EM4Soil

A program for 1-D laterally constrained inversion of EM data

Quasi-3D Module

Version-0.0

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DISCLAIMER

The programs (software) included in any version of the **EM4Soil** packed are provided "as are" without any express or implicit warranties including their suitability for a particular purpose. The authors and EMTOMO LDA will not assume any responsibility for any indirect or consequential damages or any loss caused by the use of these programs. Efforts will be made to correct any program bug that appears during the usage of the package.

CONTENTS

1. Introduction

The software described in this manual is for inversion of EM data (LIN approach) using the 1D spatially constrained algorithm. This software is a module of the **EM4Soil** package. Moreover, the Q-3D module (**Q3Dm**) is composed by a set of tools for data processing, visualization and inversion that are available through the **EM4Soil** -Map module.

The data is the measured apparent soil electrical conductivity (σ_a) as measured by EM instruments and is input through **EM4Soil** using the **Input/ input data/area** in the menu bar (please, see the **EM4Soil** manual).

This version of **Q3Dm** only can deals with data collected with **DUALEM and GEONICS** instruments**.**

The inversion procedure used in **Q3Dm** is a 1-Dimensional Spatially Constrained technique (1-D SCI). It is also known as a Quasi-3D inversion (Monteiro Santos et al. 2011). The forward modelling is based upon the cumulative function (McNeil, 1980). The called full solution of EM fields is not implemented in this version. The inversion algorithm is based upon the Occam regularization method (e.g. DeGroot and Constable 1990; Sasaki 1989).

2. The menu bar for Q3Dm

Figure 2.1 shows the screen shot of the **EM4Soil** Map module containing the **Q3Dm** functions.

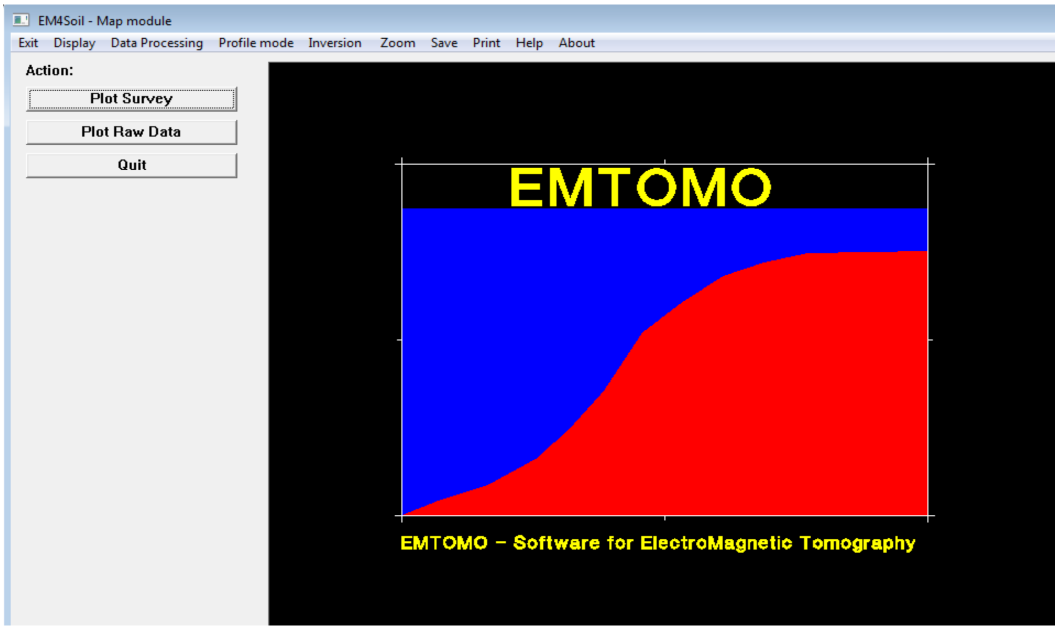


Figure 2.1. Screen shot of the **EM4Soil Map** module with Q3D functions.

At follow, a short description of those **Q3Dm** functions is presented.

2.1 Display

Click in the **Display/Q3D Model** entrance to display the results of an inversion. The results can be displayed as horizontal or vertical slices or in a 3D cube. Note that options or display Thickness and Bottom Elevation should be used with results calculated with algorithm S3. The Misfit entrance will display maps of misfit for each sensor. In **Settings** you can make choices about how to display your results.

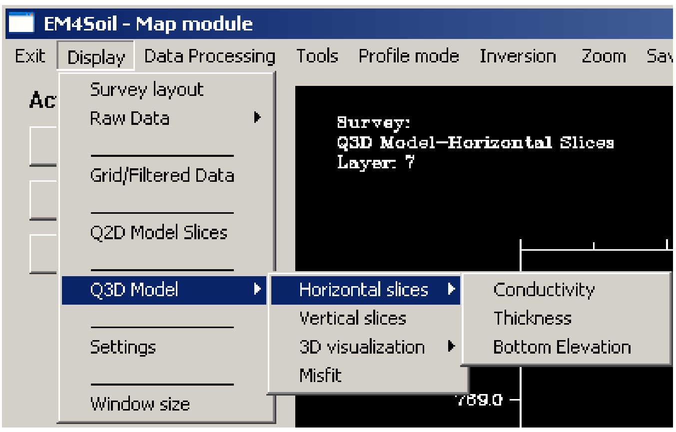


Figure 2.1.1. Displaying the results of a Q-3D inversion.

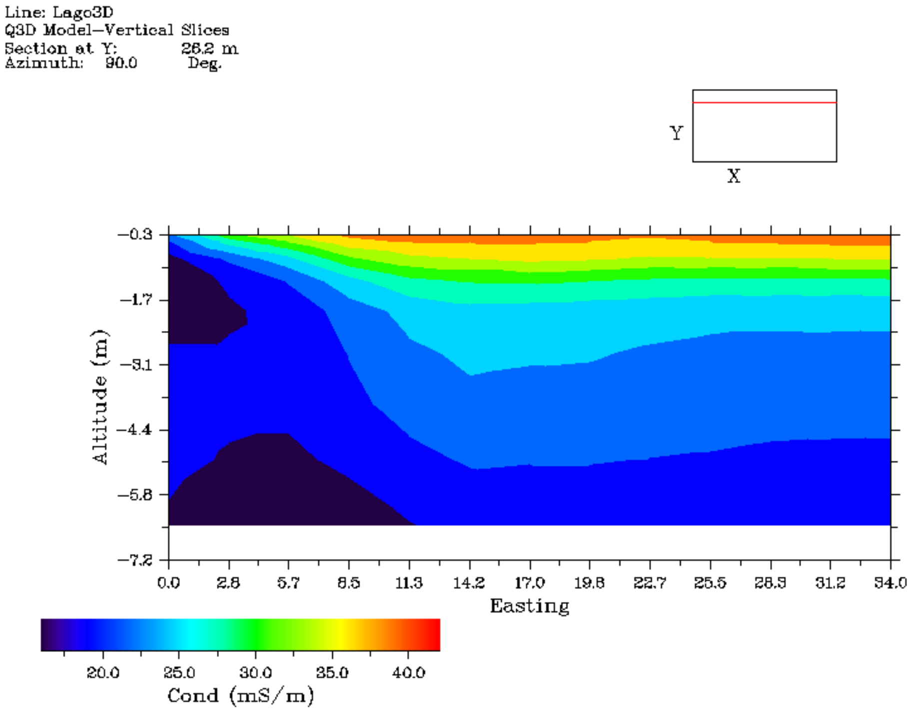


Figure 2.1.2. Displaying a vertical slice of the Q-3D model.

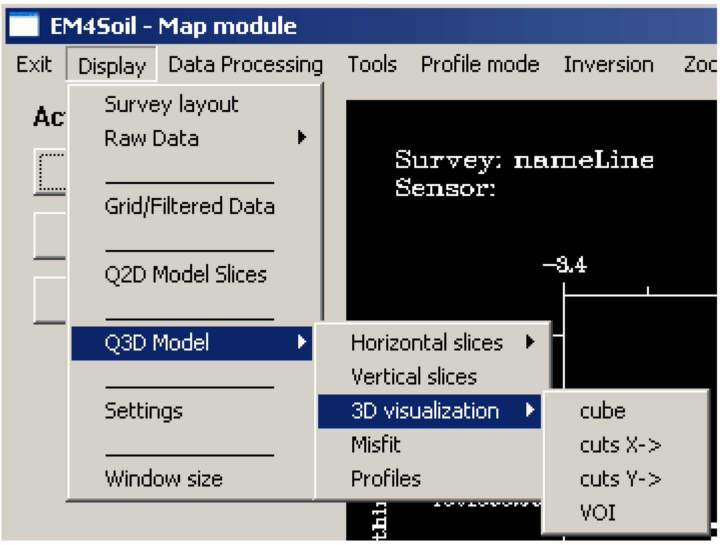


Figure 2.1.3. The different options for displaying results of a Q-3D inversion.

Figure 2.1.3 shows the different options to display the results in a 3D cube.

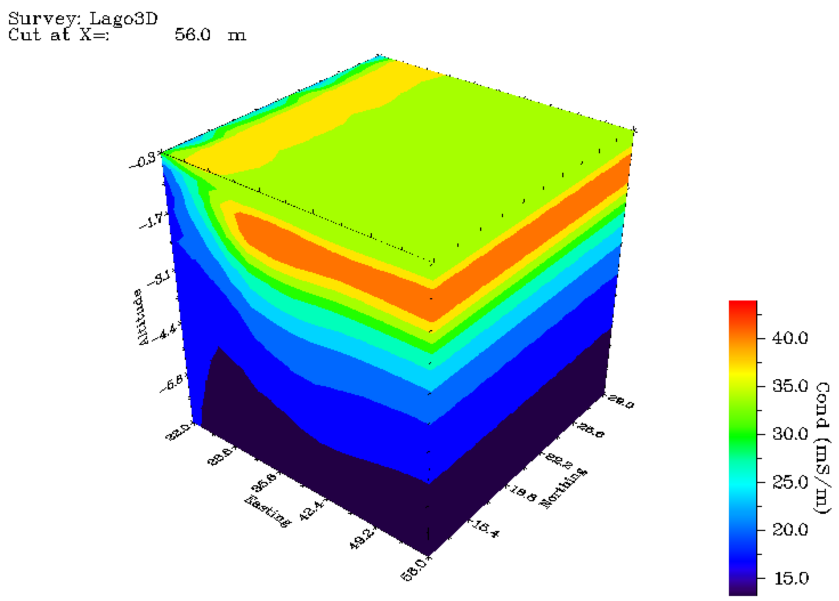


Figure 2.1.4. Displaying the model in a 3D cube.

The user can move through the 3D cube pushing the right mouse button.

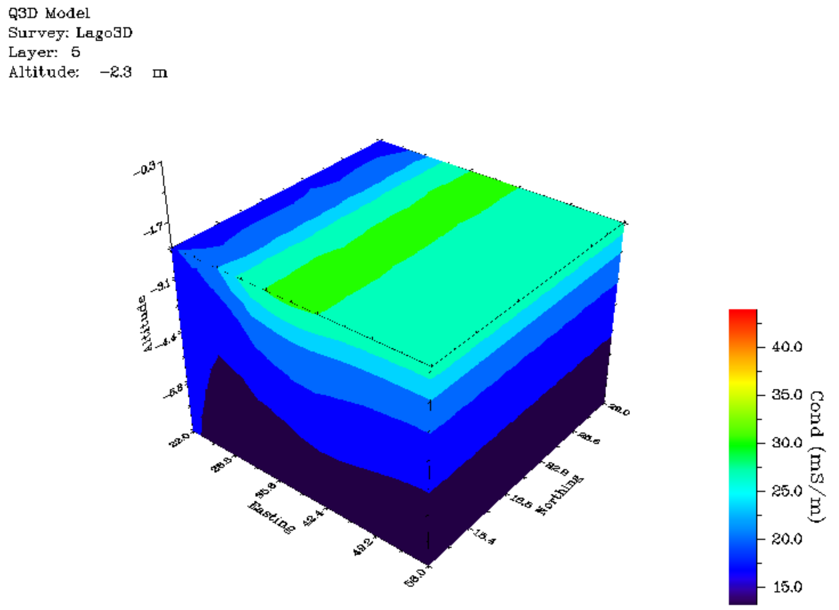


Figure 2.1.5. Displaying horizontal slices.

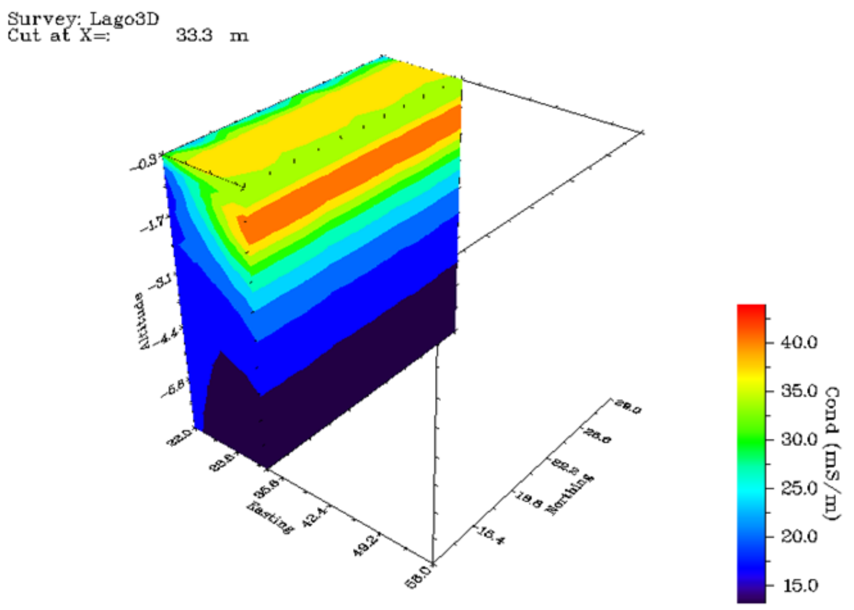


Figure 2.1.6. Displaying vertical slices parallel to Y direction.

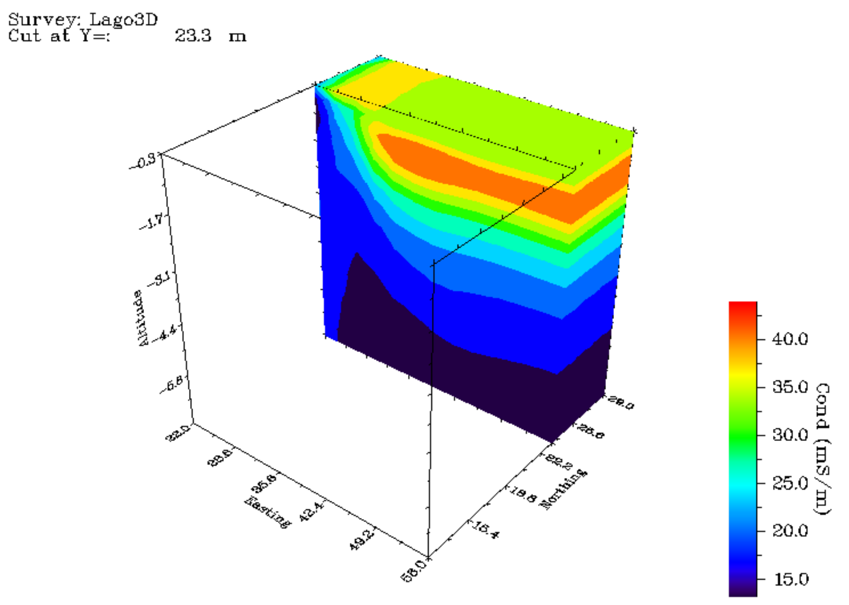


Figure 2.1.7. Displaying vertical slices parallel to X direction.

Clicking in the option **profiles** with the Q3D cube in the screen, the program will display the mesh of measurements used in the inversion (Figure 2.1.8) and the mouse pointer will be modified into a cross. Move it till the row and column of the mesh you want to see and click sequentially (without moving the mouse) in the left and right buttons. The easting and northing profiles of data and model response will be displayed (Figure 2.1.9).

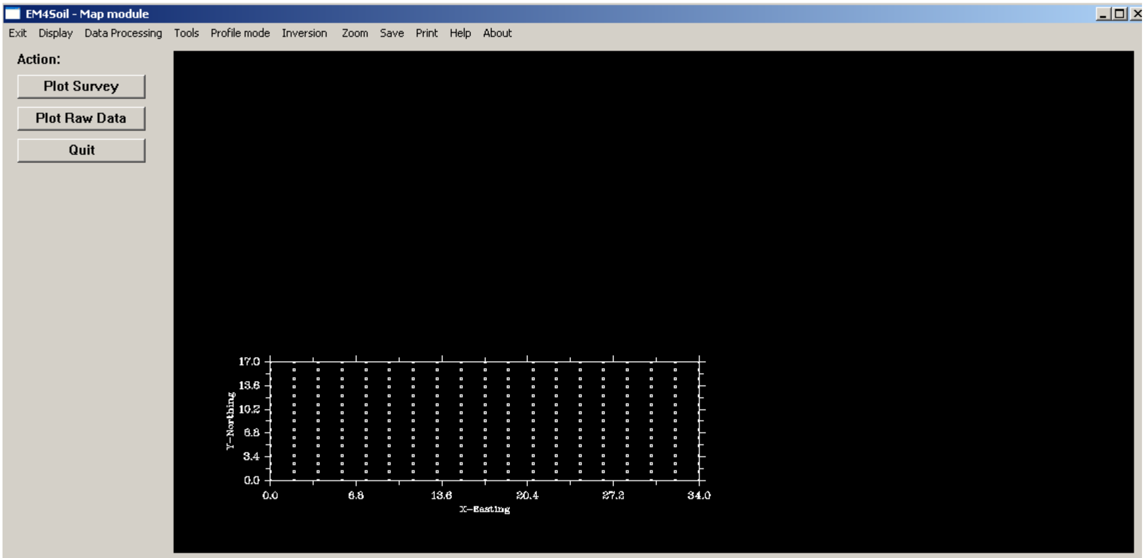


Figure 2.1.8. Mesh for selection of the profiles.

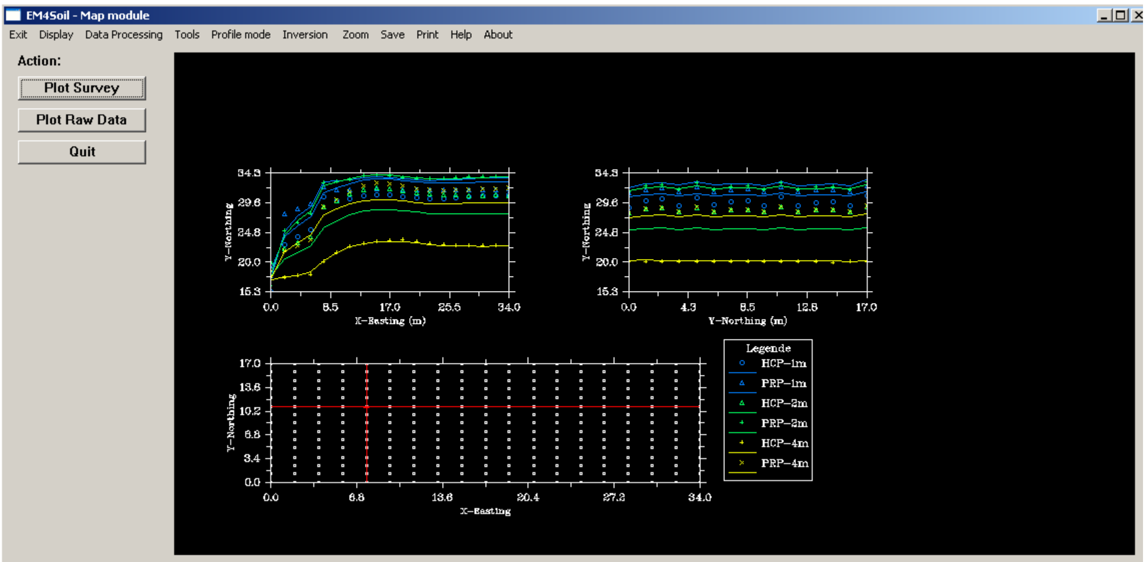


Figure 2.1.9. Easting and Northing profiles (data and model response) containing the selected point.

Figure 2.1.9. shows the **Setting menu** when the **Q3Dm** is active (after inversion). The menu is almost the same for the **EM4Soil** Map menu with the distance view scroll added. This allows the user to vary the distance between the observer and the 3D cube.

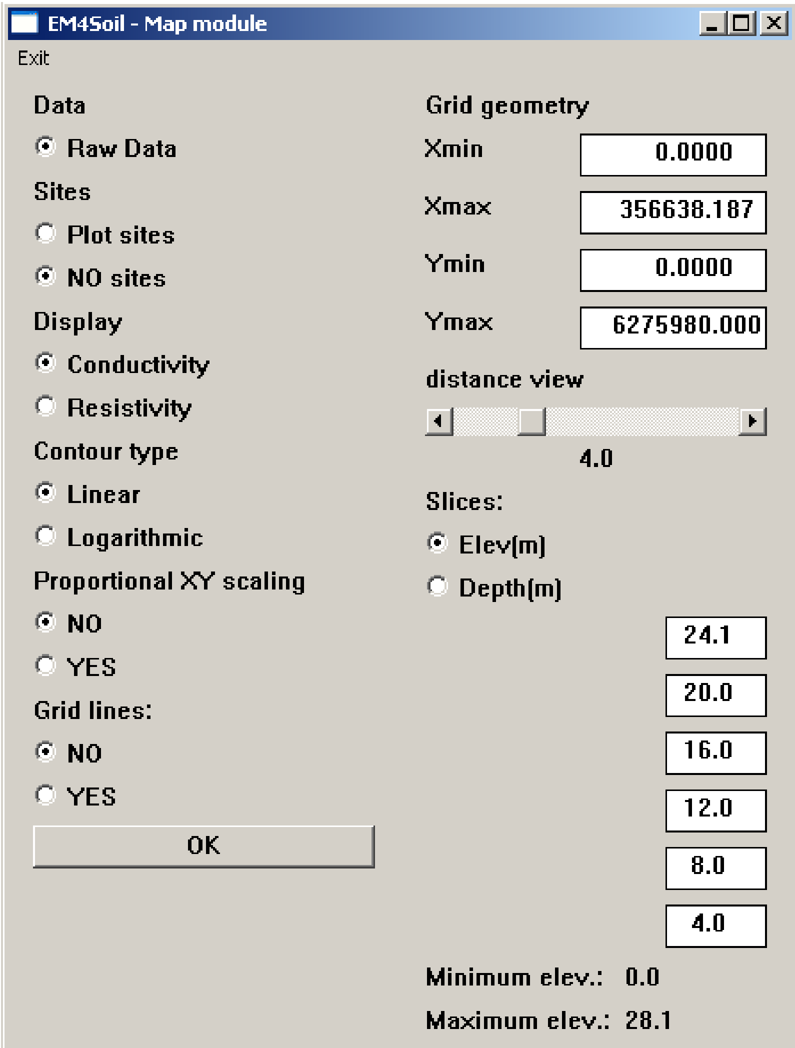


Figure 2.1.9. Settings menu.

The elevation/depth options only will select the horizontal slice of the Q-3D model that will be displayed if the option Display/Horizontal slices is used. It does not have influence in the 3D cube display.

2.2 Data Processing

These options are mainly devoted to prepare data for Q3D inversion. However, they can be used in any imported data. Their use was already explained in the EM4Soil manual and is repeated here.

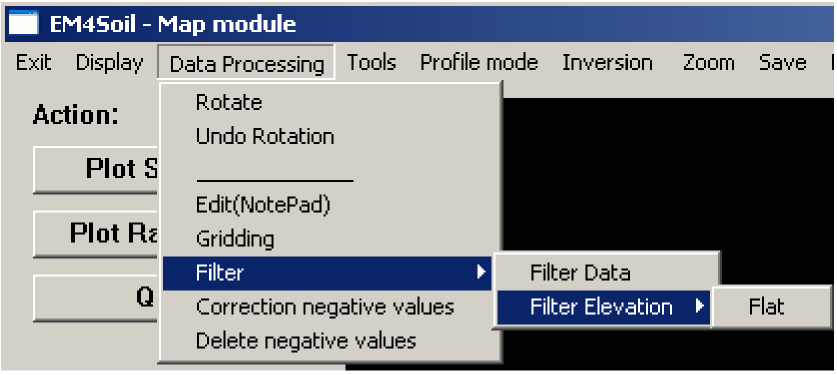


Figure 2.2.1. The **Data Processing** menu.

Grid files are necessary for the Q3-D inversion. Data files contain in general randomly spaced measuring sites, and should be converted into a regular grid before inversion. **To create a grid file** the user must specify the parameters (limits of the area to grid, number of points in the X and Y directions), as well as, the output file. The output file has the mask EMGr (it is assumed by default). The output file menu will appear after click OK.

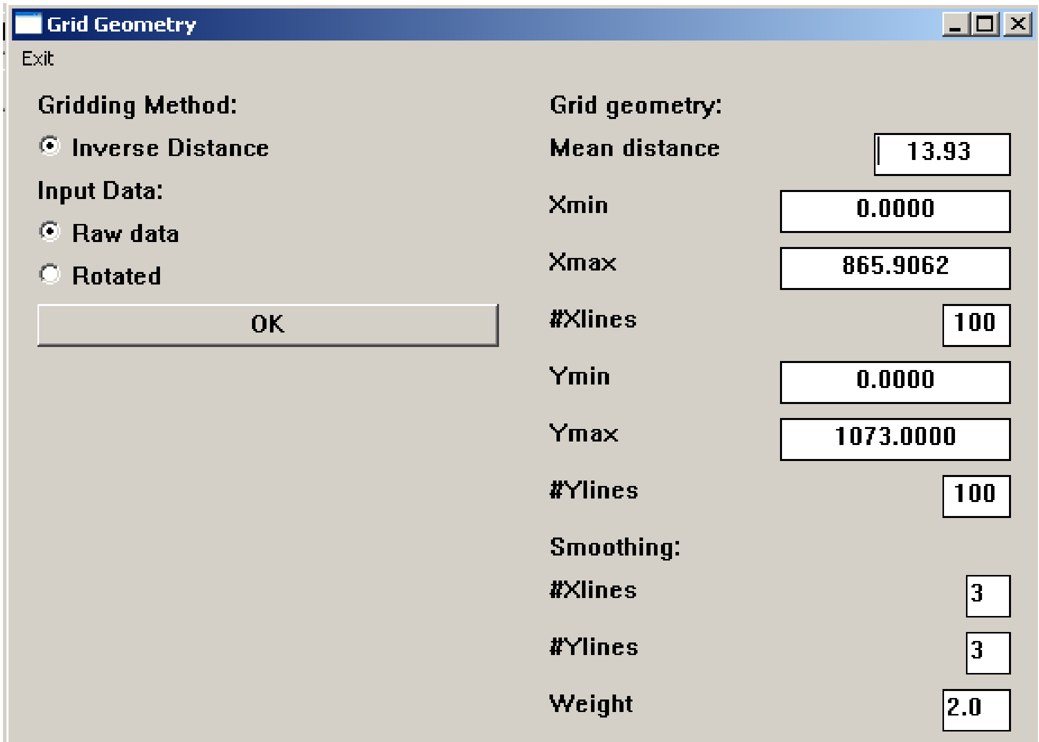


Figure 2.2.2. The **Data Gridding** widget.

The *mean distance* between measuring sites (=1.25*average distance) is used to suggest values for the number of points in X and Y directions. The number of points in X directions is approximately calculated by (Xmax-Xmin)/(mean distance). A similar calculation is applied to the Y direction. If those values are >100 the program write the value 100 recalculating also the *mean distance value*.
Changing the Xmax, Xmin, Ymax and Ymin allows to grid only a part of the area covered by the survey.

Rotated files can also be rotated. The gridding must be done immediately after rotation. Click OK firstly to get the limits and mean distance corresponding to the rotated survey.

The inverse distance option uses the GETMAT subroutine in DISLIN. The value at the grid point (j,k) is calculated by:

$$z_{i,j} = \frac{\sum_{i=1}^{N} \frac{z_i}{d_i^w}}{\sum_{i=1}^{N} \frac{1}{d_i^w}}$$

Where, (j,k) are the indices from 1 to Nx lines and 1 to Ny lines, respectively, d_i is the distance of the grid point (i,k) from the point P_i, w is a weighting number (default is 2.0) and N is the number of data points lying in the area (controlled by the parameters in the smoothing section) around the grid point (j,k).

The grid files can be filtered. The available filters are linear low-pass filters and should be applied to reduce the high frequency noise. They calculate weighted averages of the neighbouring input grid nodes. In the **Moving Average** (SxT) filter the weight are equal to one.
In the **Inverse Distance** (SxT) filter, the weights fall-off with increased distance. The role of the distance is controlled by the Power. The higher the power the more rapidly the weights fall-off with distance. The filter can be applied to all data set or only to specific channels.

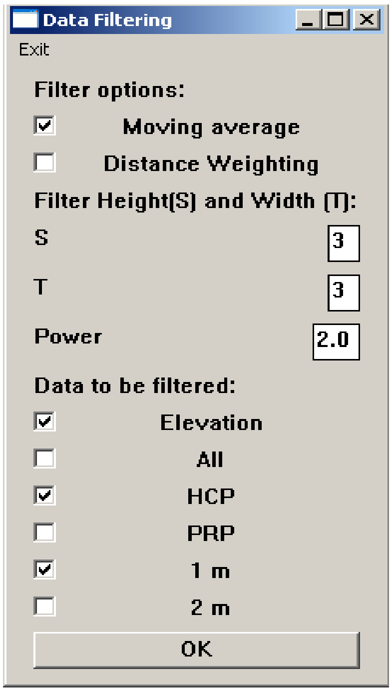


Figure 2.2.3. The **Filter parameters** menu (D-21S).

If the number of negative values in the data set is less than 30% of all data, the user can try to **correct** or **delete** them.

It must be noted that correcting data can originate false anomalies. The user must pay attention to this relevant issue.

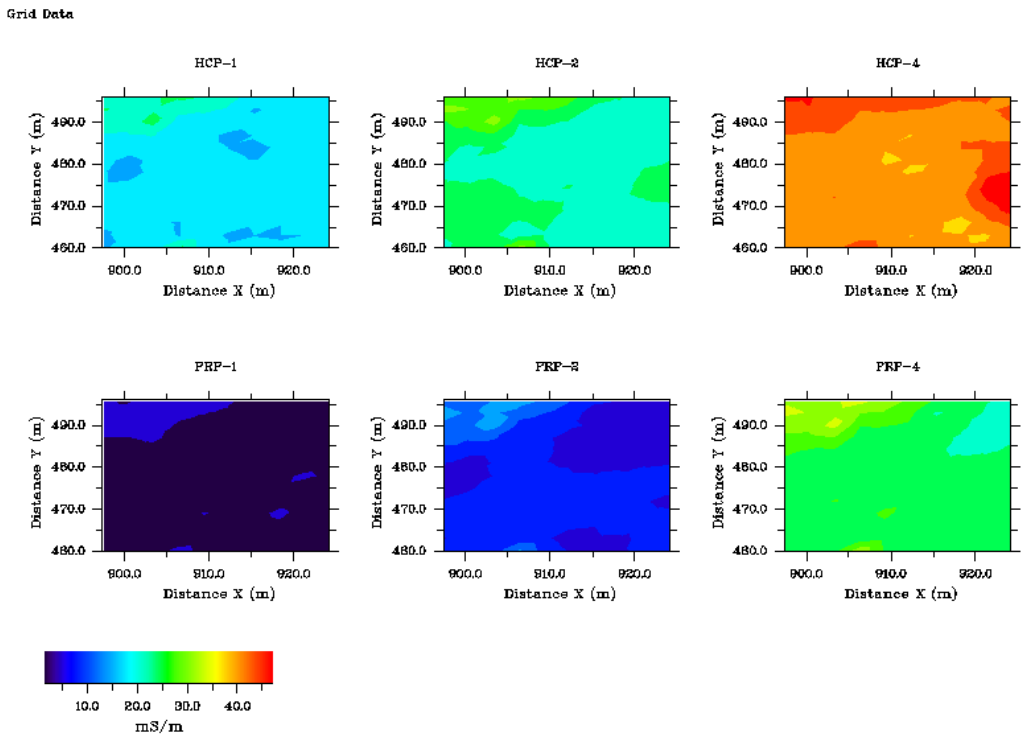


Figure 2.2.4. Example of a gridded data set.

The survey can be rotated according to an angle measured from North. The program can calculate the rotation angle, selecting the option Automatic. However, the user should confirm the survey is properly rotated. New rotations are added to previous ones.

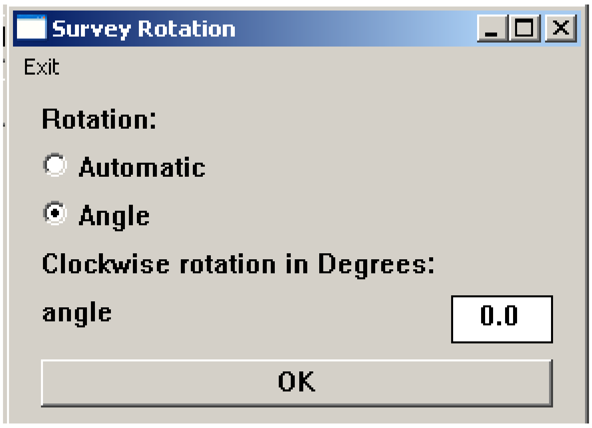


Figure 2.2.5. Options for rotation.

The rotated survey will be displayed in a new window. The rotation is made relatively to a point located approximately in the geometric centre of the survey which is the origin of the local coordinates used for the rotated survey. When a rotated survey is inverted the original coordinates are recovered at the end of the inversion.

2.3 Inversion

The inversion entrance allows the user to define the parameters of the inversion, the initial model as well as to run the inversion (Figure 2.3.1 to 2.3.3).

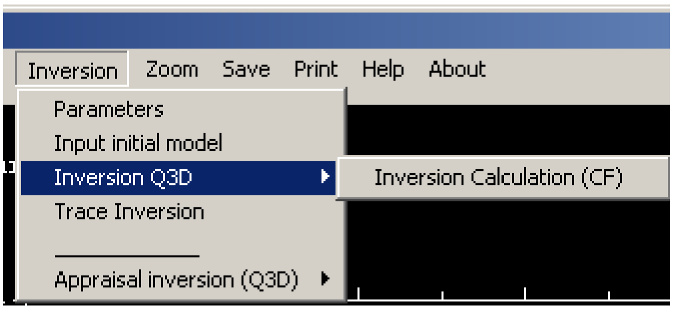


Figure 2.3.1. The inversion menu.

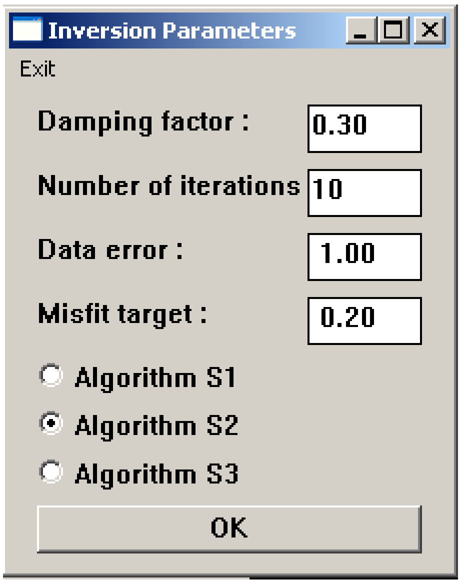


Figure 2.3.2. Selecting parameters for inversion.

The algorithms used in the Q-3D inversions are basically the same of those used in the Q-2D inversion with one exception: the S3 algorithm. The S3 algorithm is designed to invert data collected with instruments containing only one sensor like DUALEM-1s, -2s, -4s or with EM38 and EM31. In this case the initial model should be defined manually (usually a two-layer model), or read in a file.

Regarding algorithms S1 and S2, the reader is referred to the **EM4Soil** manual. The same is valid for the different formats of initial model.

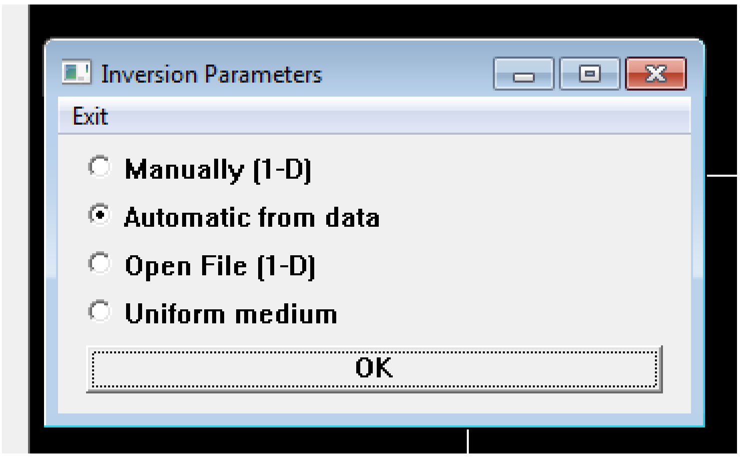


Figure 2.3.3. Selecting the initial model.

In this version of **Q3Dm** the inversion only can be done on gridded data. Therefore, the user must produce a grid file (see how to do that in 2.2). Such files should have the EMGR mask (or other that have been chosen by the user),

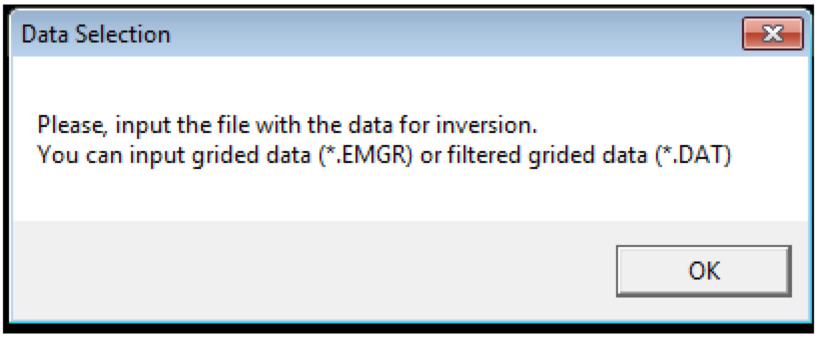
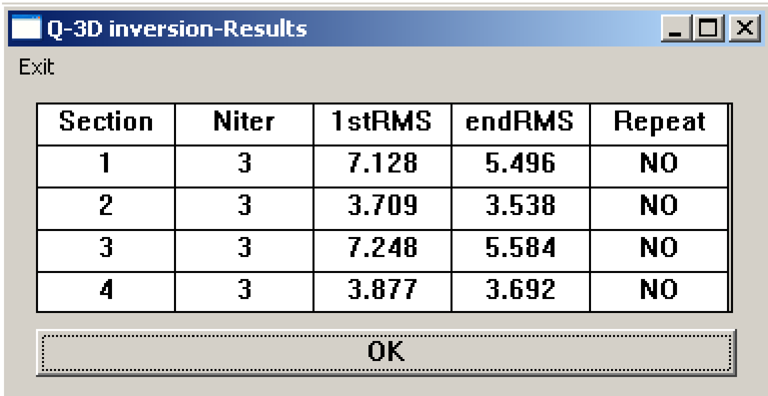


Figure 2.3.4. Inputting a grid file for inversion.

According to the dimensions of the grid, the program will divide the area in sections, performing the inversion of each section separately. However, contiguous sections will have common areas in the border zones in order to avoid inconsistencies in the final model. Nevertheless, the process can originate undesirable effects in special occasions. We recommend a careful analysis of the final models.



Section	Niter	1stRMS	endRMS	Repeat
1	3	7.128	5.496	NO
2	3	3.709	3.538	NO
3	3	7.248	5.584	NO
4	3	3.877	3.692	NO

Figure 2.3.5. Tracing the inversion.

The initial and final misfit for each section will be displayed in a table (Figure 2.3.5). The user can repeat the inversion of any section changing the NO in the last column into YES (or Y) and repeating the inversion.

After the inversion has finished the results can be displayed using the options mentioned in 2.1.

2.4 Initial models

The initial model used in the inversion is one of the most important aspects to take into account. Such initial model depends on the data set to be inverted. Different sensors have different depth of investigation that is also function of the geoelectrical profile of the earth. **Therefore, it is advisable to invert the data with different initial models before to select the final inversion**.

Examples of initial models for **DUALEM-421s**; **DUALEM-642s**; **PROFILER** (for very high conductivity terrain) and **EM34** are presented below (see formats in the section 9 of the EM4Soil Manual).

DUALEM-421s:

9
0.3 0.6 1.0 1.5 2.3 3.3 4.5 5.7
30 30 30 30 30 30 30 30 30

DUALEM-642s:

8
0.6 1.2 2.2 3.3 4.5 6.0 8.0
10 10 10 10 10 10 10 10

PROFILER:
6
0.3 0.7 1.2 2.4 3.7
1600 1600 1600 1600 1600 1600

EM34:
8
3.0 6.0 9.0 12.0 16.0 24.0 40.0
100 100 100 100 100 100 100 100

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