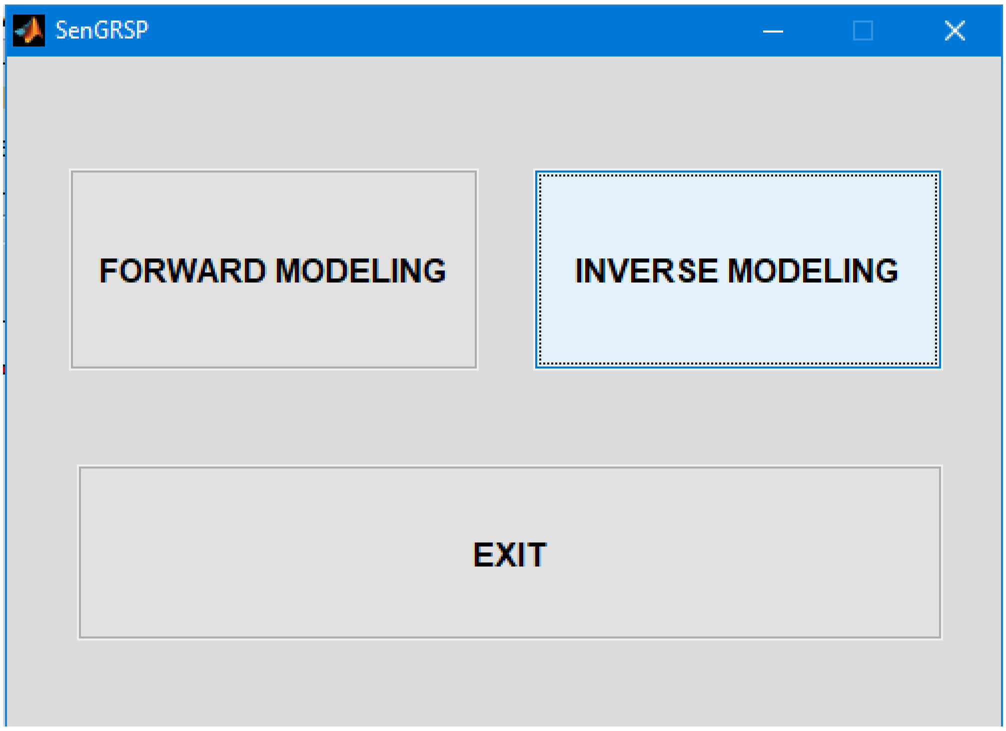


Figure 1. Screen view of the main interface of the SenGRSP Program

The gravity or SP anomaly expression

The general gravity or SP anomaly equation generated by a simple geologic structure along the profile over the body is given by (Fig. 2) (Essa, 2010),

$$J(x_i, z) = K\frac{cx_i(\cos\theta)^n + z^p(\sin\theta)^m}{(x_i^2 + z^2)^q}, \quad i = 0, \pm1, \pm2, \pm3, \dots, \pm k,$$

where θ is the angle of polarization, vertical downward for gravity and varying from -90° to + 90° for SP, z is the depth of the geologic body (in meters), x_i, represents the horizontal coordinate (in meters), K is the amplitude factor associated with the physical properties of the source (in units of mGal^{m2q-1} for gravity, mVm^{2q-1} for SP), and q is a dimensionless shape factor that varies with the geometry of the buried structure. It is seen the values for c, m, n, p, and q in Table 1. The semi-infinite vertical cylinder, the horizontal cylinder, and the sphere have shape factors of 0.5, 1, and 1.5, respectively.

Table 1.

	Gravity				Self-potential			
Shape	*c*	*m*	*n*	*p*	*c*	*m*	*n*	*p*
Semi-infinite vertical cylinder (q = 0.5)	0	0	0	0	1	1	1	1
Horizontal cylinder (q = 1.0)	0	0	0	1	1	1	1	1
Sphere (q = 1.5)	0	0	0	1	1	1	1	1

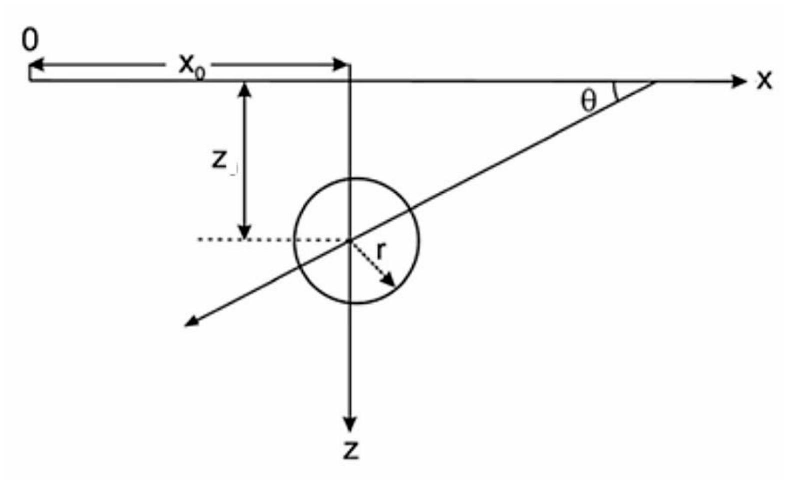


Figure 2. Schematic representation of a simple geological structure model.

1- FORWARD MODELING MODULE

Click **Forward Modeling** from the main interface. The Forward Modeling module is used to calculate synthetic model anomaly. The first step is to define the model parameters manually or by loading them using an input file.

1.1. Defining the model parameters for forward modeling

1.1.1. Defining the model parameters manually;

Users can define the model parameters manually using the menus of the Forward modeling module (Fig. 3).

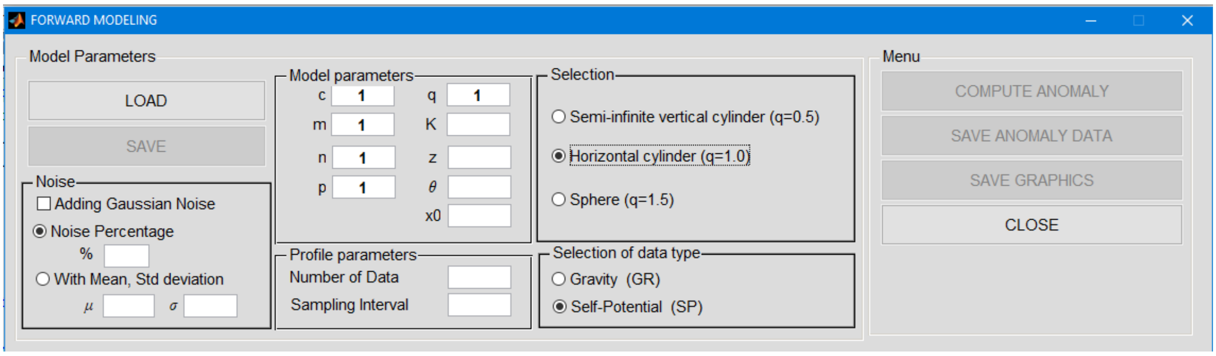


Figure 3. Appearance of the Forward Modeling module interface

- Select data type (Gravity or Self-Potential)

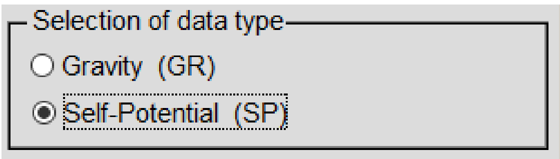


Figure 4. Users can select the data type manually.

- Enter the number of data;

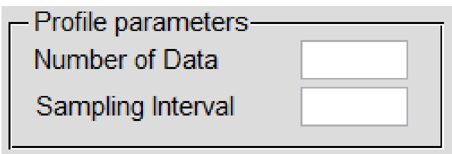


Figure 5. Users can manually enter the number of data and sampling interval in the profile.

- Select model type (shape factor (q))

Click the model type from the **Selection** menu.

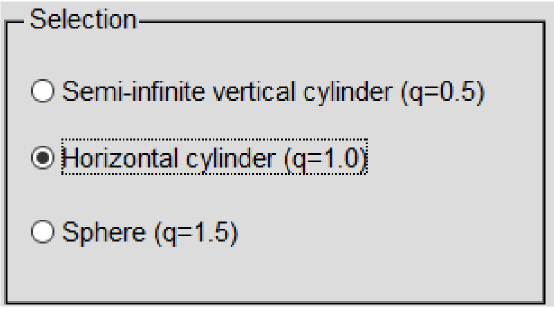


Figure 6. Selection module

- Enter model parameters

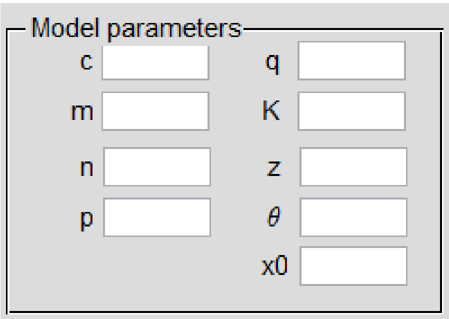


Figure 7. Model parameters module

Enter model parameters (Depth (z), Amplitude (K), Horizontal distance (x_0), polarization angle(θ), in case of SP ranging from $-90°$ to $+ 90°$ but in case of gravity is vertical downwards) and c, m, n and p parameters manually. The user can also automatically define the parameters c, m, n and p according to the parameter q specified in the selection module.

To save the model parameters into a text file, click the **SAVE** button. Then, in the save dialog box, a filename should be typed and the Save button should be clicked (Fig. 8). The entered/saved model parameters are displayed as in Figure 9.

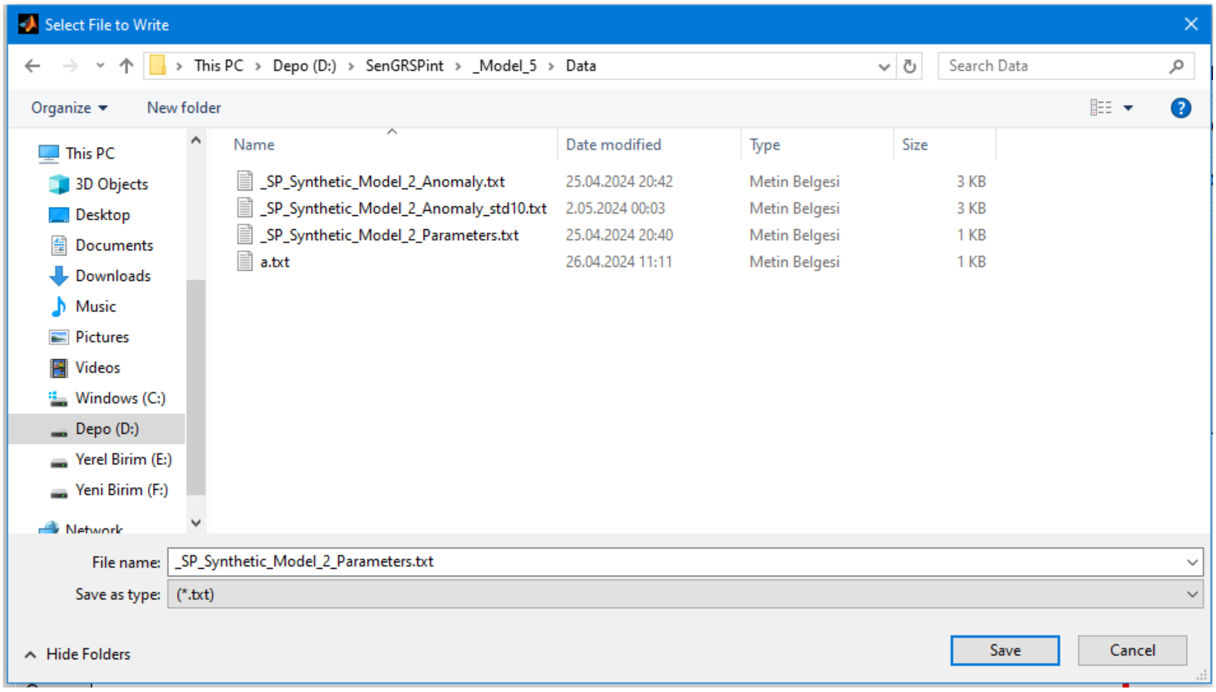


Figure 8. Model parameters are saved in a text file and input file/saved file name.

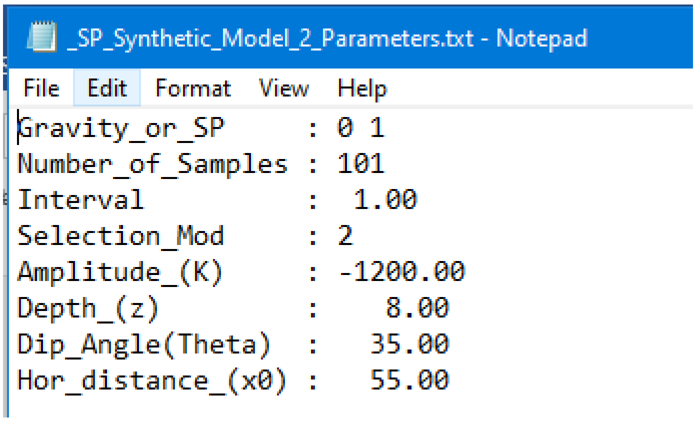


Figure 9. View of the text file containing the entered/saved model parameters

*1.1.2. Defining the model parameters by the **LOAD** button*

Click the **LOAD** button (Fig. 10) and select the input file that contains the model parameters from the opening window (Fig. 11). Then click the **Open** dialog box.

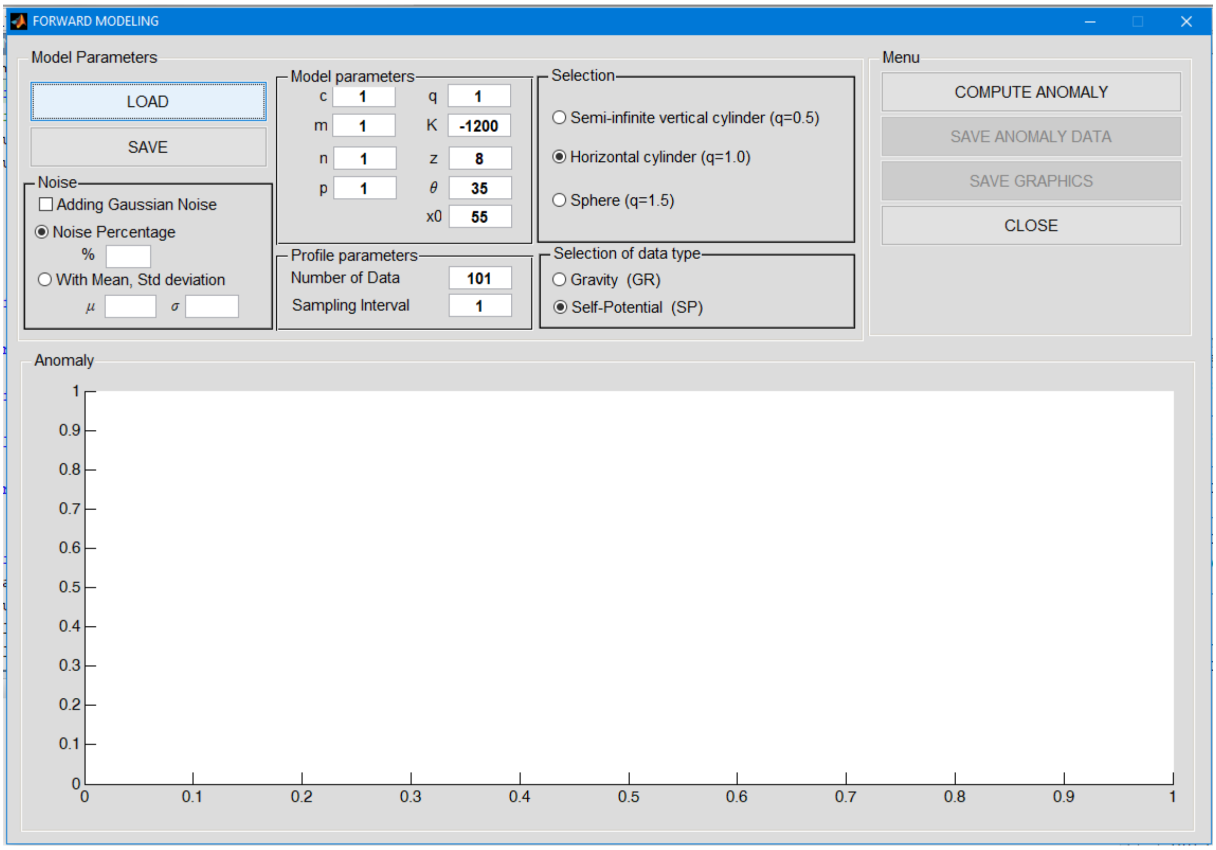


Figure 10.

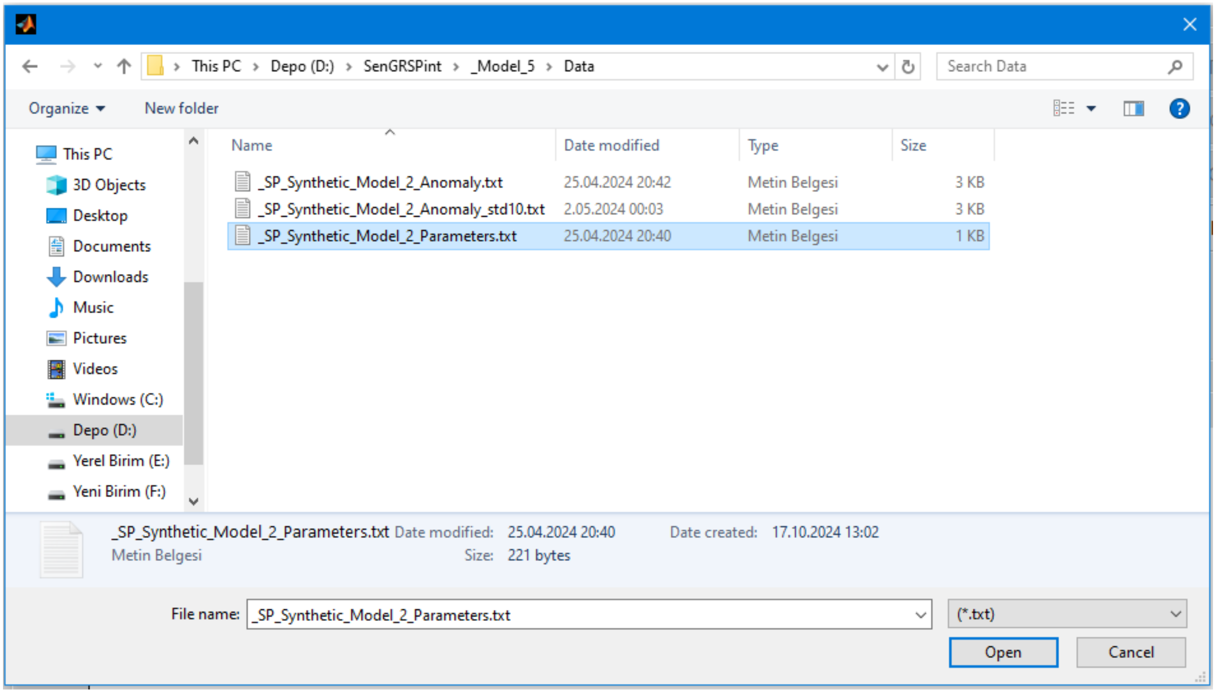


Figure 11.

1.2. Anomaly Calculation

Click the button labelled **COMPUTE ANOMALY** (Fig.12**).** After clicking this button, the theoretical gravity/self-potential anomaly is calculated using the linear modeling approach (please refer to Essa (2011) for the model equation), and its graphic appears in the Anomaly menu of the Forward Modeling module (Fig.12).

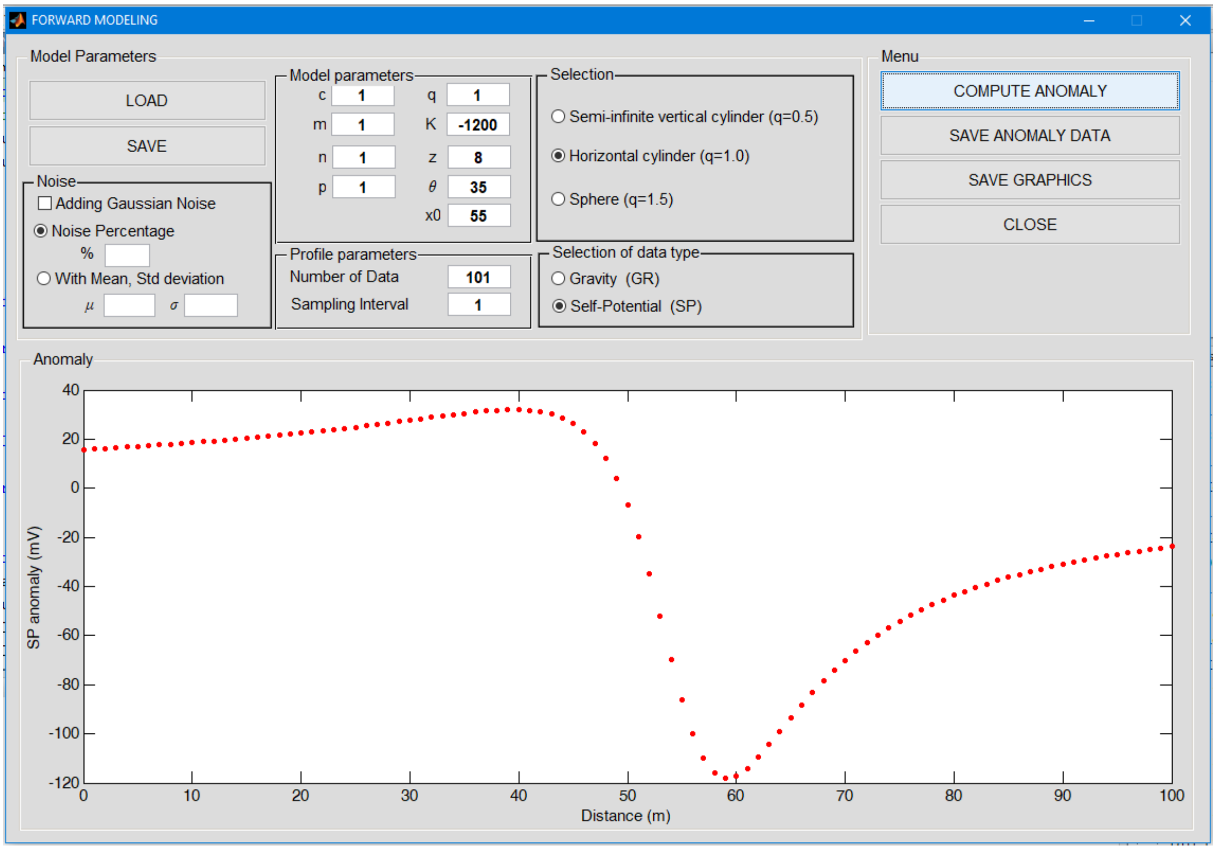


Figure 12. Forward modeling- computing the anomaly

To save the calculated discrete anomaly values into a text file, click the **SAVE ANOMALY DATA** button. Then, **Select File to Write** dialog box appear, a desired filename should be typed, and the **Save** button should be clicked (Fig 13). The calculated theoretical anomaly values versus the horizontal distances are seen in the saved text file in Fig. 14.

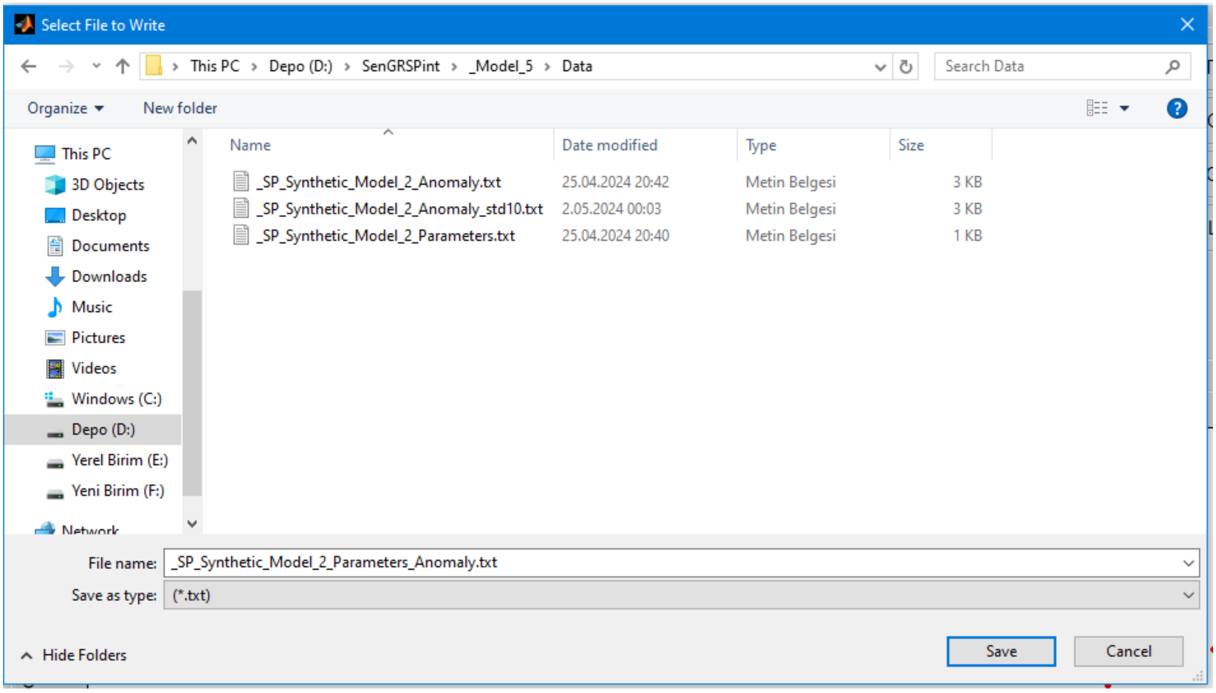
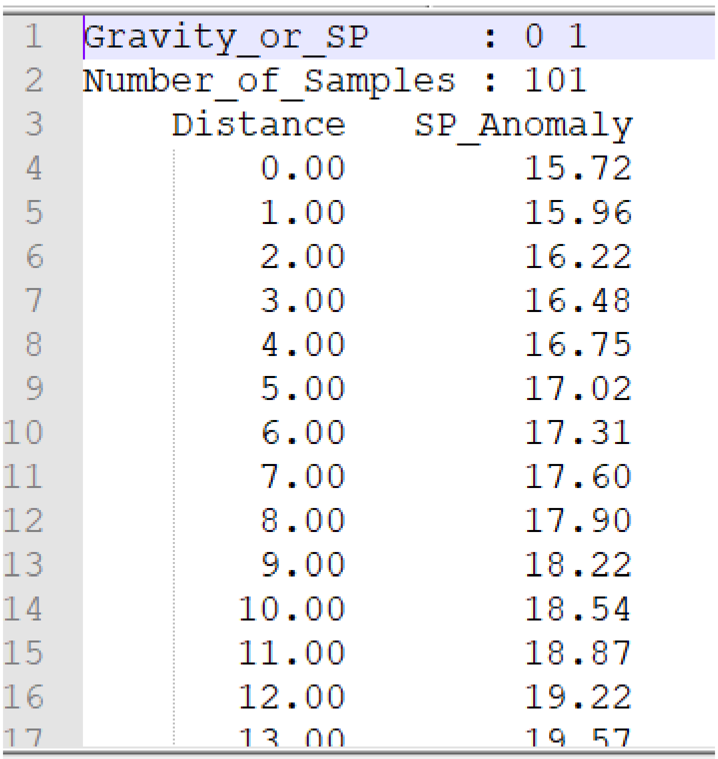


Figure 13. Saving the calculated theoretical anomaly values



```
Gravity_or_SP      : 0 1
Number_of_Samples : 101
    Distance    SP_Anomaly
        0.00         15.72
        1.00         15.96
        2.00         16.22
        3.00         16.48
        4.00         16.75
        5.00         17.02
        6.00         17.31
        7.00         17.60
        8.00         17.90
        9.00         18.22
       10.00         18.54
       11.00         18.87
       12.00         19.22
       13.00         19.57
```

Figure 14. View of the text file containing the calculated theoretical anomaly values

Additionally, it is possible to add noise to the anomaly. Noise ratio can be added to the program as a percentage or defined by its mean and standard deviation (Fig. 15). To proceed, the user must first select the **Adding Gaussian Noise** checkbox in the **Noise** menu, input the noise ratio (as percentage) or its mean and standard deviation manually, and then select the **COMPUTE ANOMALY** button.

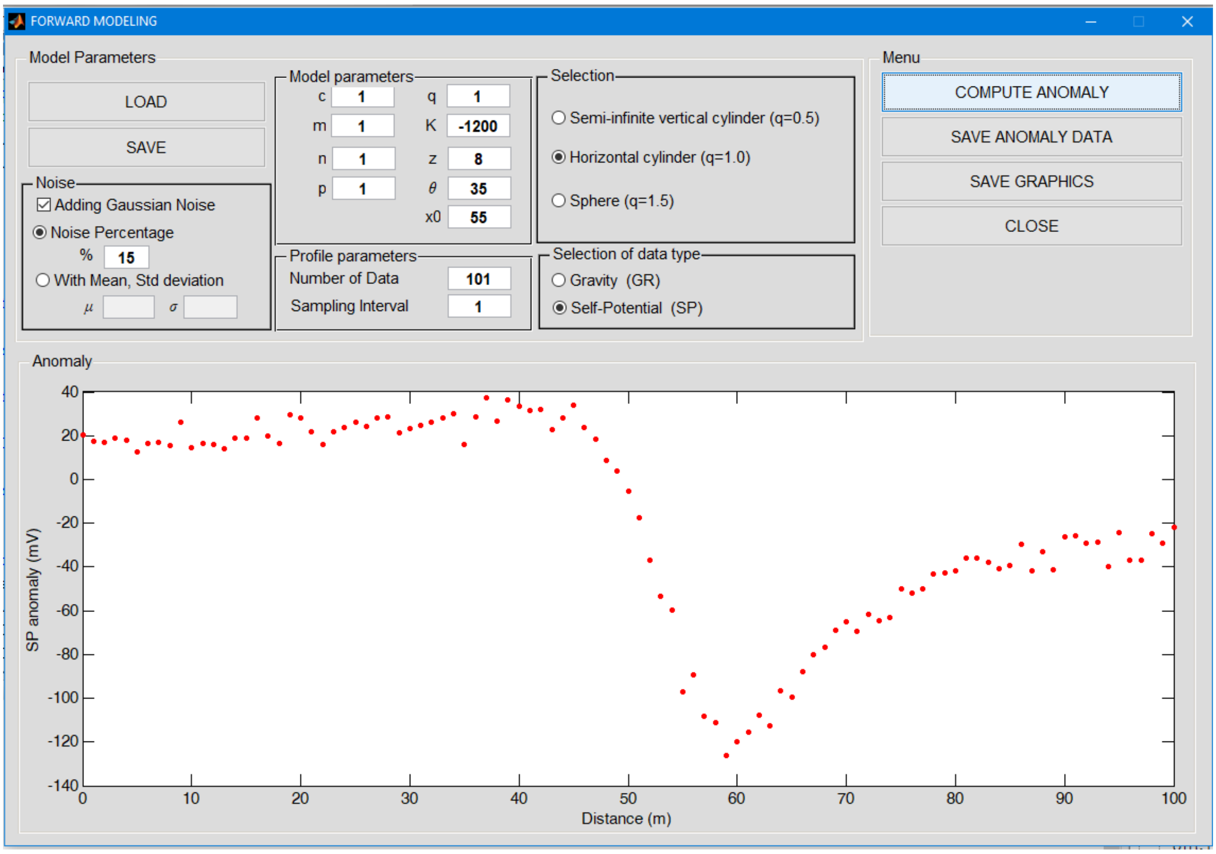


Figure 15. Adding Noise to the anomaly either as a percentage or with mean and standard deviation.

The **SAVE GRAPHICS** button allows you to save the noise-free or noisy graphics of the theoretical anomalies (Fig. 15). Figure 16 displays the output visuals. Click the **CLOSE** button to exit the Forward modeling menu.

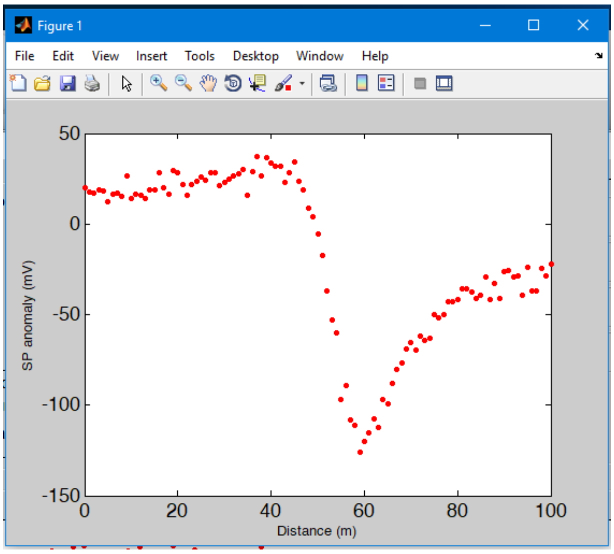


Figure 16. Graphical representation of the calculated anomaly

2- INVERSE MODELING MODULE

The inverse modeling module of SenGRSP provides an interface for interpreting gravity or self-potential data. This module has various graphical objects to facilitate the user's evaluation (Fig. 17).

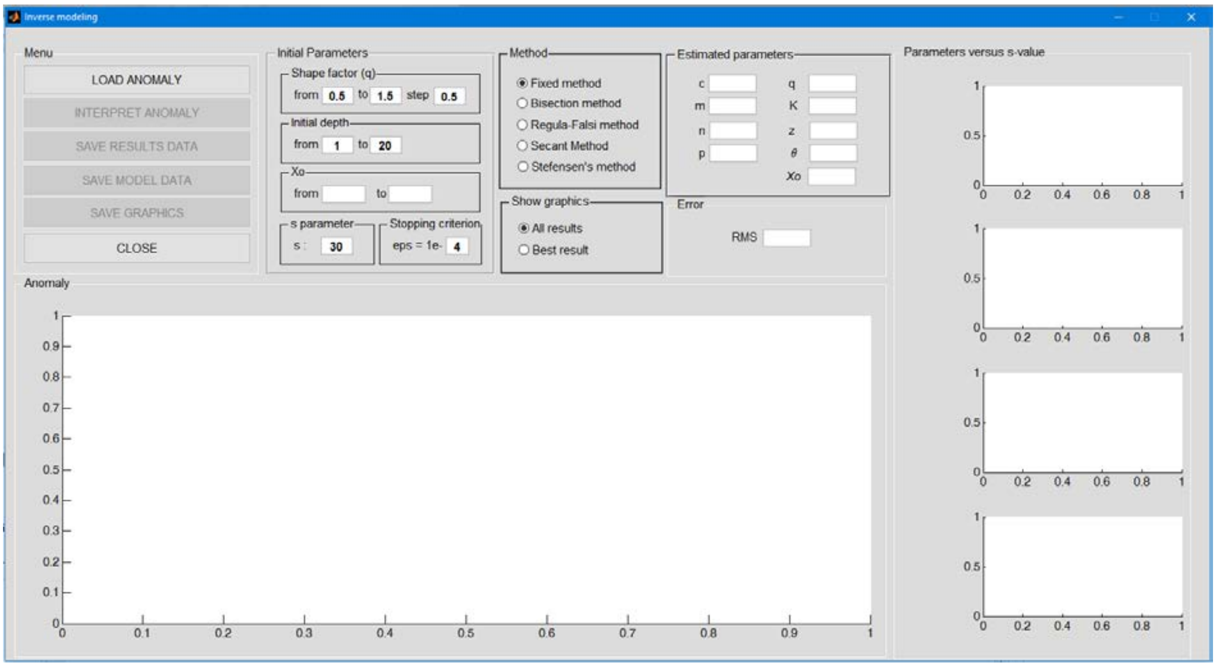


Figure 17. Inverse modeling module interface

The first step of the interpretation is loading the anomaly data. To perform this process step, the **LOAD ANOMALY** button is clicked (Fig. 17), selected the input file from the pop-up window, and clicked the

Open button (fig. 18). After clicking the **LOAD ANOMALY** button, the initial parameters menu (fig. 17) are automatically loaded. The user may change them if desired. When the **LOAD ANOMALY** button is clicked, the Fixed Point method in the **Method** menu is also selected. The user can also choose a different iteration method from this menu (Fig. 17). The origin point of the possible structure is calculated according to the Stanley (1977) method in SenGRSP, and it is shown with the green vertical line in Figure 19.

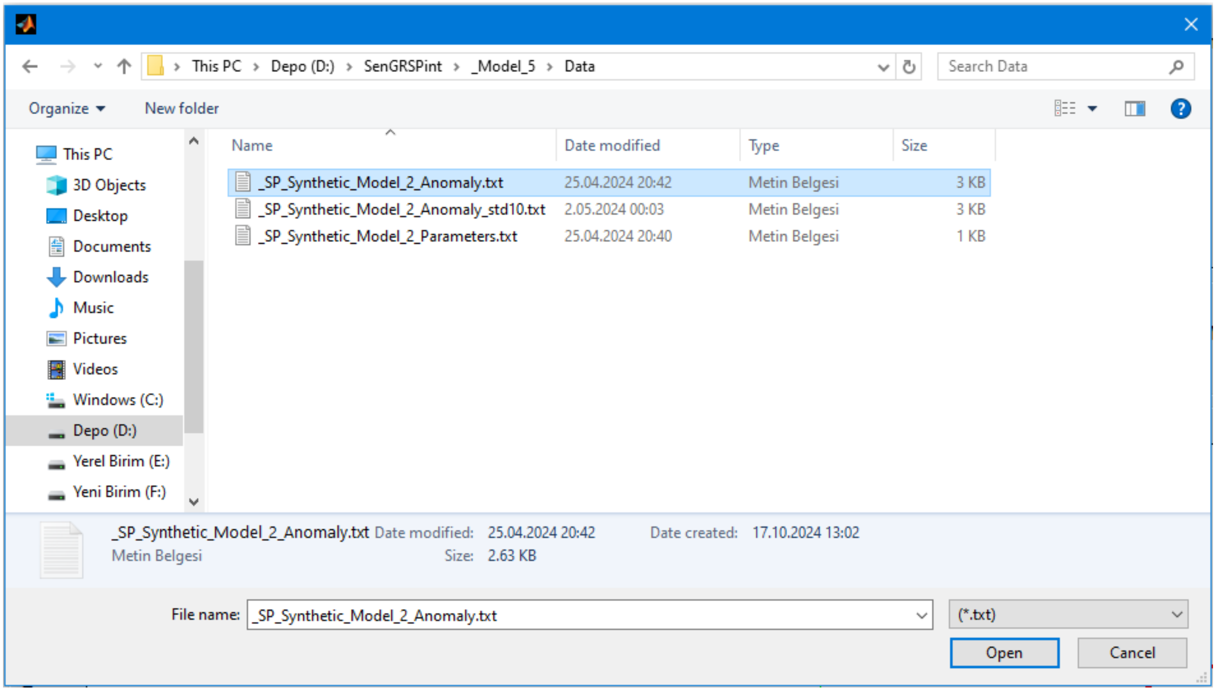


Figure 18. Selecting the data for interpretation

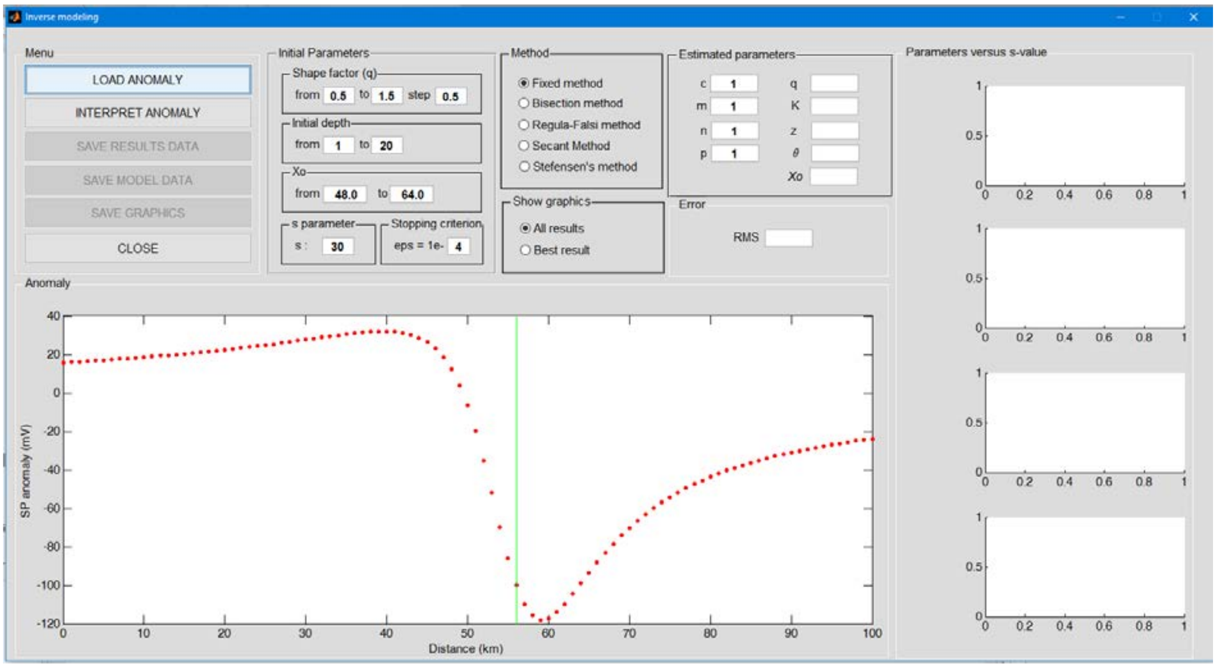


Figure 19. Display of variables such as structure initialization parameters, selected evaluation method and origin line in the program window.

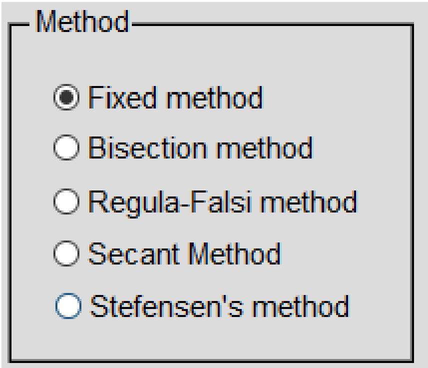


Figure 20. Selection of one of the iterative approach/evaluation methods (such as Fixed point, bisection, Regula-Falsi, etc.) to be used in the evaluation.

In the last step for interpretation, click the **INTERPRET ANOMALY** button. Then, the results are displayed iteratively for each q value according to the selected approximation method (Fig. 21). The **Show Graphics** menu allows the user to plot the calculated gravity and SP anomalies with different shape factor values. While the **All Results** button is used to plot all calculated anomalies (Fig. 21), the **Best Result** button allows the anomaly calculated as the result of the best inverse solution to be plotted (Fig. 22).

The estimated best model parameter values and RMS error value of the model also take place on the inverse modeling module (Fig. 22).

RMS and calculated parameter chancing for each s-value through the inverse solution are displayed in the right panel of the inverse solution module (Fig. 21-22). The first graphic of the panel is the RMS variation versus the s-value. A green circle indicates the minimum root-mean-square (RMS) value on the RMS graph. The other graphics of the panels show the variation of z, K and θ values calculated for each s-value through the inverse solution (represented by the blue line) and their cumulative changes (depicted by the red line). The estimation values of z, K and θ parameters correspond to the point values on the cumulative curve that coincides with the s-value (marked by the green circle) where the RMS is minimized. Users can save the graphics clicking by the **SAVE GRAPHICS** button.

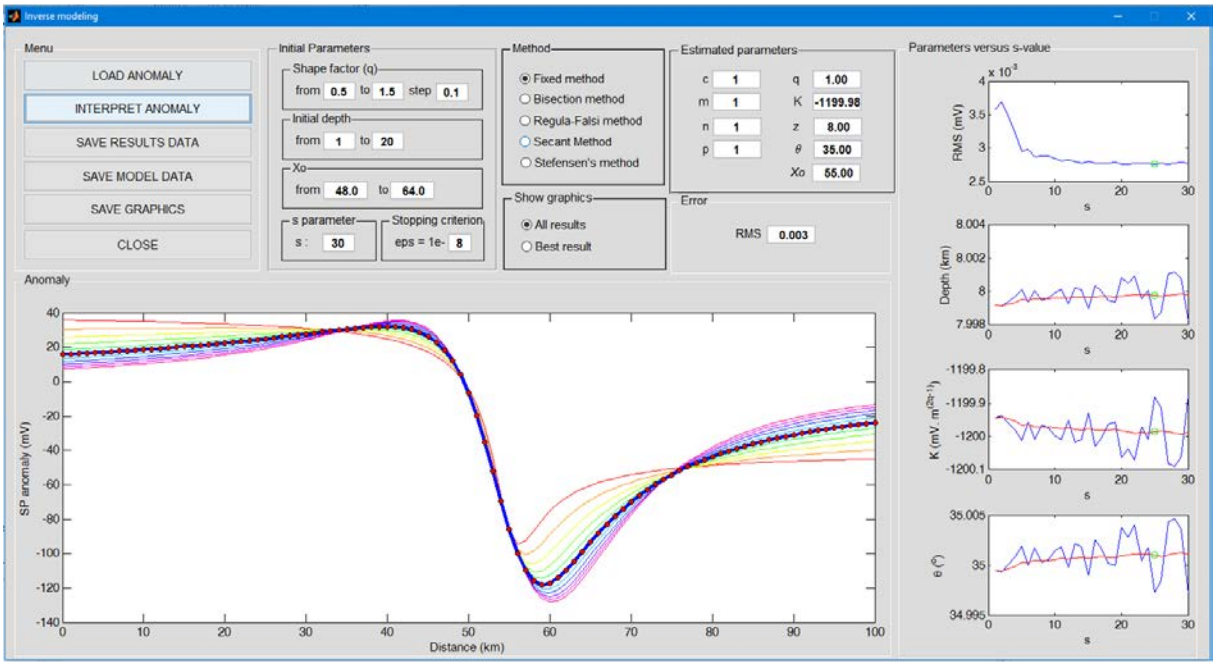


Figure 21. The best structure parameter values and anomaly graph were obtained iteratively for each q value according to the selected approximation method.

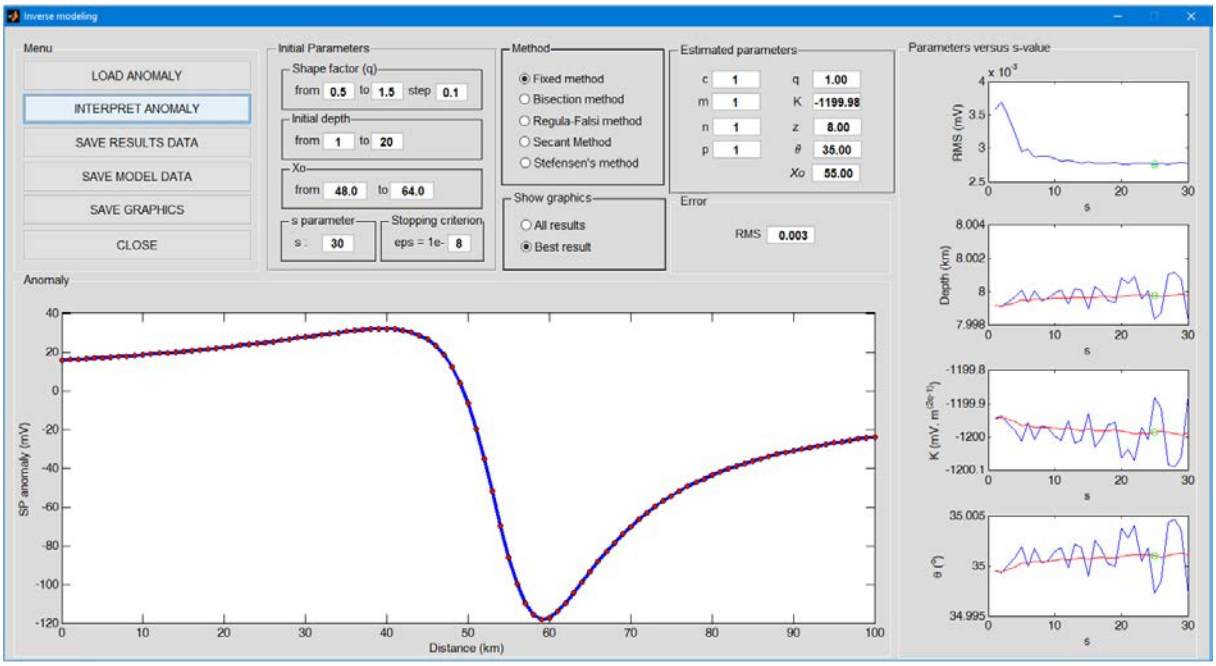


Figure 22. The best structure parameter values and anomaly graphs are obtained iteratively according to the selected approach method.

2.1. Saving the results

The **SAVE RESULTS DATA** button should be clicked to save the observed and calculated best model anomaly values into a text file. Then, enter a filename and click the **Save** button in the pop-up window (Fig. 23).

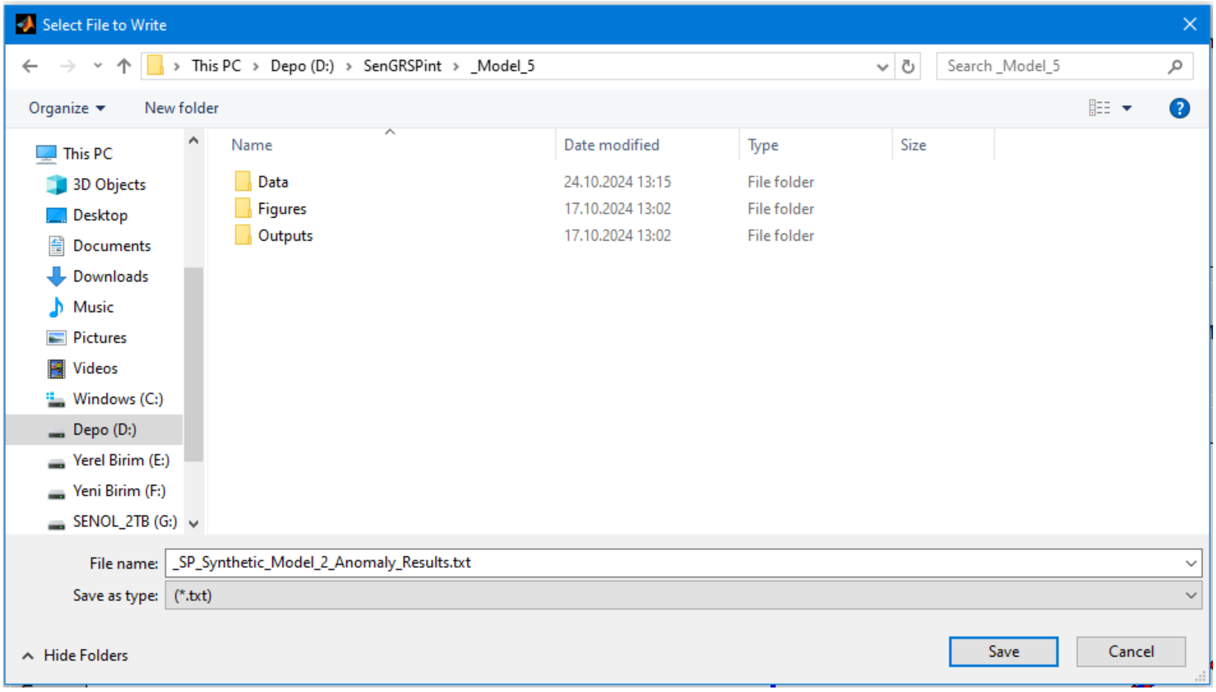


Figure 23. Saving the obtained best structure parameter values in a text file with a given name.

The format of the output file (Fig.24), including the observed and calculated anomaly values, is as follows:

The 1st column: The distance values,

The 2nd column: The observed anomaly values,

The 3rd column: The calculated anomaly values,

The last column: the difference between the observed and calculated anomaly.

Distance	Observed	Calculated	Difference
0.00	15.720	15.719	0.001
1.00	15.960	15.964	-0.004
2.00	16.220	16.217	0.003
3.00	16.480	16.477	0.003
4.00	16.750	16.745	0.005
5.00	17.020	17.021	-0.001
6.00	17.310	17.306	0.004
7.00	17.600	17.600	0.000
8.00	17.900	17.903	-0.003
9.00	18.220	18.216	0.004
10.00	18.540	18.539	0.001
11.00	18.870	18.872	-0.002
12.00	19.220	19.216	0.004
13.00	19.570	19.572	-0.002
14.00	19.940	19.940	0.000
15.00	20.320	20.320	0.000
16.00	20.710	20.712	-0.002
17.00	21.120	21.118	0.002

Figure 24. Output file appearance after evaluation.

When the **SAVE RESULTS DATA** button is clicked again, the iteration steps depending on the s-value are recorded as a text file (Fig.25-26)

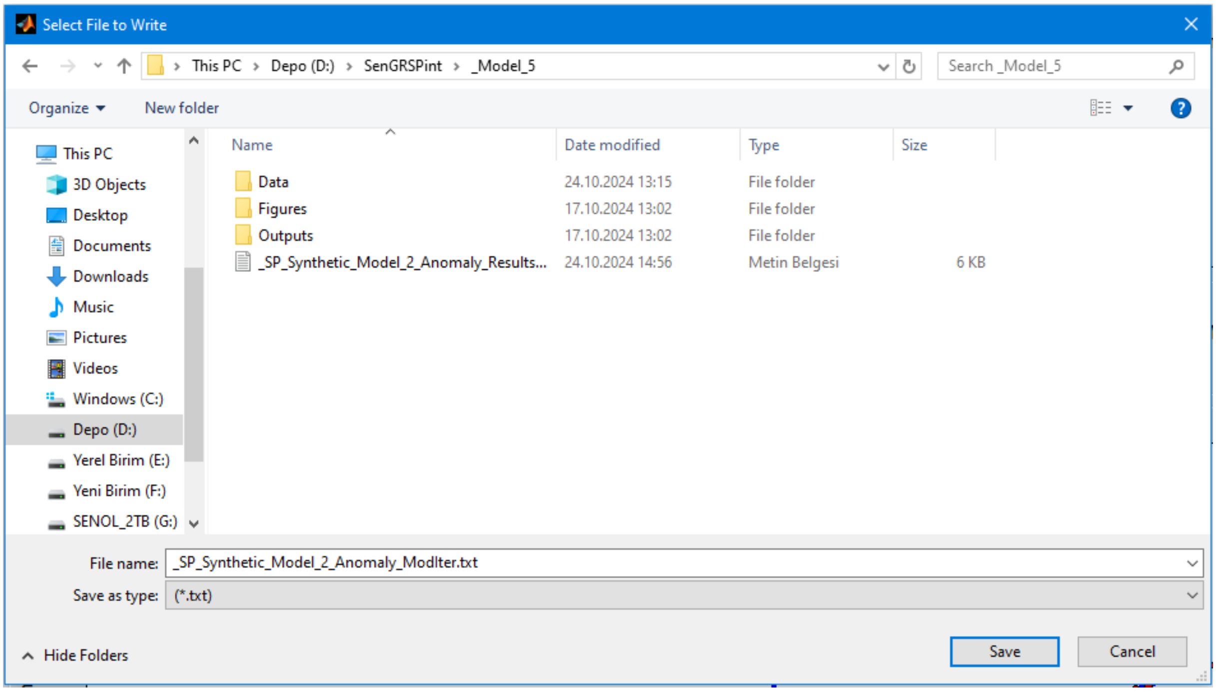


Figure 25. The results of the iteration steps depend on the s-value saved as a text file

s	RMS	x0	Depth	Ampl.	Angle	MeanDepth	MeanAmpl.	MeanAngle
1	3.5880e-03	55.0000	7.9992	-1199.9431	34.9995	7.9992	-1199.9431	34.9995
2	3.6859e-03	55.0000	7.9991	-1199.9376	34.9993	7.9992	-1199.9403	34.9994
3	3.4842e-03	55.0000	7.9994	-1199.9576	35.0000	7.9992	-1199.9461	34.9996
4	3.2165e-03	55.0000	7.9997	-1199.9807	35.0008	7.9994	-1199.9548	34.9999
5	2.9485e-03	55.0000	8.0001	-1200.0109	35.0019	7.9995	-1199.9660	35.0003
6	2.9795e-03	55.0000	7.9994	-1199.9566	35.0000	7.9995	-1199.9644	35.0003
7	2.8714e-03	55.0000	8.0001	-1200.0069	35.0017	7.9996	-1199.9705	35.0005
8	2.8813e-03	55.0000	7.9995	-1199.9653	35.0003	7.9996	-1199.9698	35.0004
9	2.8764e-03	55.0000	7.9996	-1199.9727	35.0005	7.9996	-1199.9702	35.0005
10	2.8389e-03	55.0000	7.9999	-1199.9970	35.0014	7.9996	-1199.9728	35.0005
11	2.8029e-03	55.0000	8.0001	-1200.0090	35.0018	7.9996	-1199.9761	35.0007
12	2.8244e-03	55.0000	7.9993	-1199.9512	34.9998	7.9996	-1199.9740	35.0006
13	2.7922e-03	55.0000	8.0002	-1200.0171	35.0021	7.9997	-1199.9774	35.0007
14	2.7766e-03	55.0000	8.0001	-1200.0096	35.0018	7.9997	-1199.9797	35.0008
15	2.8017e-03	55.0000	7.9990	-1199.9285	34.9990	7.9996	-1199.9763	35.0007
16	2.7773e-03	55.0000	8.0004	-1200.0289	35.0025	7.9997	-1199.9795	35.0008
17	2.7702e-03	55.0000	8.0000	-1200.0044	35.0017	7.9997	-1199.9810	35.0008
18	2.7750e-03	55.0000	7.9995	-1199.9623	35.0002	7.9997	-1199.9800	35.0008
19	2.7825e-03	55.0000	7.9994	-1199.9558	34.9999	7.9997	-1199.9787	35.0008
20	2.7644e-03	55.0000	8.0008	-1200.0632	35.0037	7.9997	-1199.9829	35.0009
21	2.7629e-03	55.0000	8.0005	-1200.0364	35.0028	7.9998	-1199.9855	35.0010
22	2.7742e-03	55.0000	8.0009	-1200.0704	35.0040	7.9998	-1199.9893	35.0011
23	2.7703e-03	55.0000	7.9996	-1199.9698	35.0004	7.9998	-1199.9885	35.0011
24	2.7737e-03	55.0000	8.0001	-1200.0064	35.0017	7.9998	-1199.9892	35.0011
25	2.7627e-03	55.0000	7.9983	-1199.8810	34.9973	7.9998	-1199.9849	35.0010
26	2.7665e-03	55.0000	7.9988	-1199.9118	34.9984	7.9997	-1199.9821	35.0009
27	2.7632e-03	55.0000	8.0011	-1200.0807	35.0043	7.9998	-1199.9857	35.0010
28	2.7746e-03	55.0000	8.0012	-1200.0886	35.0046	7.9998	-1199.9894	35.0011
29	2.7900e-03	55.0000	8.0008	-1200.0592	35.0036	7.9999	-1199.9918	35.0012
30	2.7684e-03	55.0000	7.9983	-1199.8766	34.9972	7.9998	-1199.9880	35.0011

Figure 26. The results of the iteration steps depend on the s-value

The **SAVE MODEL DATA** button should be clicked to save the model parameters into a text file. Then enter a filename and click the **Save** button in the pop-up window (Fig. 27). The output of the best model parameter values is saved as a text file in Fig. 28.

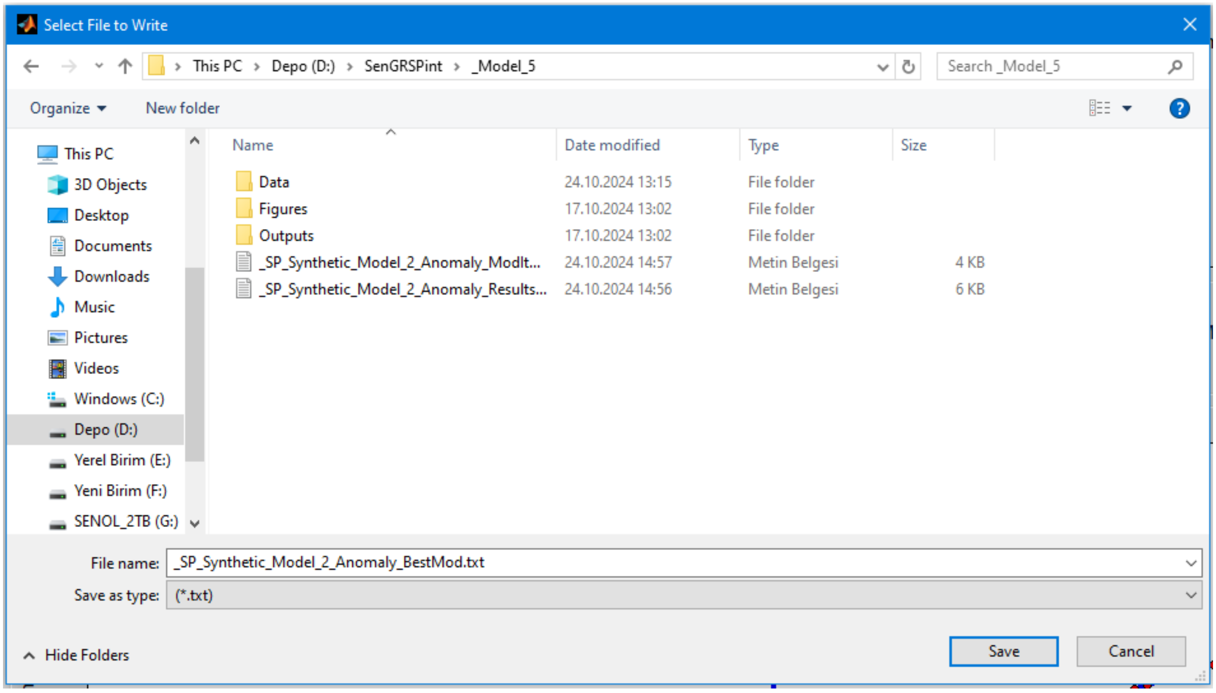


Figure 27. Saving the results obtained at the end of the iteration as a text file by giving a file name

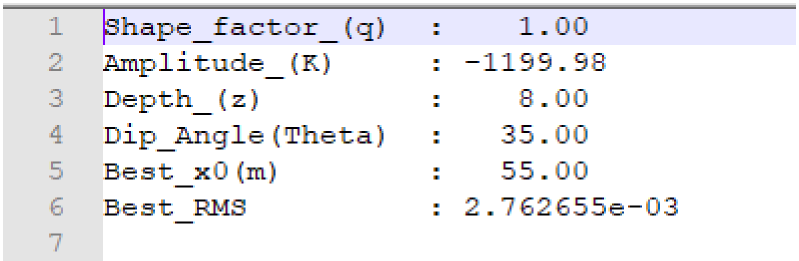


Figure 28. Output file view of the best parameter values obtained at the end of the iteration