VLF2DMF

A program for 2-D inversion of multifrequency VLF-EM data

Version-2.2

This Software is produced by EMTOMO
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DISCLAIMER

The programs (software) included in any version of the **VLF2DMF** packed are provided “as are” without any express or implicit warranties including their suitability for a particular purpose. The author **EMTOMO LDA** and **REFLEXOS** will not assume any responsibility for any damage or loss caused using these programs. Efforts will be made to correct any program bug that appears during the usage of the package and reported to the author.

Content

1. Introduction

VLF2DMF is a software package that has been developed to enable the processing and inversion of electromagnetic (EM) induction data acquired at Very Low Frequency (VLF). A review of the VLF theory, as well as practical applications regarding the geology and hydrogeology, can be found in McNeill and Labson (1991).

VLF2DMF is capable of inverting VLF-EM and VLF-R data acquired along a survey line (i.e. transect) at different frequencies. Inversion of magnetic total field and cooperative inversion of VLF-EM and magnetic data are also available when required. Data collected in a survey area can also be processed but not inverted as a set. The input data is the real and imaginary parts of the tipper (or the tilt angle and the ellipticity), also designed as in-phase and quadrature components as measured by VLF-EM instruments or the apparent resistivity and phase when dealing with VLF-R. The package includes a 3D viewer (**3DViewVLF**) that allows the display of the survey results. The program can also be used in modelling studies. The user can build a complex resistivity model and calculate its VLF-EM and VLF-R response.

VLF2DMF assumes a referential system with the vertical axis (Z) positive upwards (Figure 1.1). The line survey is assumed to be carried out along Y direction.

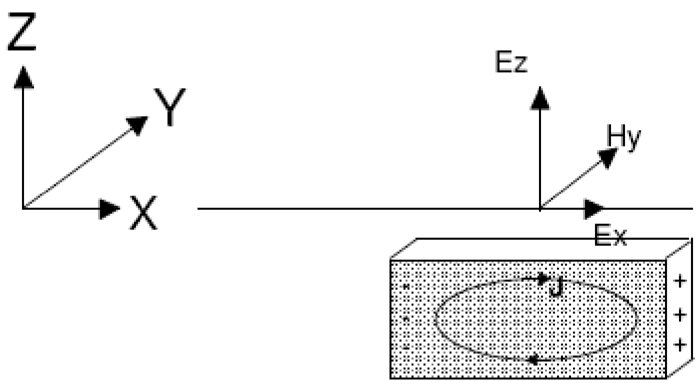


Figure 1.1. The VLF-EM electromagnetic field. Data acquisition is along Y direction.

The inversion procedure used in **VLF2DMF** is two-dimensional (2-D) and is based on the Occam technique (e.g. DeGroot and Constable 1990, Sasaki 1989, Sasaki 2001). The forward modelling of **VLF2DMF** program is based on the finite-element method.

2. VLF2DMF Package Items

The **VLF2DMF** package is a 64-bit application that can run on Windows. **VLF2DMF** has a graphical user interface based on the DISLIN[1] graphics library (http://www.dislin.de).

The package is distributed in two ZIP files:

VLF2DMF.zip
3DViewVLF.zip

3. VLF2DMF Installation

To install the **VLF2DMF** program in your computer, take the following steps:

1) Create a new folder on the disk C: (for example c:\VLF2D)
2) Unzip all files on the new folder
3) Run the **SETUP** file

The first time you run the **VLF2DMF** software you will be asked to provide an alpha-numeric key (see left hand panel of Figure 3.1). In order to obtain the key you will need to send an email (**emtomog@gmail.com**) with the CODE displayed by the program (e.g. RXHTR). You will get a file (key.key) that must be saved on the folder overwriting the old one. After that you can begin using **VLF2DMF**.

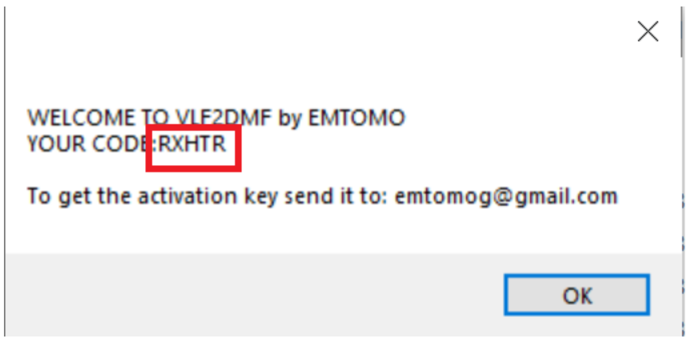


Figure 3.1. Screen snapshots which show the **VLF2DMF** CODE corresponding to your software package and where to input the key once the CODE has been sent.

NOTE: The key links the program to a particular computer. A new key is necessary to run the program in another computer.

It is recommended to create a shortcut for **VLF2DMF**. Use the logo.ico to identify the software in your desktop.

To use the logo.ico file proceed as follow:

- Create a shortcut of the **VLF2DMF** file (click on the right mouse button on the file),
- Move the shortcut icon to Desktop,

[1] DISLIN is authored by Helmut Michels, Max-Planck-Institute

- Go to its properties using the right mouse button and there use the Change icon option to change for the new one,
- Go to the General properties and change the name to **VLF2DMF.**

Install the **3DViewVLF** program in a different folder doing a similar proceeding. **3DViewVLF** does not need an activation key.

NOTE: Save the key in a safe place. You may need it in the future.
NOTE: Make a copy of all files in a safe support for future replacements.

4. Running VLF2DMF

To run the software, double click on the **VLF2DMF** icon. The software will start up and the screen snapshot shown in Figure 4.1 will appear. This is the welcome page.

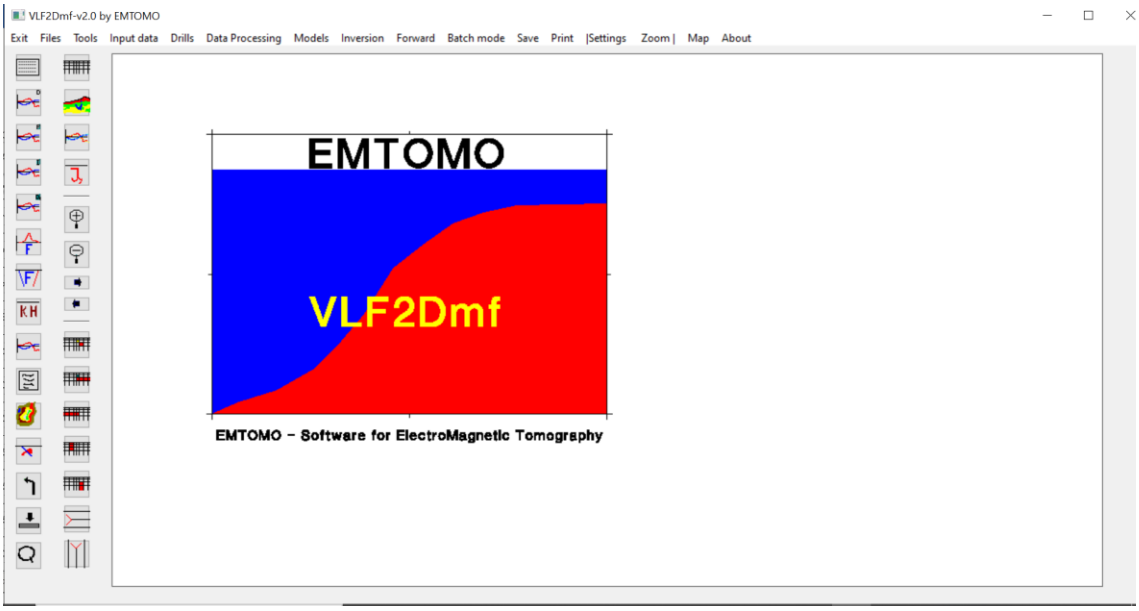


Figure 4.1. Screen shot of the **VLF2DMF** main screen.

Figure 4.2 shows the welcome page of **VLF2DMF** that has a menu bar with operational buttons.

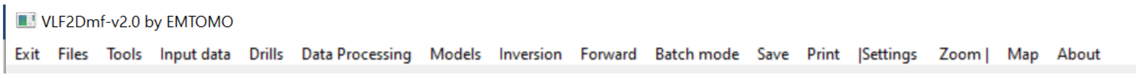


Figure 4.2. Screen shot of the **VLF2DMF** menu bar operation buttons.

In addition, and along the left-hand side of the welcome page, there are several buttons to facilitate some actions (Figure 4.3).

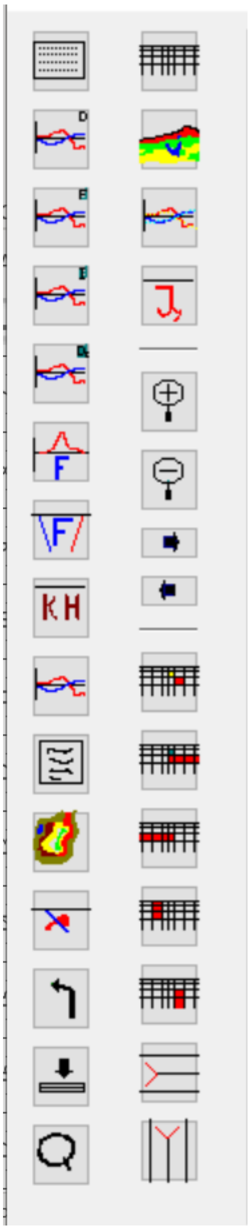
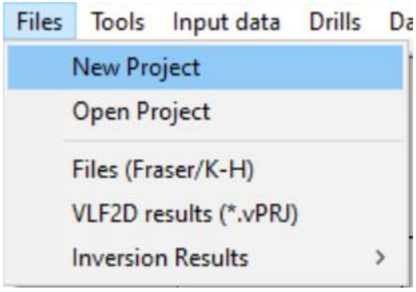


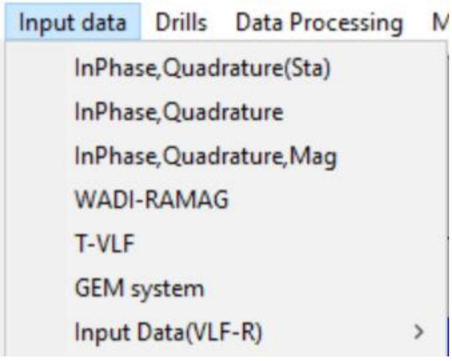
Figure 4.3. Screen shot of the **VLF2DMF** plotting action buttons.

5. Input data

5.1. The first action must be to create a new project file. Click in New Project and give a name for the project files. Four PROJ files will be generated named #PI.PROJ; #P.PROJ; #MI.PROJ and #M.PROJ. All the four files are needed to save the results.

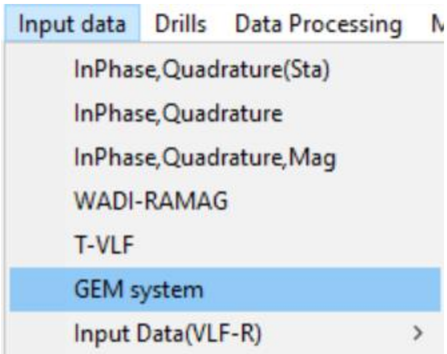


5.2. Data must be input using one of the options displayed in the Input data menu,

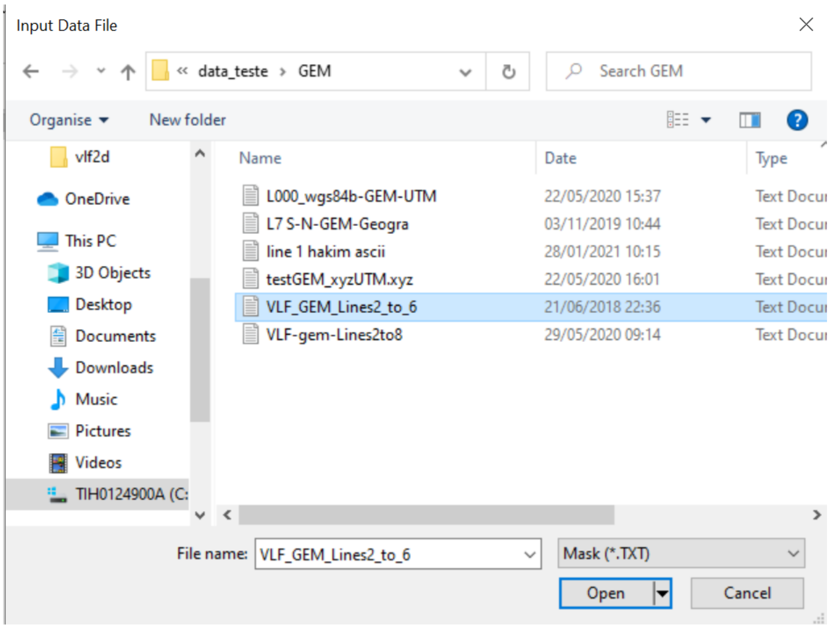


The three first options are for data files written using specific formats explained later (in Input Formats). Data exported by RAMAG, T-VLF software and GEM System data logger can be input using the respective option (see below details about each option).

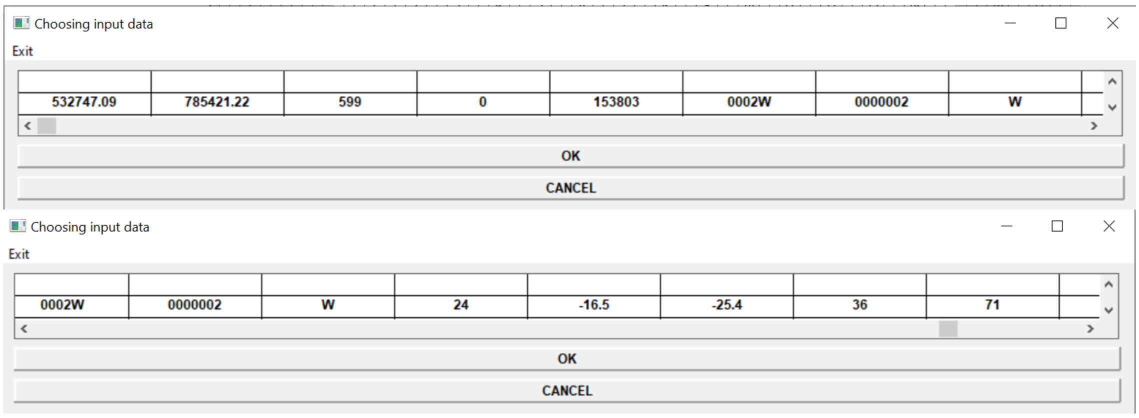
Let us see here the option to read a GEM System file. Start choosing the correct option,



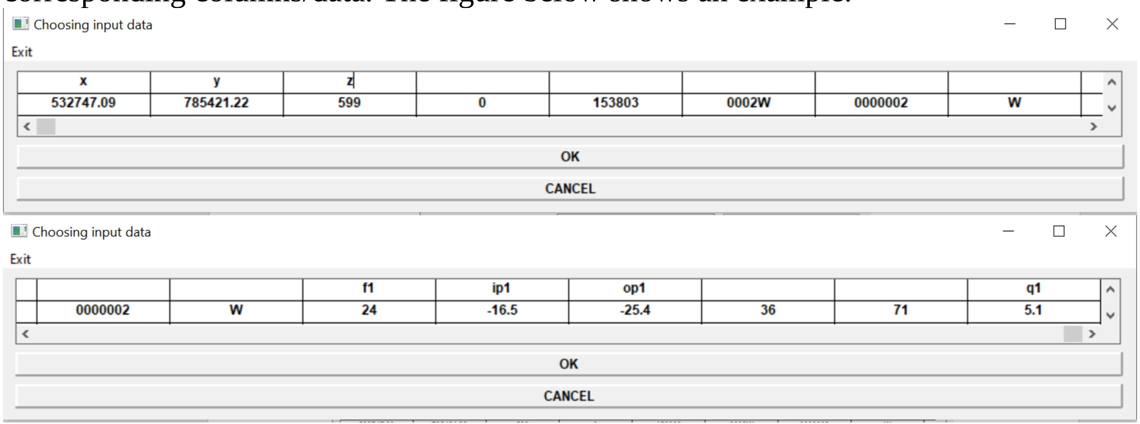
Select the data file,



The program displays the first row of the data. The user must select the correct columns with the data (coordinates, elevation, frequency, in-phase and out-phase for each frequency)



The uppermost row of the table must be filled with the correct symbol for the corresponding columns/data. The figure below shows an example.

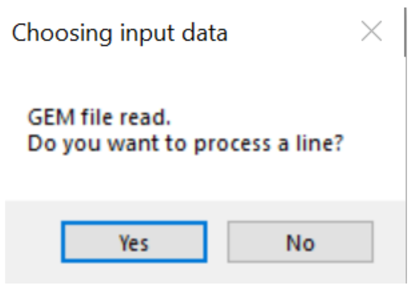


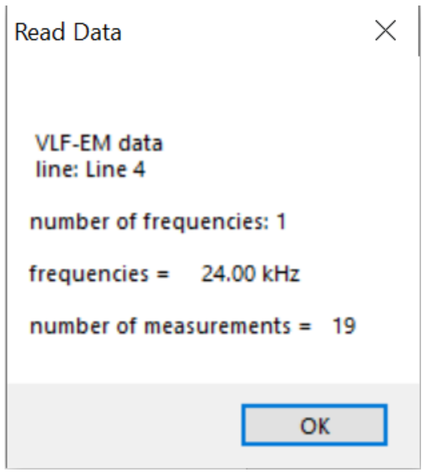
According to the data in the file the appropriated names for the columns are:

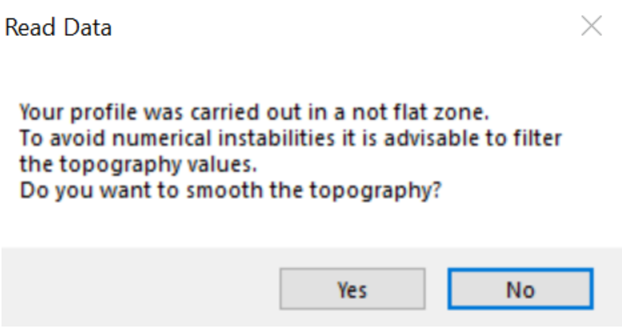
X – coordinate XUTM (eastern)
Y – coordinate YUTM (northern)
Z – elevation
Line (line, l) – for line
Site (site, s) – for station
F1 (f1) – first frequency
IP1 (ip1) – in-phase for F1
OP1 (op1) – out-phase for F1
Q1 (q1) - for the pT column (which is a data quality factor)
…similar for the other frequencies.
M (m) – for the total magnetic field if it is present on the file.

If the elevation is not present in the data, the program will assume an elevation of 0.0 m. UTM coordinates and lines/sites cannot be selected in the same input.

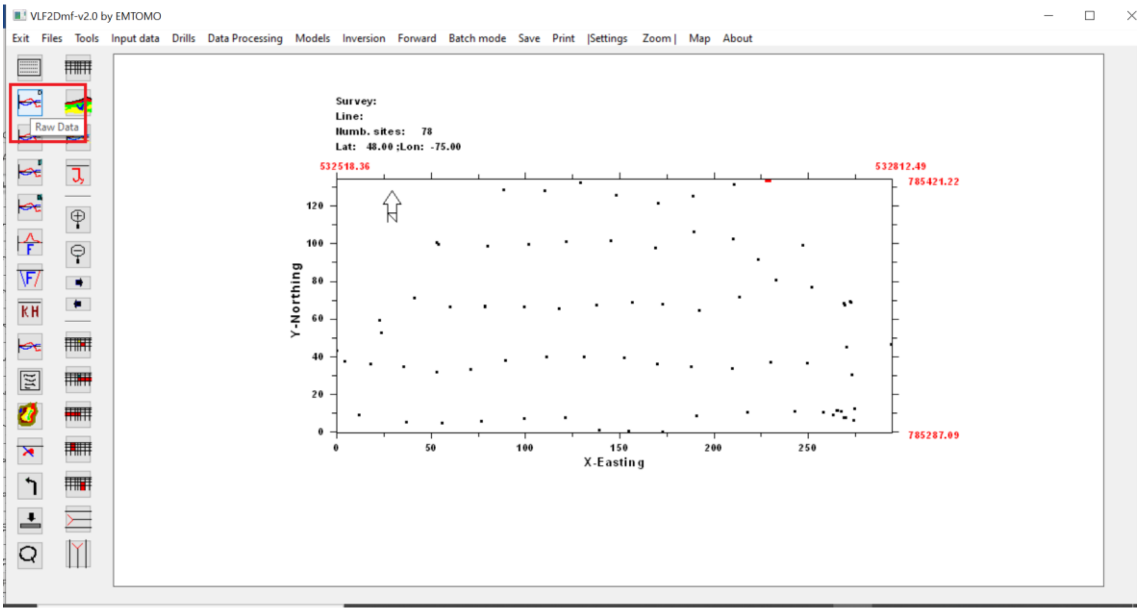
The program will display the following screens,



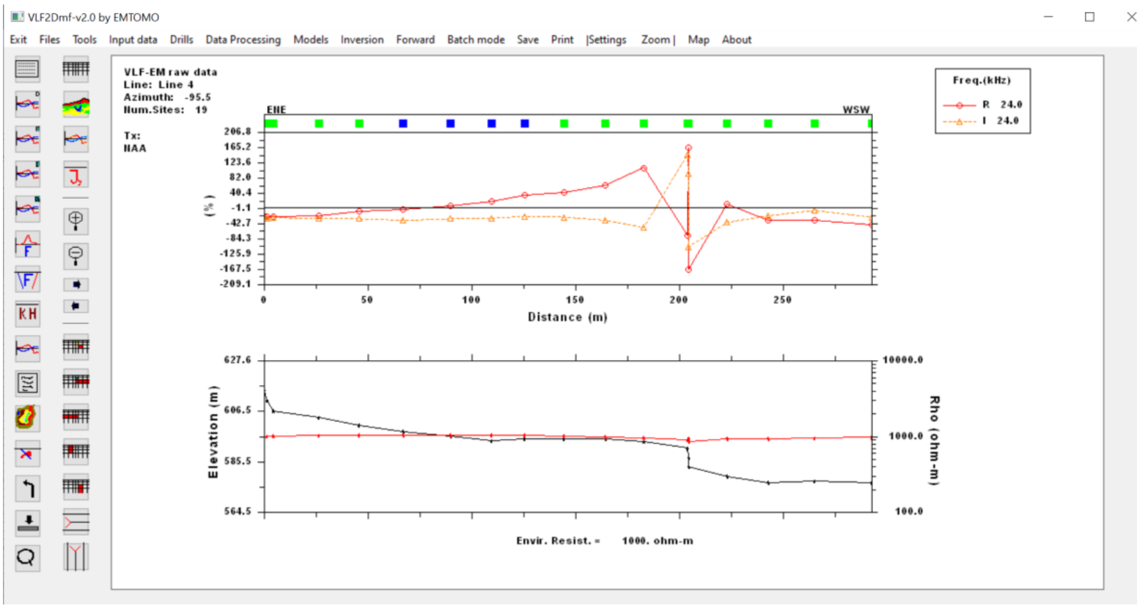




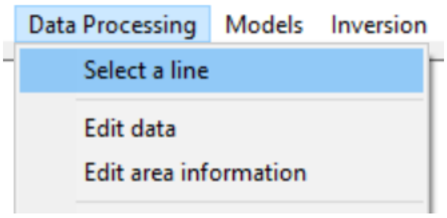
Till the survey is displayed,



The selected profile will be displayed after pushing the “raw data” button on the left panel. The figure shows the in-phase (Real part) and the out-phase (Imaginary part) for each frequency, in the top and the topography and the apparent resistivity curve in the bottom. The coloured squares on the top represents the data quality for each reading and measured site. Red colour is associated to bad data and green to good data.

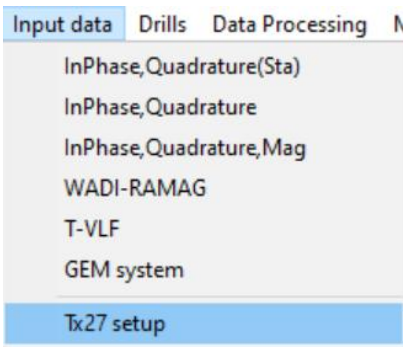


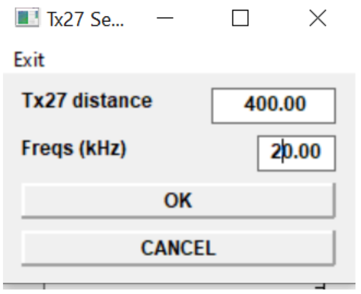
To choose another file go to Data Processing -> select a line,

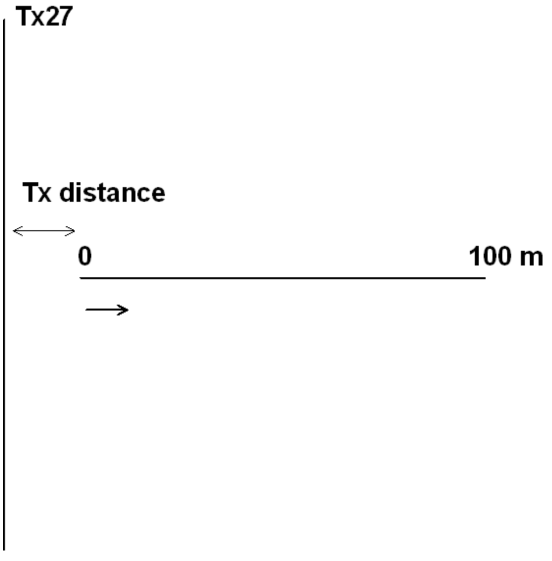


Using the Tx27 personal transmitter (only available by requirement)

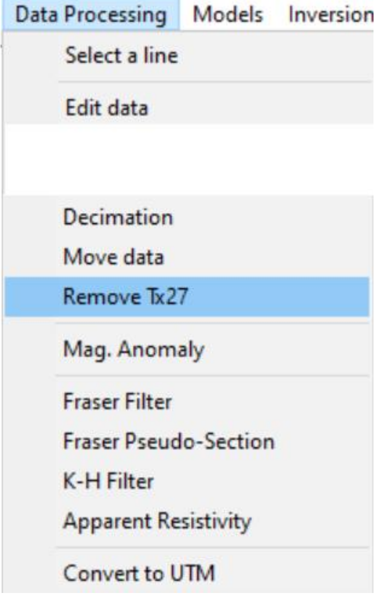
If the data was acquired using the Tx27 transmitter (from GEONICS) its location and frequency needs to be included,



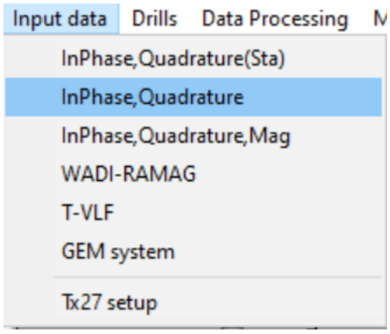




If the transmitter is a large distance from the profile the Tx27 effect can be removed and the data interpretated not considering the Tx27 presence.

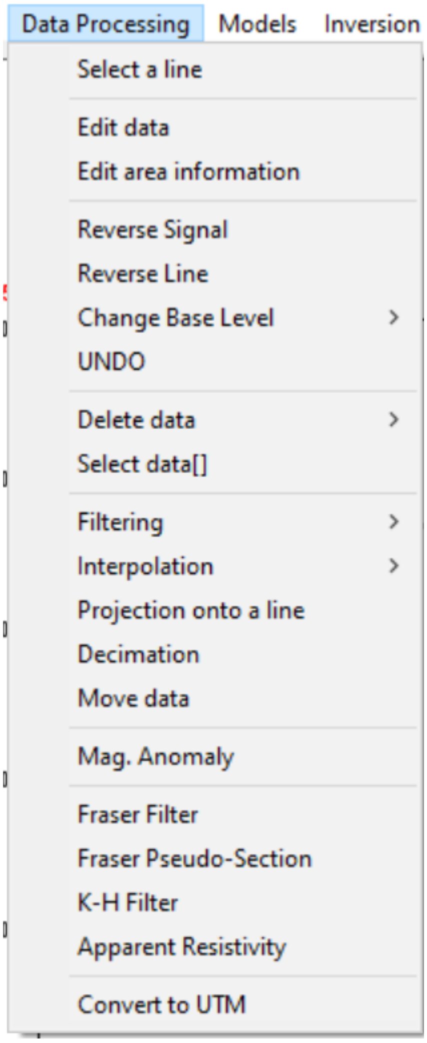


Data acquired with Tx27 must be input in files using the IQ format (see paragraph 11.2. in this manual).



6. Data processing

After the input and display the one line it is possible to process the data applying different filters,



It is advisable to apply the in the following sequence:

- Covert geographic coordinates into UTM (if necessary),
- Filter the topography,
- Change the base line if necessary (manually or automatically)
- Reverse signals/profile (if necessary),
- Data filter, interpolation, and resampling
- Average or EMD filters,
- Delete/decimate.

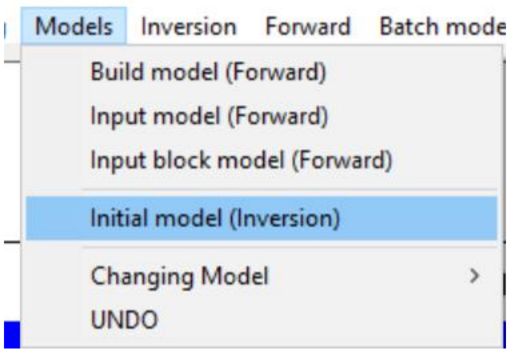
After filtering the data, the Fraser and Karous-Hjelt (K-H) filters can be applied. The calculated results can be saved in the PROJ file or in XYZ file for future display using the **3DViewVLF** program. To save in the PROJ file push the button,

To save in a XYZ file go to Save and choose the right option.

7. Inversion

7.1. Building an initial model for VLF inversion

One need to define an initial model to perform the inversion. In the Models click in Initial model (inversion). Clicking in this option will open a new menu from where different options can be selected to build an initial model for the inversion. The menu has three sections: the first one allows different ways to build or read the model; the second is about the data that will be used in the inversion, while the last one is related with the topography and initial environmental resistivity value. Default options are shown.



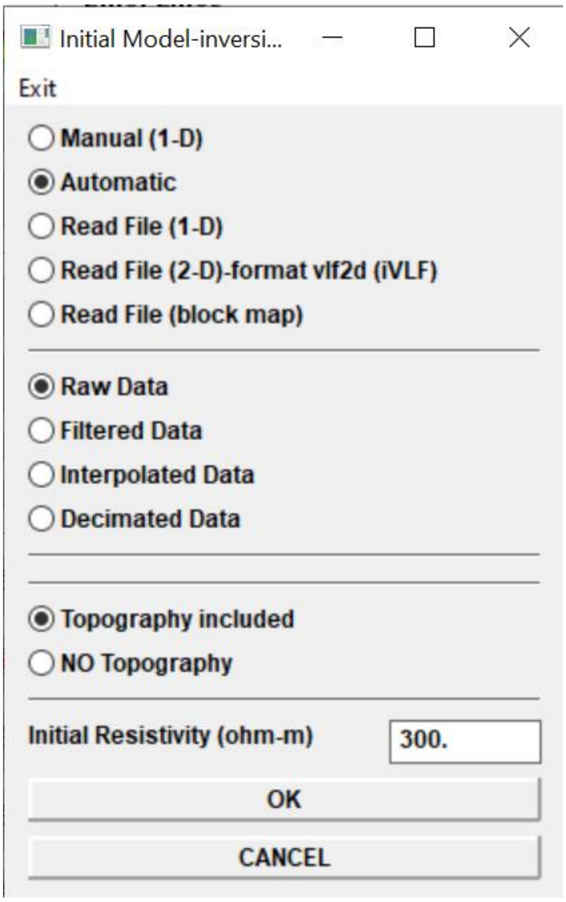


Figure. Menu for the setup of a model (inversion).

7.2. Inversion VLF-EM data

After processing, the data is ready for inversion. Selecting the **Inversion/VLF inversion** option, the program will allow you to define some inversion parameters and to start the inversion.

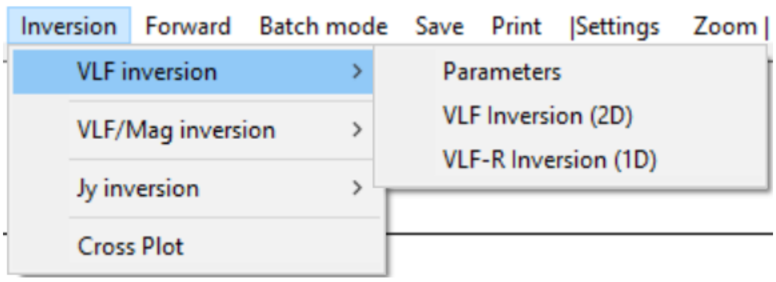


Figure. Drop down box menu for **Inversion** selection. From this main menu you can select to perform the inversion. The parameters for the inversion are chosen from this menu, too.

Selecting the **Parameters** option, the program will display the following menu, which allows you to define some of the inversion parameters.

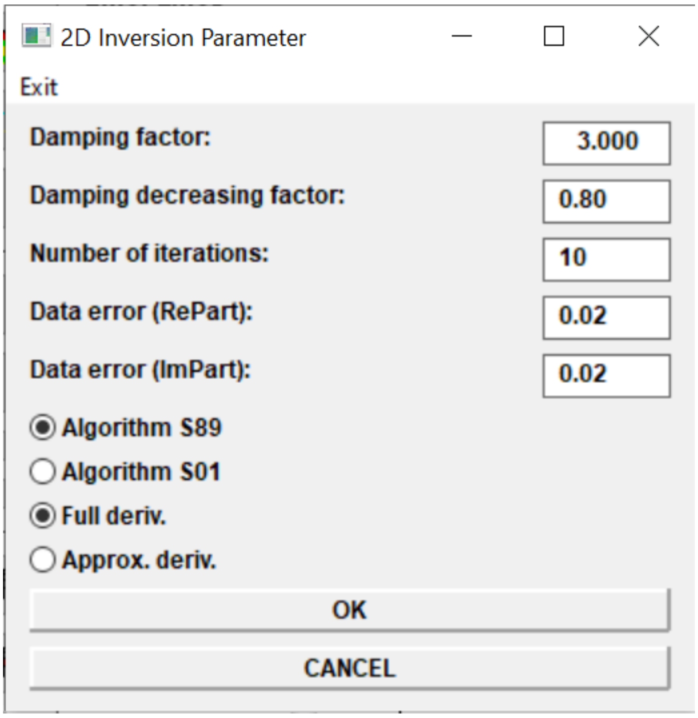
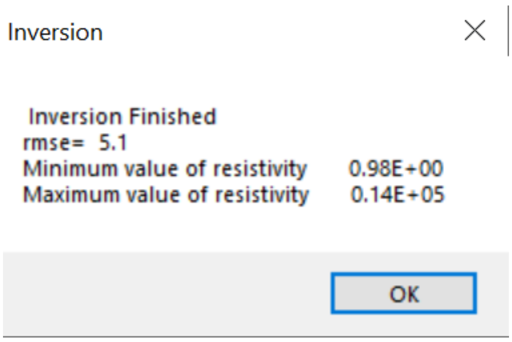


Figure. Input of parameters for the inversion (the displayed values are default values).

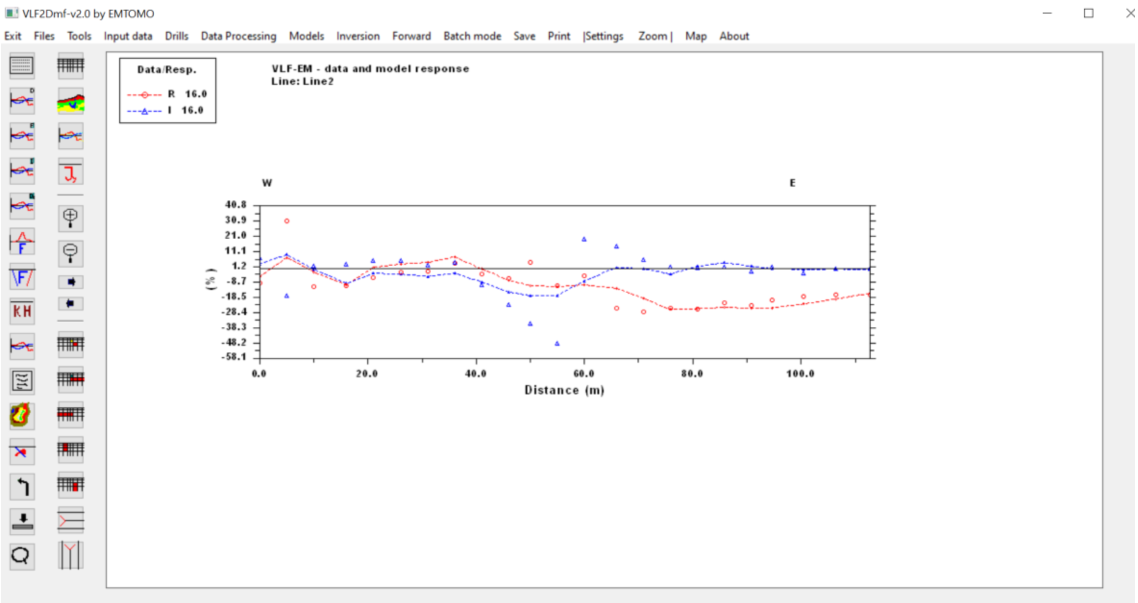
The damping factor (DF) controls the roughness of the model (see the appendices for details). The higher the damping selected smoother the model will be. The correct value should be determined empirically, performing inversions with different damping values (e.g. from 1.00 to 10). In general, for high resistivity environments (1000 ohm-m) the DF should be lower, and more iterations are necessary (10-15). The DF is not kept constant during iterations. The damping decreasing factor controls the decreasing of the DF, and this has influence in the convergence. In general, its value is within the range 0.7 to 0.9.

The program allows the use of two different inversion algorithms named here as S89 and S01 just because they are based on the work published by Sasaki in 1989 and 2001 (see appendices for details). In general, S01 algorithm produces smoother models when compared with those from S89.

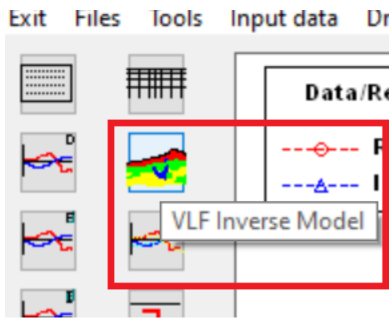
After select the parameters, click in the **VLF inversion(2D).** To start the inversion, click on the rectangle on the screen,

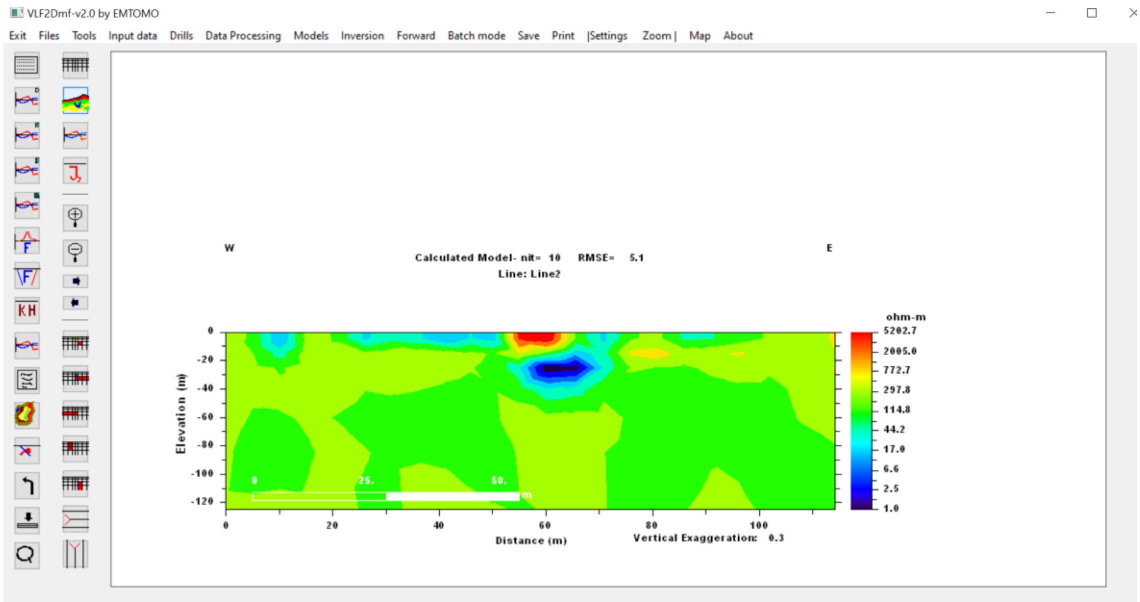


After push OK the program will display the data and the model response.

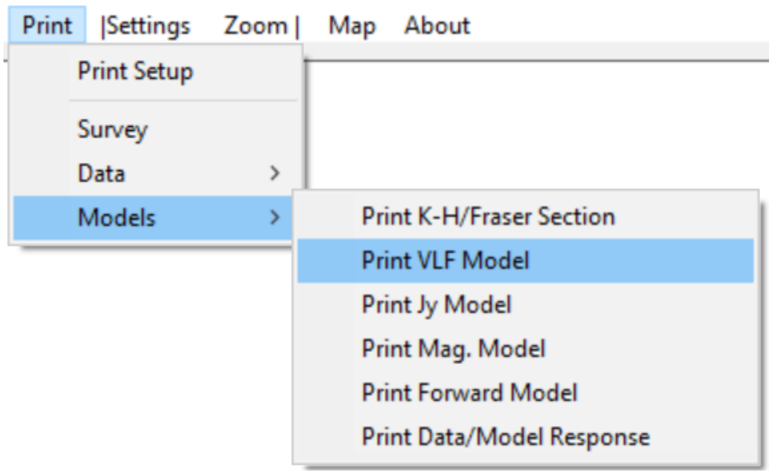


The inverted model (and the data/model response) can be displayed pushing one of the buttons on the left panel,

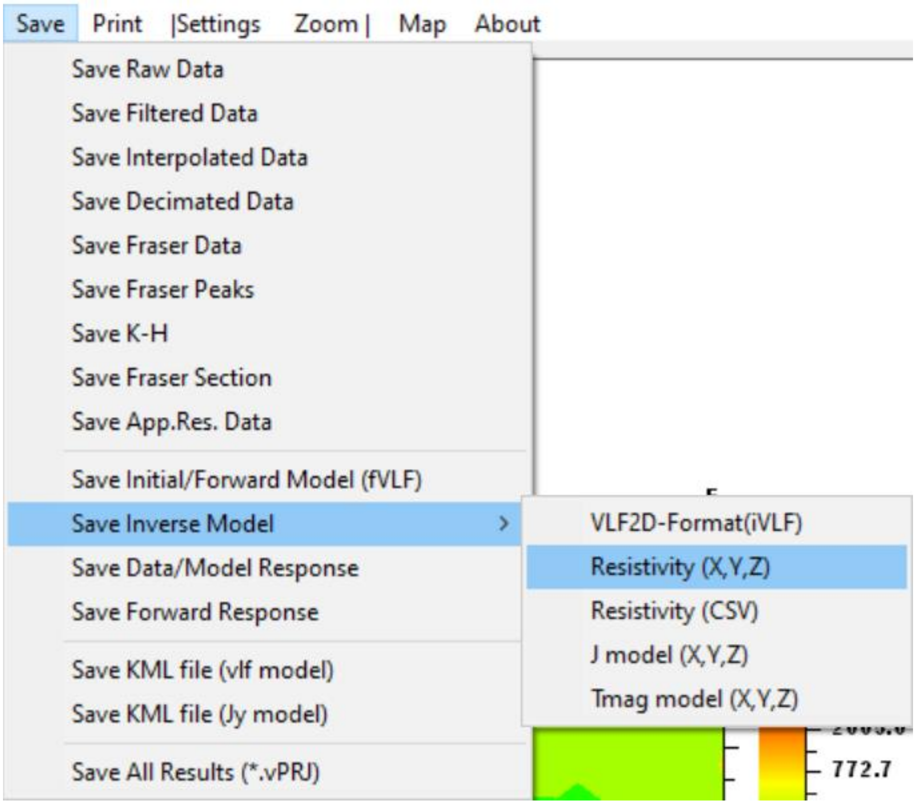


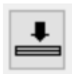


The final model can be print,

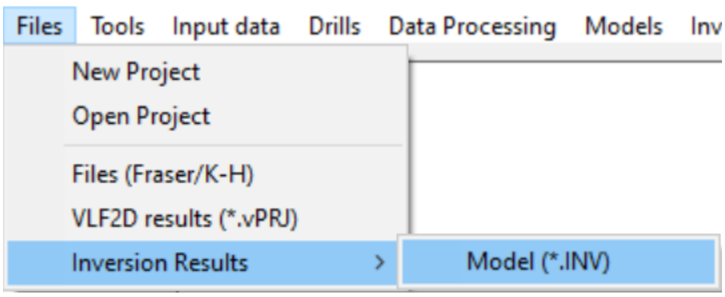


Or saved for further display in **3DViewVLF** program,



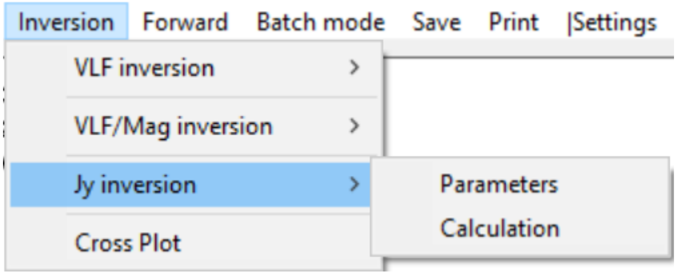
To save the model in the PRoj file push the button  .

A file *.INV is saved (in the folder …\inv_vlf) during the inversion. These files can be imported using the option **Inversion results** in the **Files** entrance.



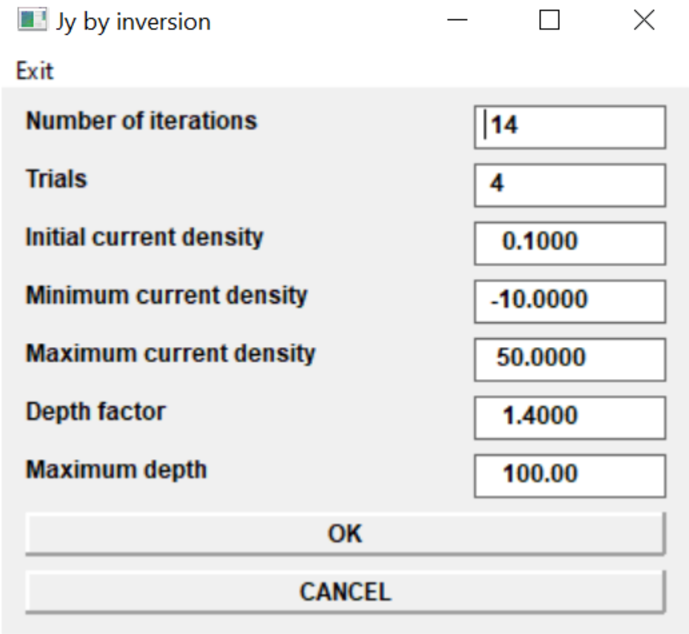
7.3. Inversion of VLF data in terms of J

The interpretation of the VLF data is also possible in terms of the current density (Pedersen and Becken 2005, Singh and Sharma 2016) using the entrance **Jy inversion**.

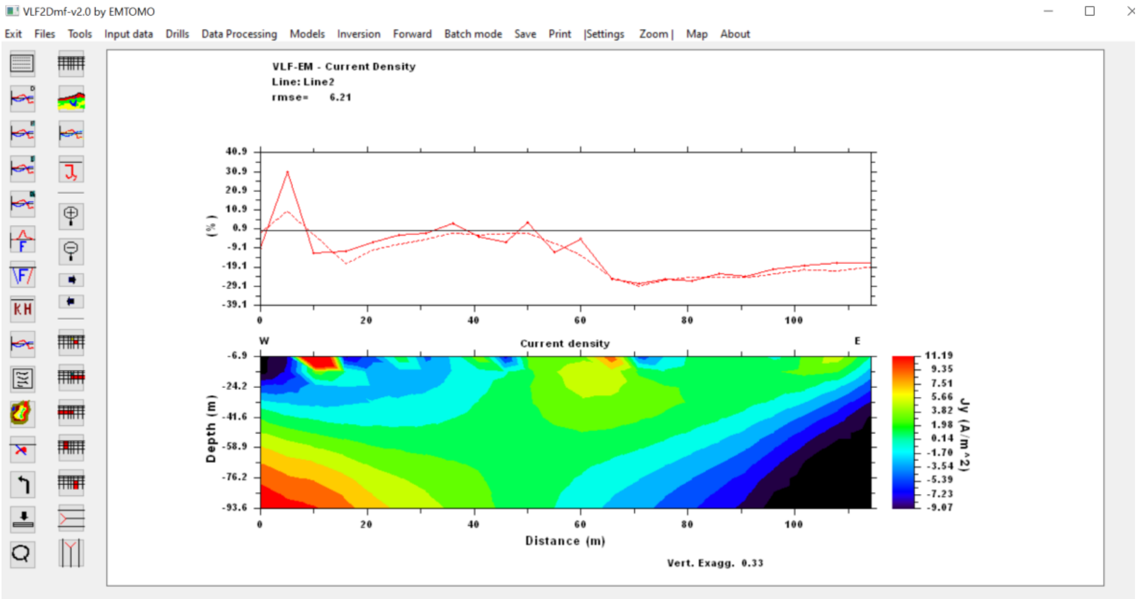


The first step is to define some parameters for the calculation:

- The number of iterations and trials. The calculation of the distribution of the current density is made using a conjugate gradient algorithm. Therefore, it is necessary to define a number limit of iterations for both cycles in the algorithm.
- initial value of the current density and its superior and inferior limits.
- the depth factor (etween 1.3 and 2.0) is a weight that controls the importance of the contribution of the deep parts of the model. Increasing the value of this parameter makes the anomalies deeper.



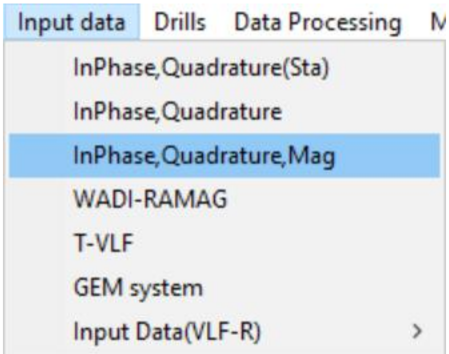
After the parameter definition the calculations can be performed and the result displayed, printed, or save according to your needs.



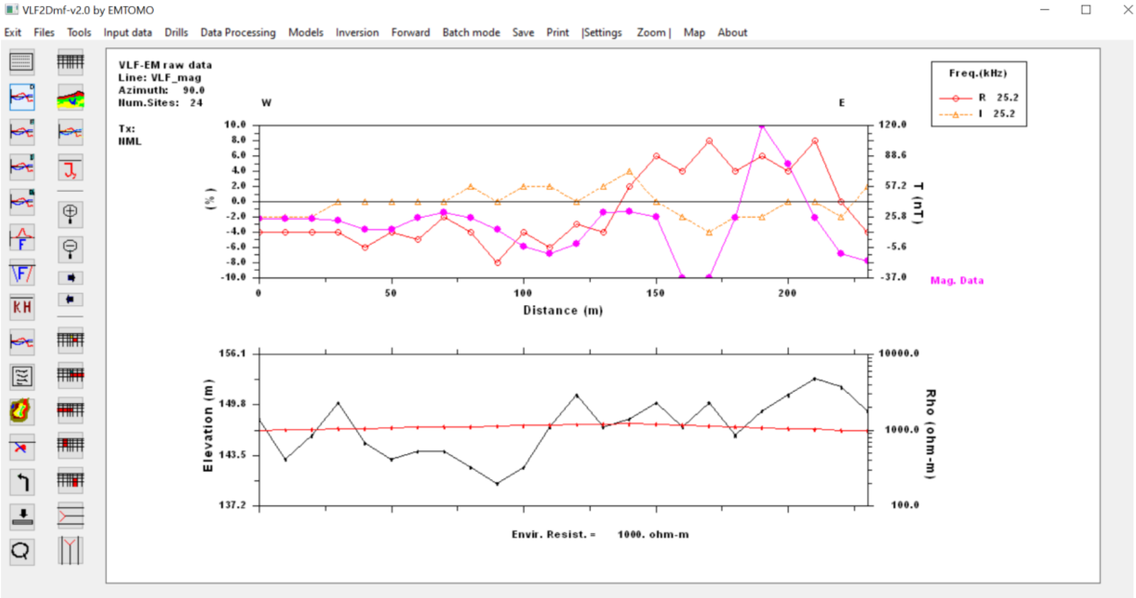
Model results can be displayed pushing the button,

7.4. Inversion of magnetic data (only available by requirement)

If the total magnetic field (anomaly) is available, it can be inverted in terms of the rock magnetization M. The magnetic data must be input together with VLF data using the standard format,

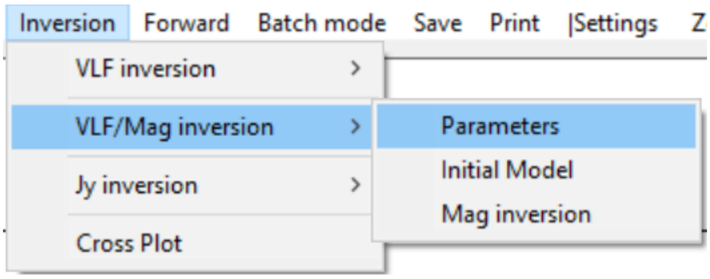


Or when inputting GEM system files. Magnetic data are displayed together with VLF-EM data.

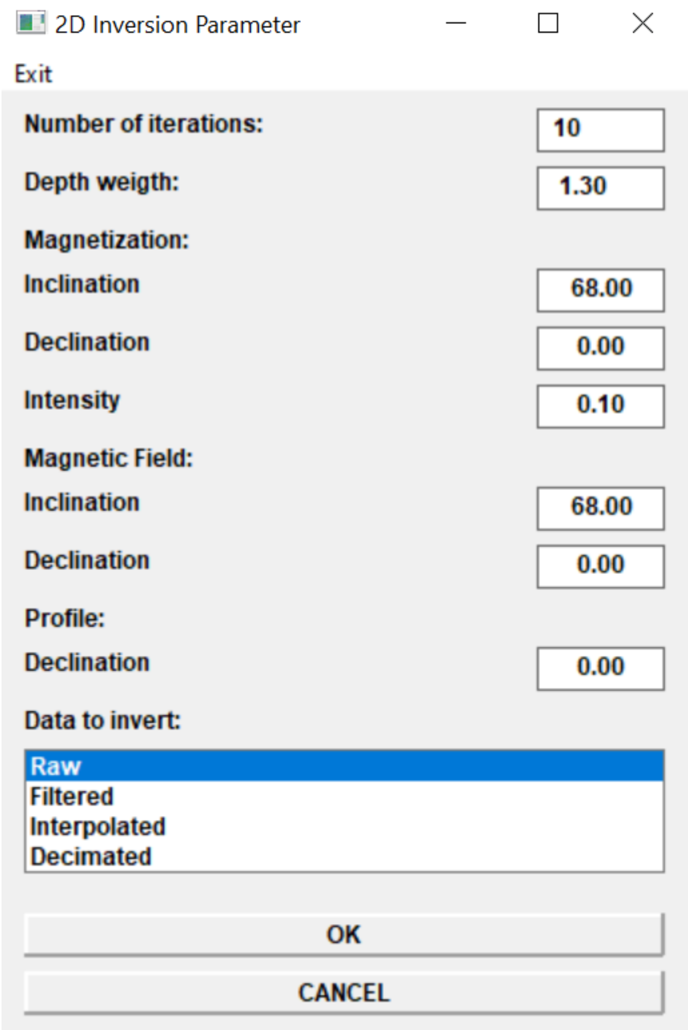


(NOTE: in this example VLF and T were not acquired in the same profile. This is just to illustrate the text).

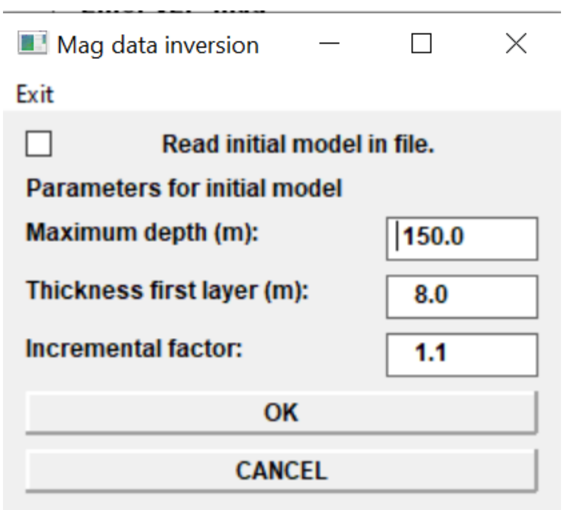
As usual we will need to define and initial model, parameters and perform the inversion. Let us see step by step starting with the parameters,



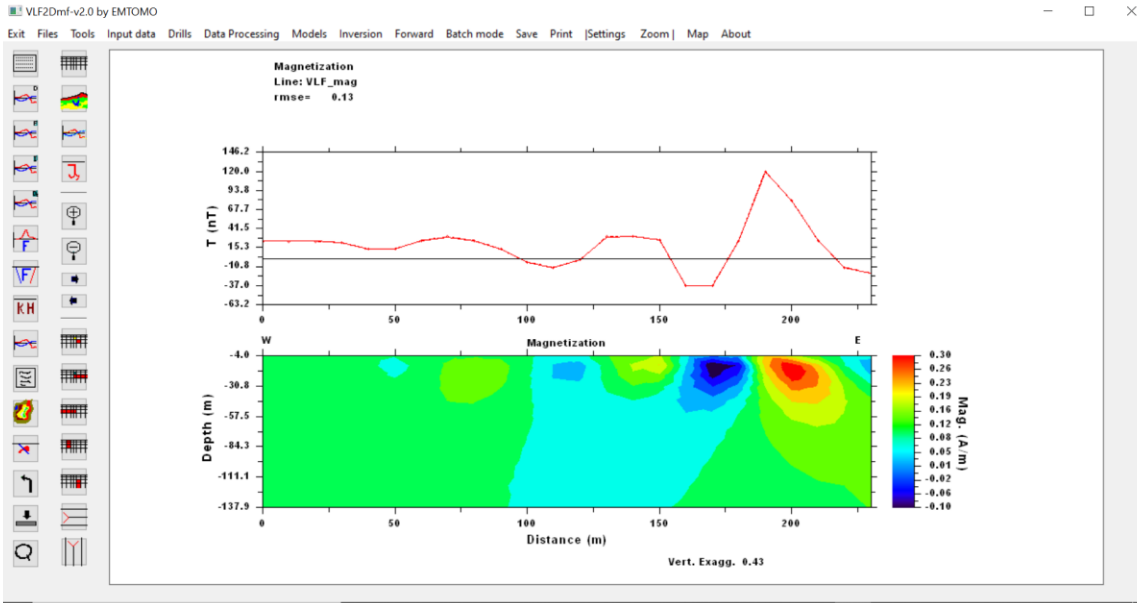
There are parameters connected to the inversion process (number of iterations, depth weight), data to invert and parameters related to the model (environmental magnetization, magnetic field in the zone) and about the profile position.



Some more information about the model must be given clicking in **Initial model**,



After parameters and initial model definition press the **Mag inversion** to perform the inversion,



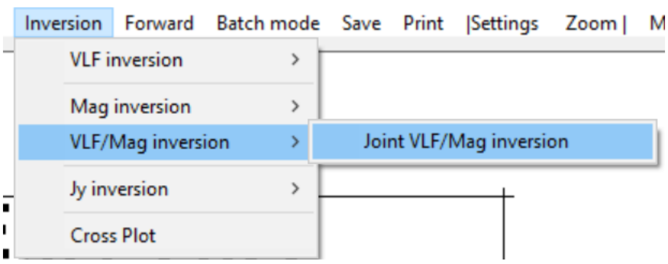
As in the other inversions the results can be save in XYZ file or in the PROJ file. These results can be displayed pushing the button,

7.5. Cooperative of magnetic/VLF-EM inversion (only available by requirement)

It is possible to perform a cooperative inversion of coincident magnetic (total field) and VLF-EM data, base in the Fuzzy-C clustering (Paasche and Tronicke (2007)).

The steps to perform the cooperative inversions are:

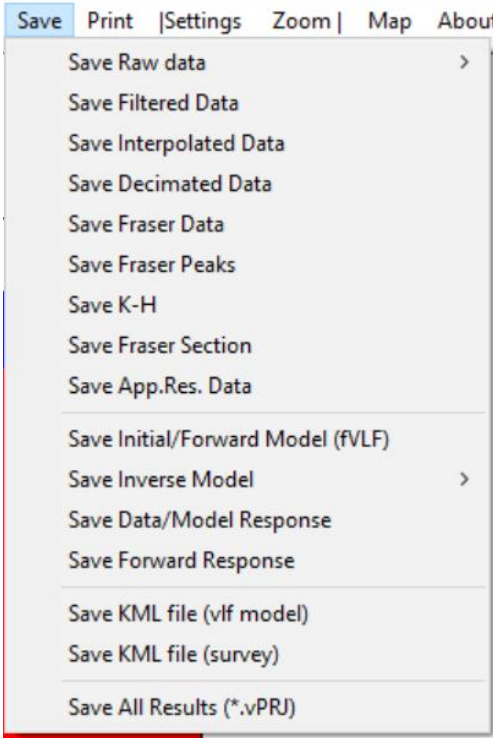
- define the VLF 2D model,
- define the VLF inverse parameters
- define the magnetic inversion parameters (use an adequate number of clusters; increase the number of iterations up to 20)
- perform the inversion,
-



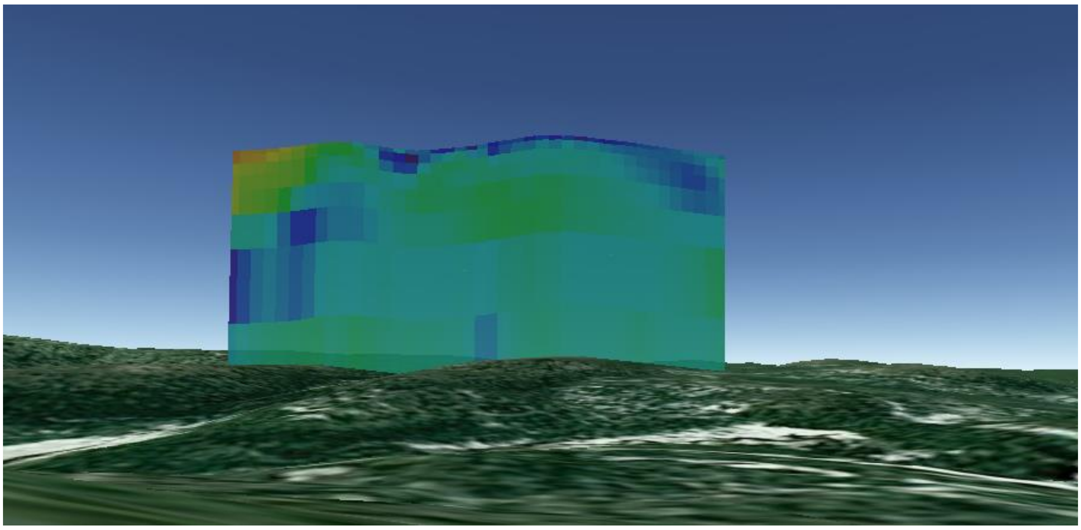
Calculate several inversions using different number of clusters. The minor normalized classification entropy (NCE) value can be used to choose the best number of clusters. According Paasche and Tronicke (2007) minimum NCE values indicate the optimum number of clusters.

8. Save/Print

The results and models obtained can be save in ASCII files for use in graphical software, Google or input into **3DViewVLF** program (files XYZ from models or K-H and Fraser section files) or read by **VLF2DMF**.

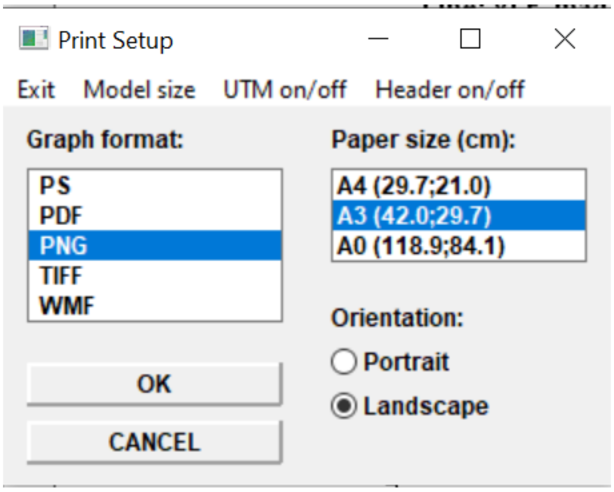


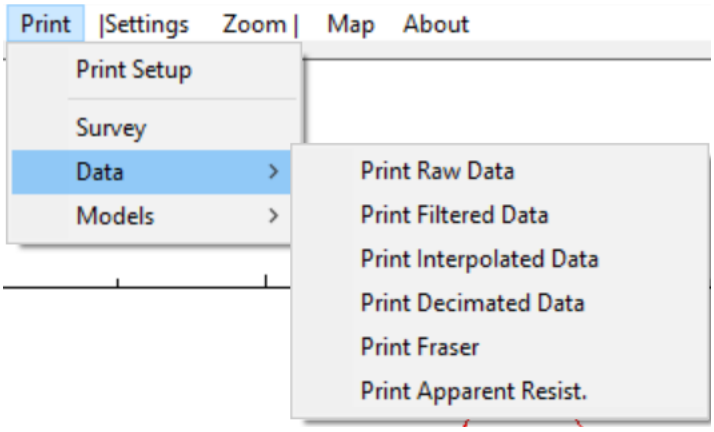
The vPRJ file, if saved after the processing or inversion of a profile, it will contain the processing and inversion results. This file is different from the PROJ file and only can be read by **VLF2DMF** program. If the coordinates UTM are used in the data file, a KML file can be constructed to display the survey location and the models in the Google Earth.

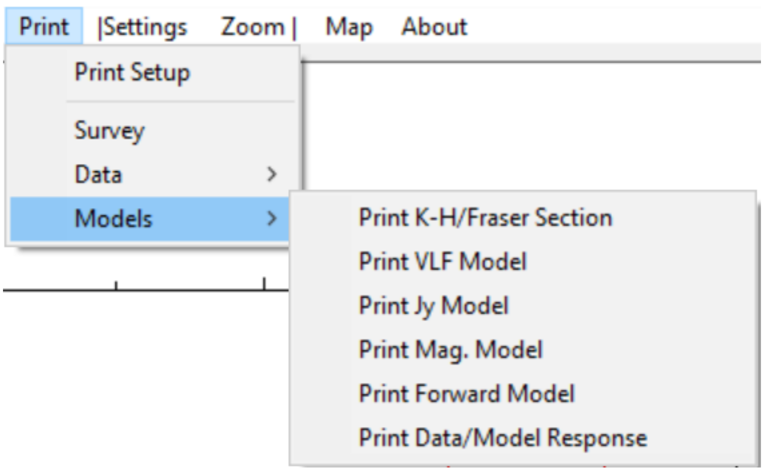


Displaying a model in Google Earth.

When printing figures, you can choose the figure file format using the Metafile format option (**Print setup**).

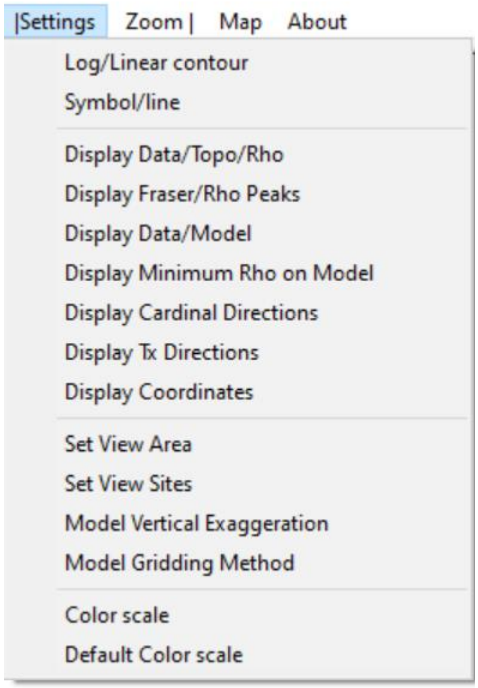






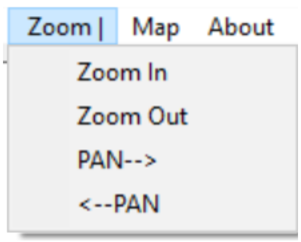
9. Display Settings/Zoom

This option allows you to choose different options to display the data and results.

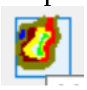


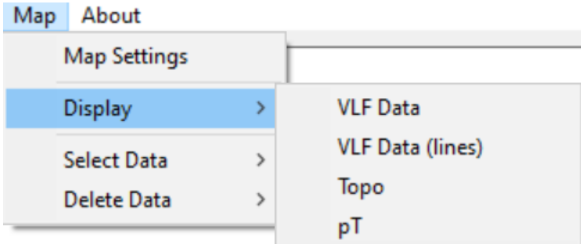
Drop down box menu for **Setting**.

The Zoom tool can be applied at maps, models, and data. There is a easier access to these tools using the buttons on left of the screen. The zoom can be combined with the PAN to move along the data (line).

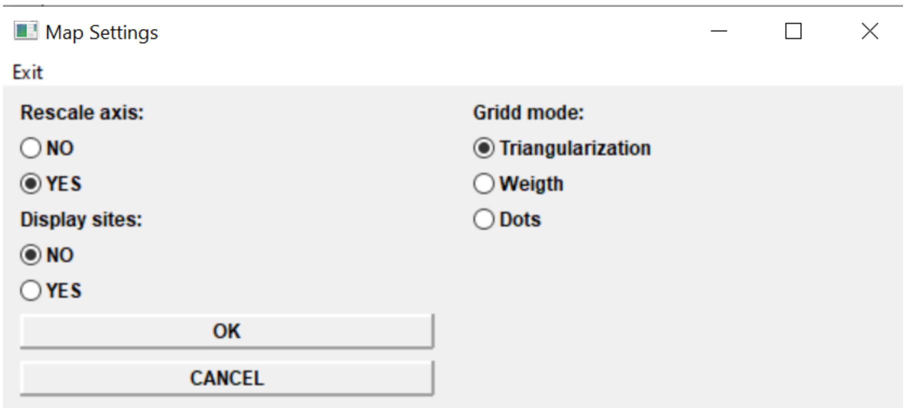


10. Map

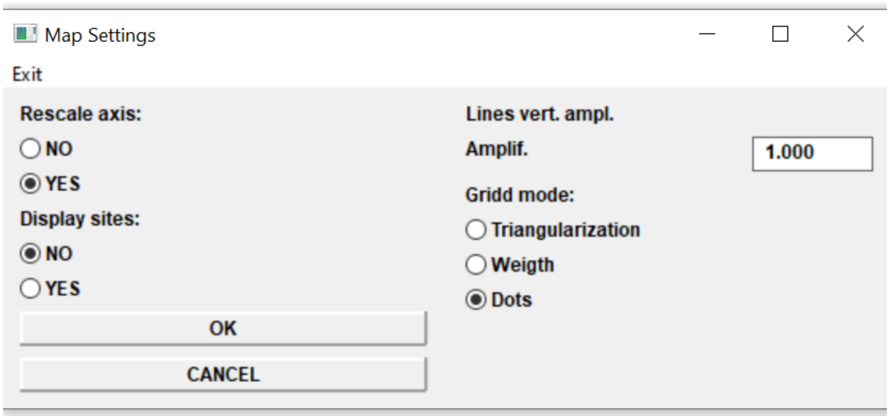
Maps of the data can be displayed using the **Map** option or pushing the left button  (only for VLF data),



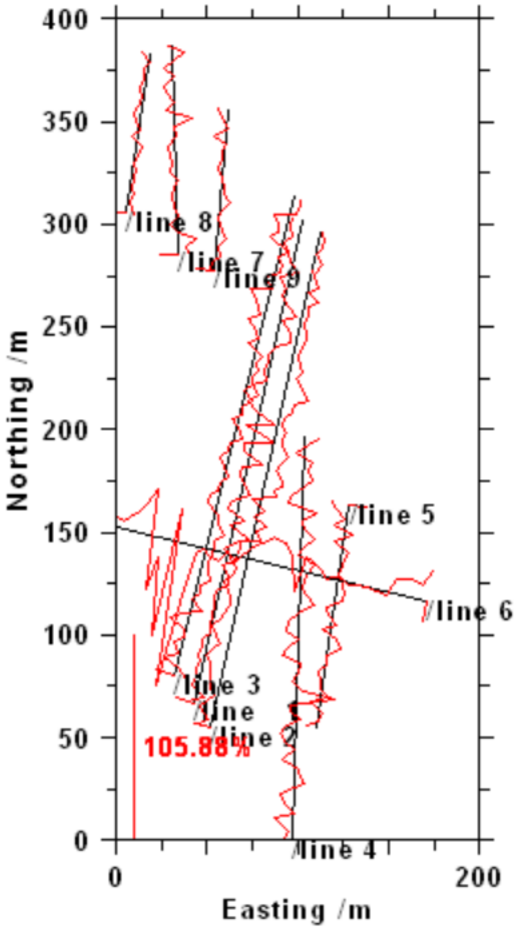
A few map settings,



If the VLF Data (lines) map (in-phase data) is displayed the Map settings is,



Allowing the control of the data display.



11. Data files Format

Input files

11.1. In-Phase and Quadrature (Sta)

This is an old format that allows the user to identify the measuring sites (**Sta**tions) and lines and to include some observations at some specific sites. The following is an example of a data file for a line (or a survey with more lines) acquired with one frequency:

```
L26+00W  <LINE NUMBER
1< VLF STATION
NLK
24.8< VLF STATION FREQUENCY
LineNum StationID      X        Y        Z      InPhase OutPhase       InPhase OutPhase
26+00W 19+40N    3653   81035     497    100     -4
26+00W 19+30N    3649   81032     499    100     -2
26+00W 19+20N    3648   81017     507    100      0
26+00W 19+10N    3642   81018     514    80      0
26+00W 19+00N    3634   81009     519    60      -2    Fault
26+00W 18+90N    3631   80998     525    60      -4
26+00W 18+80N    3622   80990     531    70      -4
26+00W 18+70N    3619   80980     537    80      -6
```

26+00W 18+60N 3614 80974 544 68 -6
…..

If your data contains short notes (like that one in station 19+00N) the program will display a red mark (symbol) when plotting the raw data. To see the information, push the button **Display Notes** ; go to one of the marks and press the left mouse button and the right button after. The note will be displayed in the screen.

The following is an example when two frequencies are used:

```
L26+00W  <LINE NUMBER
1< VLF STATION
NLK
24.8< VLF STATION FREQUENCY
2< VLF STATION
NML
25.2< VLF STATION FREQUENCY
LineNum StationID    X      Y      Z    InPhase OutPhase    InPhase OutPhase
26+00W 19+40N   3653  81035   497   100   -4        90    -2
26+00W 19+30N   3649  81032   499   100   -2        100   -2
26+00W 19+20N   3648  81017   507   100    0        120   -4
26+00W 19+10N   3642  81018   514   80     0        100   -6
26+00W 19+00N   3634  81009   519   60    -2        50     6
26+00W 18+90N   3631  80998   525   60    -4        32    16
26+00W 18+80N   3622  80990   531   70    -4        32    18
```

NOTE: the values must be separated by spaces.

11.2. In-Phase and Quadrature / In-Phase, Quadrature and Magnetic data

The data file corresponding to a line has the following format:

LineName
NF
Frequency1, frequency2,….frequencyNF
N
X_1, Y_1, Z_1, Rp_{1F1}, Ip_{1F1},…… , Rp_{1FN}, Ip_{1FN}
……
X_i, Y_i, Z_i, Rp_{iF1}, Ip_{iF1},…… , Rp_{iFN}, $Ip_{iFN,}$ fracture
....
X_N, Y_N, Z_N, Rp_N, Ip_N,…… , Rp_{NFN}, Ip_{NFN}

Where NF is the number of frequencies (Hz), N is the number of measuring sites, X, Y and Z are the easting and northing (linear) coordinates and the elevation (in meter) of each measuring site, respectively. Rp and Ip are the tipper real and imaginary parts measured at each sensor (in %). The frequencies should be in Hz.

NOTE: The data are separated must be separated by spaces and X, Y, Z, Rp, Ip must be reals, that should contain the decimal part even if it is zero.

Example of data file corresponding to a line of 6 sites (3 frequencies) measured in a flat zone:

```
F-TEST-L2
3
20000,8000,3000
6
0.0,    8.0,    0.0,    -0.15,  -0.2,   0.22,   -1.05,  1.55,   -0.72
5.0,    8.5,    0.0,    -0.13,  -0.26,  0.29,   -1.05,  1.57,   -0.68
10.0,   9.0,    0.0,    -0.1,   -0.31,  0.37,   -1.03,  1.56,   -0.62, fault
15.0,   9.5,    0.0,    -0.05,  -0.36,  0.44,   -0.98,  1.53,   -0.55
20.0,   10.0,   0.0,    0.01,   -0.41,  0.52,   -0.91,  1.47,   -0.47
25.0,   10.5    0.0,    0.09,   -0.44,  0.58,   -0.8,   1.37,   -0.38
```

NOTE: The values must be separated by comma or by space.

If there is magnetic data should be included in the last column. See the following example,

```
VLF_mag
1
25200
65
667021      5543478     148     -4      -2      1016
667040      5543468     143     -4      -2      1018
667064      5543455     146     -4      -2      1035
667087      5543442     150     -4      0       1052
667108      5543433     145     -6      0       1059
```

For both, files with and without magnetic observations, it is possible to have several lines (profiles) in the same file. The format is very similar to the previous ones. With magnetic data it will be,

Name of the survey
Line 1
NF
Frequency1, frequency2,….frequencyNF
N
X_1, Y_1, Z_1, Rp_{1F1}, Ip_{1F1},…… , Rp_{1FN}, Ip_{1FN}, $Tmag_1$
….
…
Line 2
NF
Frequency1, frequency2,….frequencyNF
N
X_1, Y_1, Z_1, Rp_{1F1}, Ip_{1F1},…… , Rp_{1FN}, Ip_{1FN},$Tmag_1$
……

11.3. GEM system format

The input of GEM system data files was already explained. Another example (for sites and lines) is present here.

Example of a GEM system data file,

File21 - Notepad

```
Append with new capture


/Gem Systems GSM-19 7017716 v7.0 4 X 2016 M e1v~v7
/ID 1 file 21yy    .v3  28 IV 17
/
/ time x y slope n*[kHz ip op h1 h2 pT]
131254.0 00000S  0000000 W   0000E  16.4 -032.5 +022.8  054 -004 005.11 19.6 -026.1 +011.4  104  046 008.93 23.4 +001.7 +000.3  083  017 022.10
131357.0 00000S  0000005 W   0000E  16.4 -036.1 +023.2  054 -006 005.10 19.6 -024.5 +013.1  103  047 008.86 23.4 +001.2 +001.3  083  017 022.13
131440.0 00000S  0000010 W   0000E  16.4 -034.4 +023.3  053 -005 005.02 19.6 -025.2 +011.8  105  049 009.05 23.4 -000.4 +003.3  084  015 022.44
131559.0 00000S  0000015 W   0000E  16.4 -034.0 +021.5  054 -006 005.08 19.6 -026.9 +011.8  107  047 009.13 23.4 +001.7 -000.4  082  016 021.98
131632.0 00000S  0000020 W   0000E  16.4 -032.5 +022.0  054 -005 005.08 19.6 -029.2 +012.0  102  041 008.65 23.4 +000.0 +001.5  083  015 022.08
131702.0 00000S  0000025 W   0000E  16.4 -020.5 +016.8  060 -007 005.62 19.6 -026.9 +012.6  106  045 009.04 23.4 +001.0 +000.7  082  016 022.03
131726.0 00000S  0000030 W   0000E  16.4 -033.3 +022.5  053 -006 005.01 19.6 -026.7 +011.4  105  046 008.97 23.4 +000.0 +001.9  082  015 021.98
131746.0 00000S  0000035 W   0000E  16.4 -031.5 +020.6  054 -005 005.12 19.6 -027.3 +010.4  102  046 008.77 23.4 +001.5 -000.5  082  017 021.90
131809.0 00000S  0000040 W   0000E  16.4 -032.9 +017.3  055 -006 005.16 19.6 -025.8 +010.9  104  048 008.98 23.4 -000.1 +001.2  083  015 022.02
131838.0 00000S  0000045 W   0000E  16.4 -028.5 +019.9  054 -005 005.11 19.6 -023.1 +011.0  103  051 009.02 23.4 +000.0 +001.9  083  015 022.18
131946.0 00001S  0000045 W   0000E  16.4 +035.8 -022.1  055 -006 005.20 19.6 +027.0 -009.8  105  046 008.98 23.4 -000.8 -001.0  082  016 022.03
132018.0 00001S  0000040 W   0000E  16.4 +036.3 -024.7  054 -006 005.10 19.6 +027.9 -013.8  108  053 009.41 23.4 -001.2 +000.0  082  016 021.98
132400.0 00001S  0000035 W   0000E  16.4 +034.0 -022.2  053 -005 005.02 19.6 +030.1 -016.0  105  047 009.00 23.4 -001.9 +001.4  081  016 021.77
132418.0 00001S  0000030 W   0000E  16.4 +032.4 -021.2  052 -005 004.94 19.6 +025.4 -012.0  105  050 009.12 23.4 -001.2 -000.4  082  016 022.08
```

Inputting this file we'll get,

Choosing input data

131254.0	00000S	0000000	W	0000E	16.4	-032.5	+022.8	054	-004	005.11	19.6	-026.1	+011.4

OK

To input the file, we must choose the appropriated columns and fill in the upper row. For the shown case the columns represents the following magnitudes (hidden cells can be reached scrolling) .

Choosing input data

time	line	site	dir	slope	f1	ip1	op1	h1	h2	T1	f2	ip2	op2
131254.0	00000S	0000000	W	0000E	16.4	-032.5	+022.8	054	-004	005.11	19.6	-026.1	+011.4

OK

However, only a few of them are needed. For the example only the following are needed:

Choosing input data

	line	site			f1	ip1	op1				f2	ip2	op2
131254.0	00000S	0000000	W	0000E	16.4	-032.5	+022.8	054	-004	005.11	19.6	-026.1	+011.4

OK

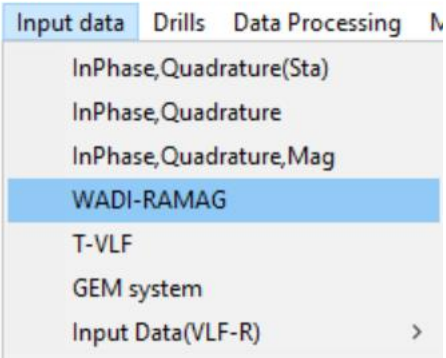
According to the data in the file the appropriated name for the columns is:
X – coordinate XUTM (eastern)
Y – coordinate YUTM (northern)
Z – elevation
Line (line, l) – for line
Site (site, s) – for station
F1 (f1) – first frequency
IP1 (ip1) – inphase for F1
OP1 (op1) – outphase for F1

M (m) – if magnetic data are present.
…similar for other frequencies.

If the elevation is not present in the data, the program will assume an elevation of 0.0 m. UTM coordinates and lines/sites cannot be selected in the same input.

11.4. WADI-RAMAG format

Data corresponding to profiles collected with WADI system and processed by RAMAG program can be input in **VLF2DMF** using the corresponding input option.

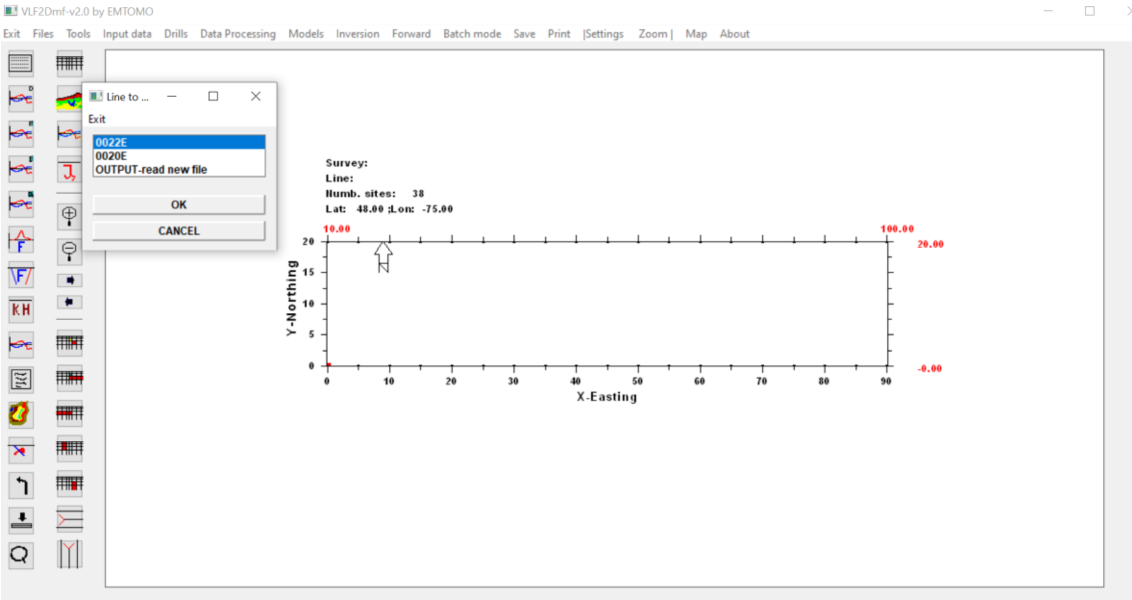


The WADI-RAMAG format is as follow (for two lines 0005E and 0015E, each one with 15 values and 280 m long and, acquired at 21.4 kHz):

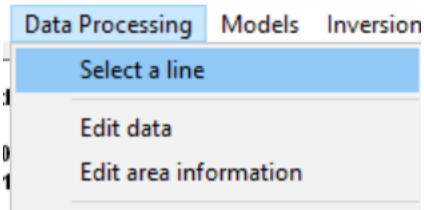
```
Field-Test
0005E
21.4
15
0      -22.3     -42.2
20      -10.6     -46.6
40       2.4     -42.2
............
280      58.6      -77.9
0015E
21.4
15
0      -45.6     -33.9
20      -33.7     -33.8
………
280      -12       -37
```

The first column gives the position of the readings along the profile. Second and third columns contain the real and imaginary VLF data, respectively.

After input, the profiles are available for processing and inversion.



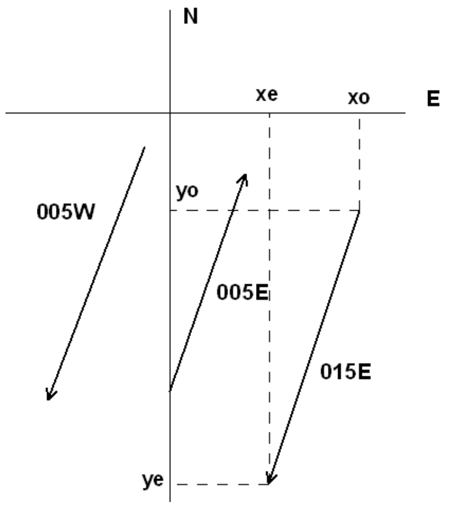
To process the next line, just go to the **Data Processing**->**Select a line**.



NOTE: WAD format is lost during the use of the program and every file saved will be in a different format (in general according to in-phase and quadrature format). So, saved files must be imported again in the program not using WADI option.

To be used in the program the data should contain X, Y and Z coordinates. The columns of these values must be filled because such values do not exist in the data. To do that we need to know the position of the profiles in the local reference (or in a global one).

Let us consider the following 3 profiles and a N-E reference system (local or UTM coordinates). In such system the origin and end of each profile will be (xo,yo) and (xe,ye). When inputting the file in **VLF2Dmf** the user should fill a table with those values.



Inputting the data file

WADI Multi profiles survey

Exit

LINE	xo	yo	xe	ye	so	se	NP
0005W	0	0	0	0	0	280	15
0005E	0	0	0	0	0	280	15
0015E	0	0	0	0	0	280	15

OK

Table to be filled (*so* and *se* are the coordinates on the line and are only informative about the length of the line).

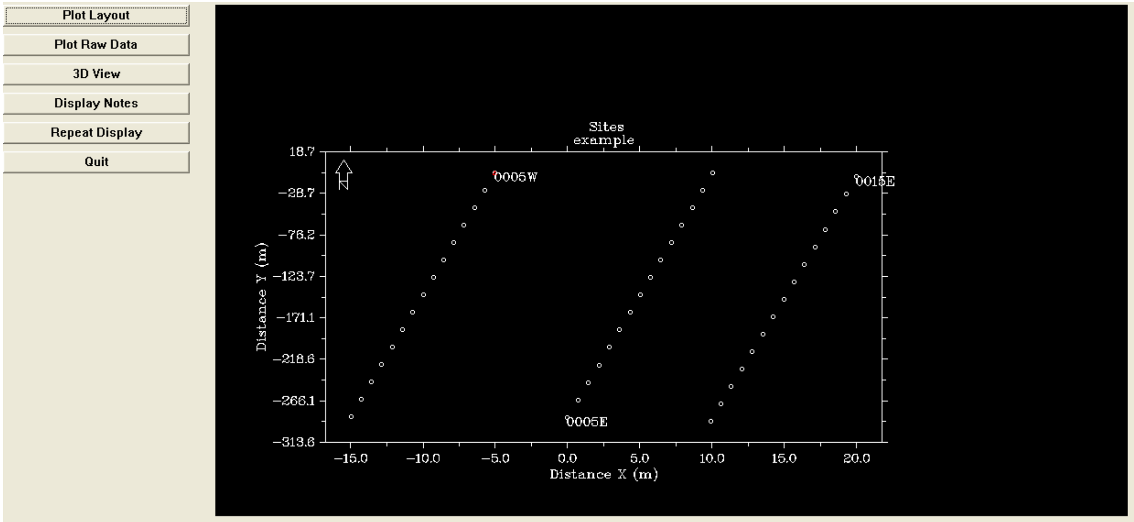
WADI Multi profiles survey

Exit

LINE	xo	yo	xe	ye	so	se	NP
0005W	-5	-5	-15	-285	0	280	15
0005E	0	-287	10	-7	0	280	15
0015E	20	-10	10	-290	0	280	15

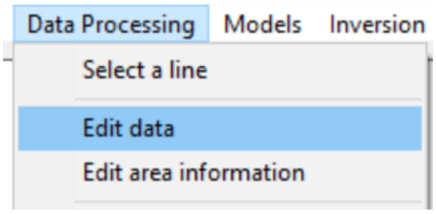
OK

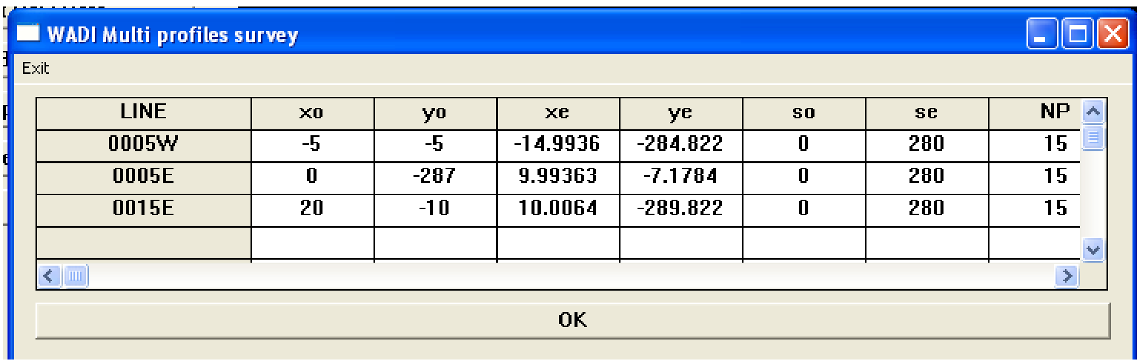
Table filled with the appropriated data (this is only an example, and the values are only informative).



Survey as displayed by Map.

The location of the profiles can be corrected in the Map module, using the Edit Data,



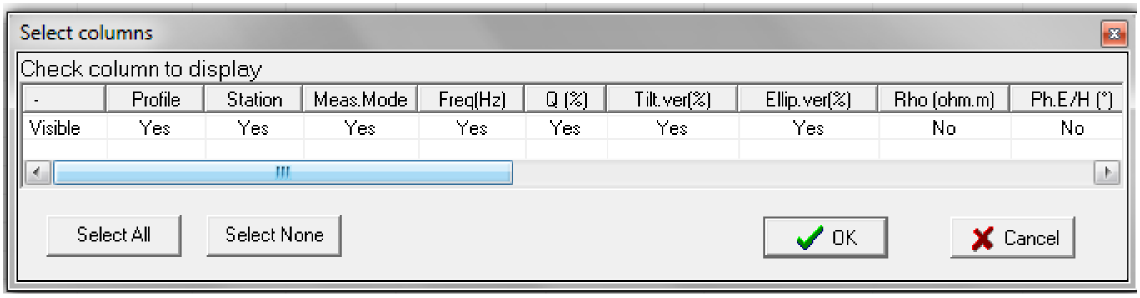


LINE	xo	yo	xe	ye	so	se	NP
0005W	-5	-5	-14.9936	-284.822	0	280	15
0005E	0	-287	9.99363	-7.1784	0	280	15
0015E	20	-10	10.0064	-289.822	0	280	15

Editing the profiles. If alterations are made, click OK. The program will ask you to save a file. That file will be saved according to the In-phase, Quadrature format.

11.5. T-VLF format

VLF2DMF read txt files written by the TVLF program (from IRIS). The user must select the wright columns that must be saved, which are:



But others can also be included.
Example of a VLF-EM file from TVLF.

```
Profile,Station,Meas.Mode,Freq(Hz),Q (%),Tilt.ver(%),Ellip.ver(%),Rho (ohm.m),Ph.E/H (°),E (µV/m),H
1,1,Tilt,18300,93,12,-10,,,,,122.00,16,4,4,0,4,0,4,0,2
1,2,Tilt,18300,90,13,-11,,,,,124.00,20,3,16,1,16,0,16,0,2
1,3,Tilt,18300,89,14,-12,,,,,125.00,22,3,4,0,4,0,4,0,2
1,4,Tilt,18300,93,16,-13,,,,,122.00,20,3,4,0,4,0,4,0,2
1,5,Tilt,18300,93,18,-14,,,,,128.00,21,3,4,0,4,0,4,0,2
1,6,Tilt,18300,94,20,-15,,,,,129.00,18,4,4,0,4,0,4,0,2
1,7,Tilt,18300,94,22,-16,,,,,122.00,17,4,4,0,4,0,4,0,2
1,8,Tilt,18300,95,25,-17,,,,,132.00,19,4,4,0,4,0,4,0,2
1,9,Tilt,18300,94,29,-18,,,,,129.00,18,5,4,0,4,0,4,0,2
1,10,Tilt,18300,95,32,-19,,,,,136.00,21,4,4,0,4,0,4,0,2
1,11,Tilt,18300,96,36,-19,,,,,138.00,20,4,4,0,4,0,4,0,2
1,12,Tilt,18300,96,38,-19,,,,,148.00,20,4,4,0,4,0,4,0,2
```

NOTE: the values MUST be separated by commas.
NOTE: txt files from TVLF do not contains elevation values (topography). If the user wants to include topography in his data it can be done as follows: i) input the txt files, ii) save the raw data file for each profile, iii) edit these files including the elevation values (by default the raw the values in the raw file are 0.00), iv) input the files for interpretation.
The elevation values can be included manually in the TVLF file adding a column with those values and Z in the header.

```
Profile,Station,Z,Meas.Mode,Freq(Hz),Q (%),Tilt.ver(%),Ellip.ver(%),Rho (ohm.r
1,1,22,Tilt,18300,93,12,-10,,,,,122.00,16,4,4,0,4,0,4,0,2
1,2,22,Tilt,18300,90,13,-11,,,,,124.00,20,3,16,1,16,0,16,0,2
1,3,23,Tilt,18300,89,14,-12,,,,,125.00,22,3,4,0,4,0,4,0,2
1,4,23,Tilt,18300,93,16,-13,,,,,122.00,20,3,4,0,4,0,4,0,2
1,5,24,Tilt,18300,93,18,-14,,,,,128.00,21,3,4,0,4,0,4,0,2
1,6,25,Tilt,18300,94,20,-15,,,,,129.00,18,4,4,0,4,0,4,0,2
```

11.6. Drill files format

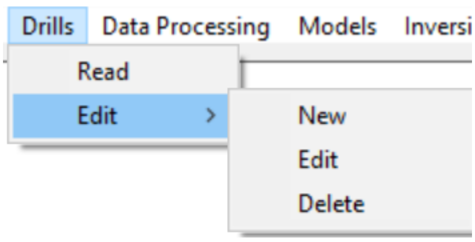
The format for files containing information about drills is as follows:

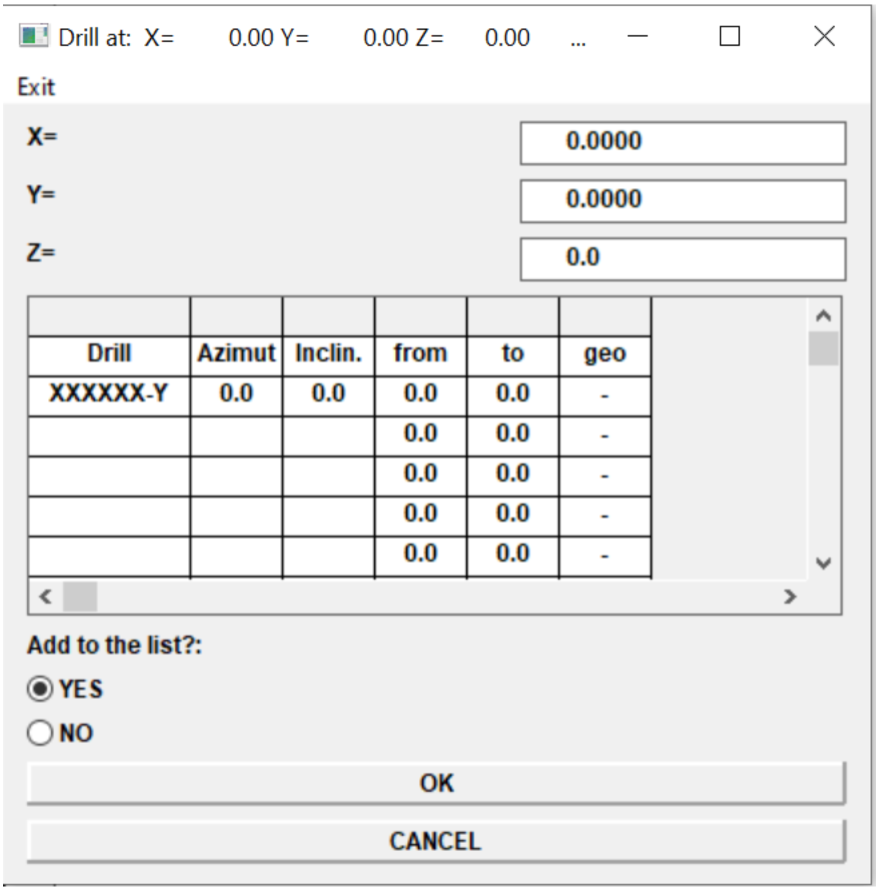
Name of well
X_UTM, Y_UTM, Z, Inclination, Azimuth
z1, z2, geology
z2, z3, geology
.....[15 levels are allowed]
END

Here it is an example:

```
dril1
  309260.0       6183632.      349.0000      0.0000000E+00   60.00000
  0.0000000E+00   200.0000     granite
  200.00000E+00  220.0000E+00 granite
  0.0000000E+00  0.0000000E+00 -
  0.0000000E+00  0.0000000E+00 -
  0.0000000E+00  0.0000000E+00 -
  0.0000000E+00  0.0000000E+00 -
  0.0000000E+00  0.0000000E+00 -
  0.0000000E+00  0.0000000E+00 -
  0.0000000E+00  0.0000000E+00 -
  0.0000000E+00  0.0000000E+00 -
  0.0000000E+00  0.0000000E+00 -
  0.0000000E+00  0.0000000E+00 -
  0.0000000E+00  0.0000000E+00 -
  0.0000000E+00  0.0000000E+00 -
  0.0000000E+00  0.0000000E+00 -
end
```

Drills can be displayed in models and in K-H sections. The drill information should be included in an ascii file previously saved (see the format above) or using the entrance Edit/New.





11.7. Topography (Elevation)

A topography file (elevation above sea level or any other reference) can be input to be included in the forward modelling (**and only for forward models**). For inversion, the topography should be included in the data file. The file should contain the elevation at each measuring site. The values (in meter) must be written in a row, like:

$z_1, z_2, z_3, \ldots\ldots.z_N$

To build the model mesh the program will redefine the elevation values taking as reference the lowest elevation value. The models will display this new elevation where, z = 0 m corresponds to the lowest values of the inputted elevation.

11.8 Initial model for inversion and forward

1D Initial model (inversion)

The format for the file containing a 1D initial model is as follows:

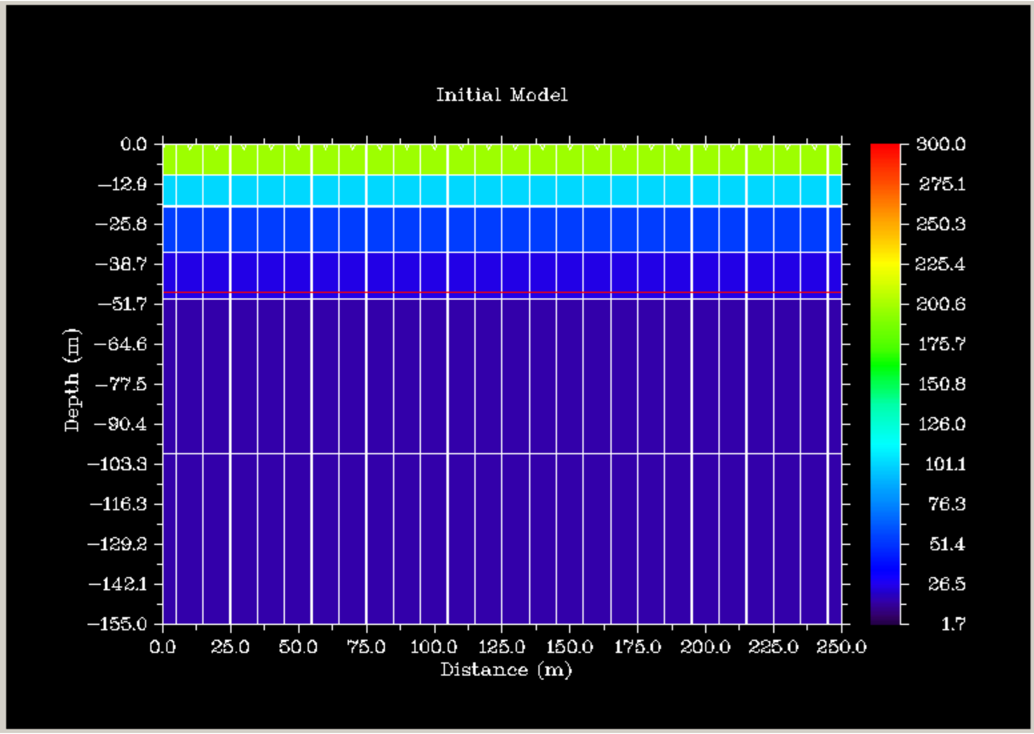
NL
$d_1, d_2, \ldots.d_{NL}$
$r_1, r_2, \ldots..r_{NL}$

Where NL is the number of layers, d_i and r_i are the depth of the bottom of the layer-i (in meter m) and the resistivity (in ohm-m) of the i^{th}- layer, respectively. To impose the boundary conditions the program adds one more layer. The depth of the (NL+1)th-layer is infinite, and its resistivity will be the same of layer NL.

Example of a file for a 5 layer medium where the resistivity decreases with depth:

5
10 20 35 50 100
200 100 50 20 10

Figure 53 displays the 2D model built from such file considering a flat topography.



Example of a 2D initial model.

2D Initial model (inversion)

Files for 2D model are necessarily more complex since must contain information about the cells mesh and topography, as well as information about the mesh for the finite element calculations.

NOTE: As this option is mainly to read files saved by the program, the user interested in building files for 2D models is invited to contact us.

2D Initial model for inversion (block map)

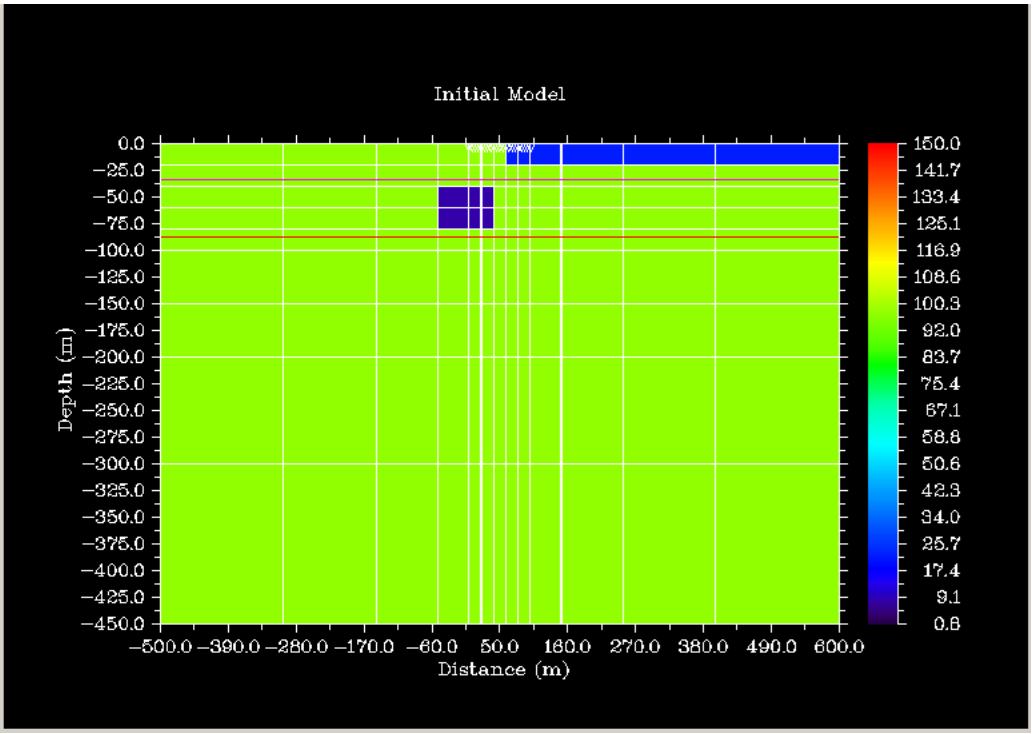
This option allows the user to define an initial model according to his needs. The user can define the number and dimensions of cells, the resistivity of each cell, the position of the cells relatively to the sites, etc. All the parameterization is defined in a file, where the earth is represented by rows and columns of cells. The format is as follows:

Nameofmodel
N,M
x_1, x_{2},........, x_{n-1}, x_n
z_1,z_2,........,z_m
1 1 ....1 1
1 1 ....1 1
....
1 1 ....1 1
r_1, r_{2},....,r_p

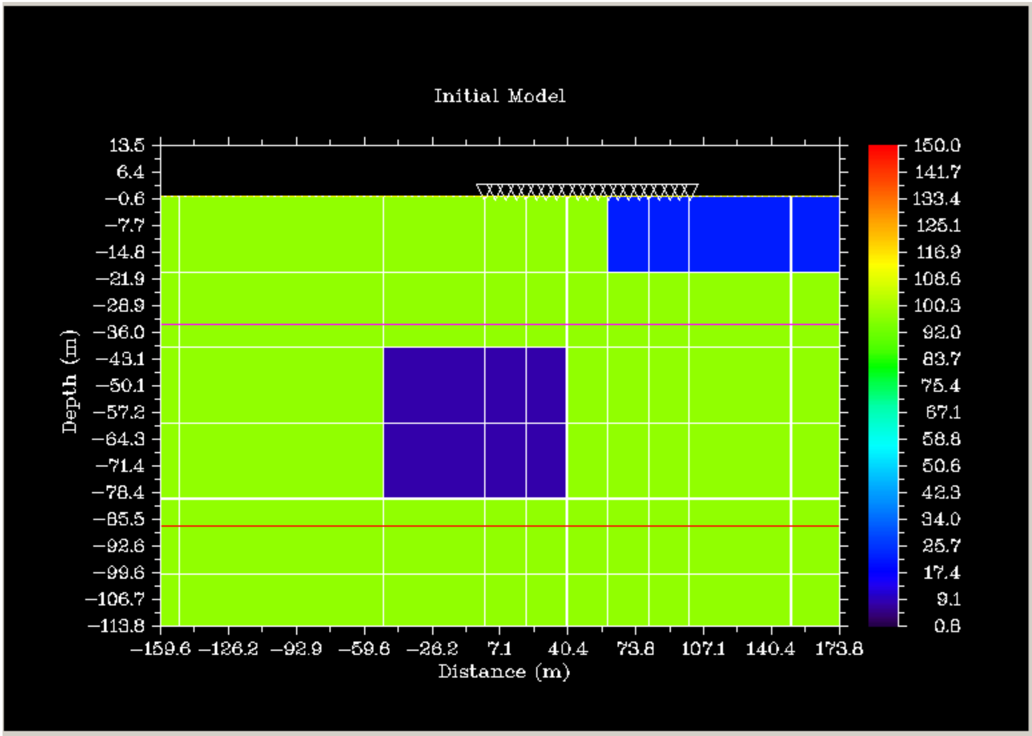
ere (N-1) and (M-1) are the number of cells in one row and in one column, respectively. xi, xi+1 are the horizontal limits of the cells in ith-column, zj, zj+1 are the vertical limits of the cells in the jth-row. The (N-1)x(M-1) matrix of integers represents the resistivity of each cell. The correspondent resistivity value is codified in the last row of the file: rj is the resistivity value of the cells assigned with j in the matrix of integers.

Example of a file defining a model containing two bodies (5 and 20 ohm-m) in a 100 ohm-m environment (Figures 54 and 55). The sites are localized between x = 0 and x = 100 m.

Model-map
14 10
-500 -300 -150 -50 0
20 40 60 80 100
150 250 400 600
0 20 40 60 80 100 150 200 300 450
1 1 1 1 1 1 1 3 3 3 3 3 3
1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 2 2 2 1 1 1 1 1 1 1
1 1 1 2 2 2 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1
100 5 20



Full section of the model.



Zoom In of the model in the sites area.

NOTE: After input all these initial models can be saved as TXT files (save initial model). The TXT file will be written in the format "not explained" in section 8.3.2.

2D Initial model for forward (block map)

The format explained before can be slightly modified to define a model for forward calculations.

Line_Name
Np, xS0, dxS
Nf, $freq_1$,…..$freq_{Nf}$
nBx1, nBz1
x_1,……..x_{nBx1}
z_1,……..z_{nBz1}
$c_{1,1}$…………………………………………………$c_{1,nBx}$
……………………………..
…………………..
$c_{nBz,1}$……………………………………………$c_{nBz,nBx}$
r_1…r_n

where,

Np- is the number of sites for reading
xS0- is the coordinate of the first site (usually is 0.0..if not, it must be considered when define coordinates x).
dxS- is the distance between sites
Nf – number of frequencies
Freq is the frequencies in Hz
nBx1 and nBz1 is the number of coordinates in X and Z directions
x… – are the coordinates that limit the blocks in X direction
z…- are the coordinates that limit the blocks in Z direction
$c_{i,j}$- code connected to the resistivity of each block (the blocks form a matrix of nBx x nBz blocks)
r_i value of the resistivity associated to the code c. If there is n different codes, there are n different resistivity values.

Here it is an example, with 2 blocks of 5 ohm-m (code c=2) and 20 ohm-m (code c=3) in an environment of 100 ohm-m (code c=1). The mesh of blocks has 13 x 9 blocks. The reading sites starts at x=0 and go till x=100 m, each 10 m.

```
Model-map
10 0 10.
1 20000.
14 10
-500 -300 -150 -50 0  20 40 60 80 100  150 250 400 600
0 20 40 60 80 100 150 200 300 450
1 1 1 1 1 1 1 3 3 3 3 3 3
1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 2 2 2 1 1 1 1 1 1 1
1 1 1 2 2 2 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1
100 5 20
```

XYZ Output files

XYZ files contains the results of the data inversion. The general format is:
1st row – header
2nd row – number of values along the profile and in depth
Following rows- values

X(eastern UTM) Y(northern UTM) distance z_cell Elev_cell Elev property

"distance" (in m) is the location of the cells of the 2D model measured along the profile. "property" can be the resistivity (in ohm-m); current density (A/m^2) or magnetization, according to the data.

CSV Output files

The format of CSV files is as follows:

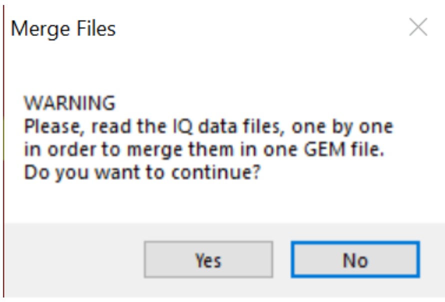
X, Y, Elevation, Station, elevation of model cells…., cell's property…

X and Y are the eastern and northern UTM coordinates, Station is the distance measure along the profile.

12. Tools

12.1. Merge IQ/IQM data into a GEM format file

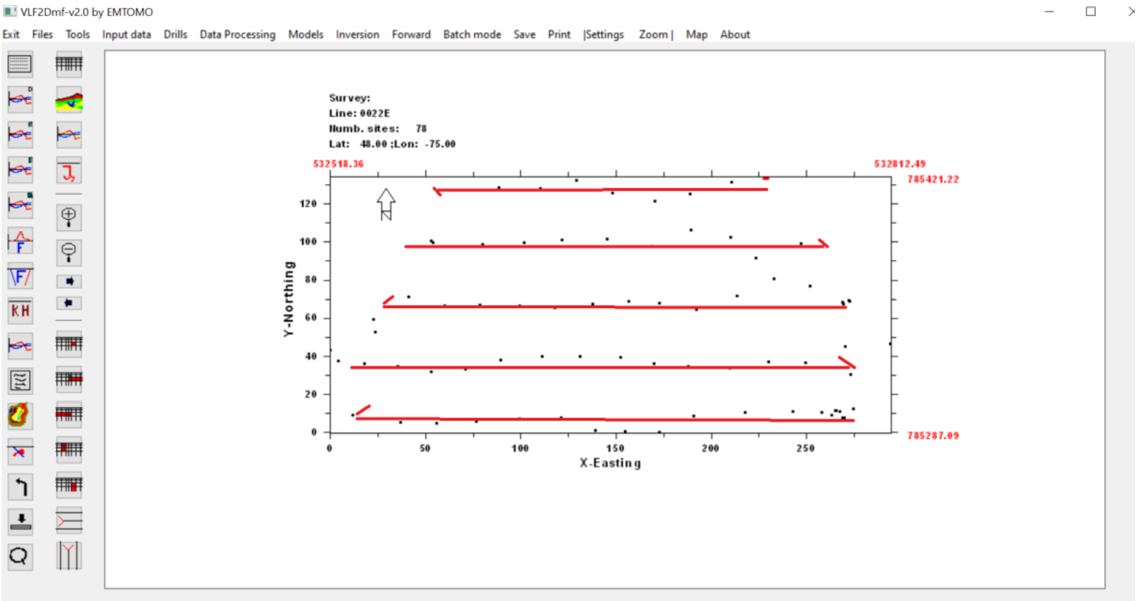
This tool allows to write in one file (in GEM format) several individual lines (profiles) written in IQ or IQM format. The files to merge must be input one by one. To finish the merging just push CANCEL.



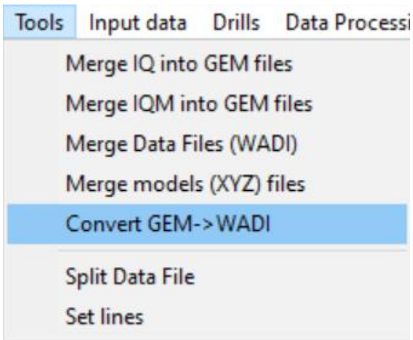
The program will ask for the name of the output file.
Merge of models output files (in XYZ format) are also possible.

12.2. Convert GEM file into WAD file

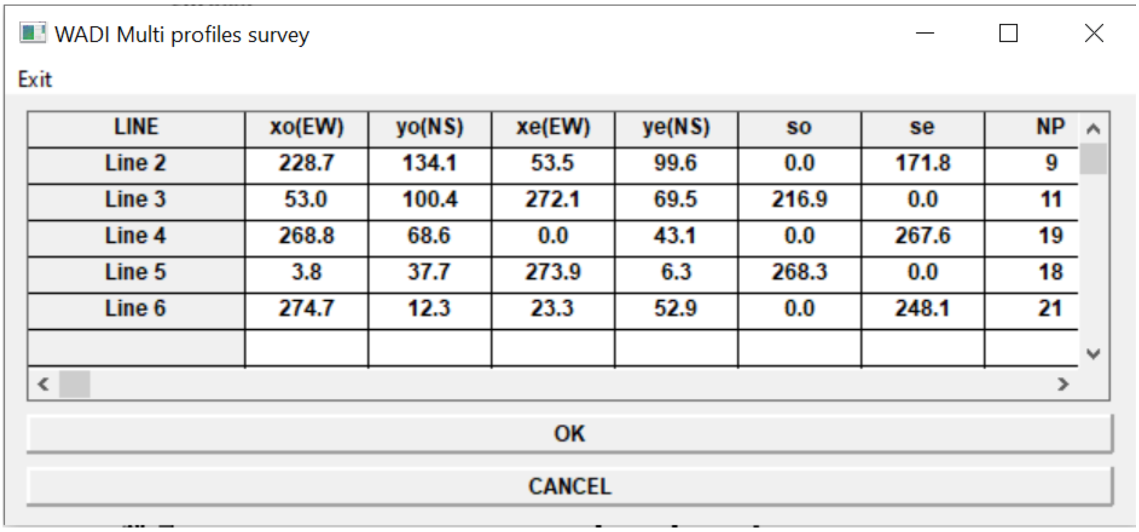
Let us export data acquired with GEM system saving the data in a WAD file. Suppose we want to export the lines in the following survey.



Go to Tools -> Convert GEM->WADI



The program will display the following Table. The values in the different cells are calculated based on the data and can be corrected by the user.



LINE	xo(EW)	yo(NS)	xe(EW)	ye(NS)	so	se	NP
Line 2	228.7	134.1	53.5	99.6	0.0	171.8	9
Line 3	53.0	100.4	272.1	69.5	216.9	0.0	11
Line 4	268.8	68.6	0.0	43.1	0.0	267.6	19
Line 5	3.8	37.7	273.9	6.3	268.3	0.0	18
Line 6	274.7	12.3	23.3	52.9	0.0	248.1	21

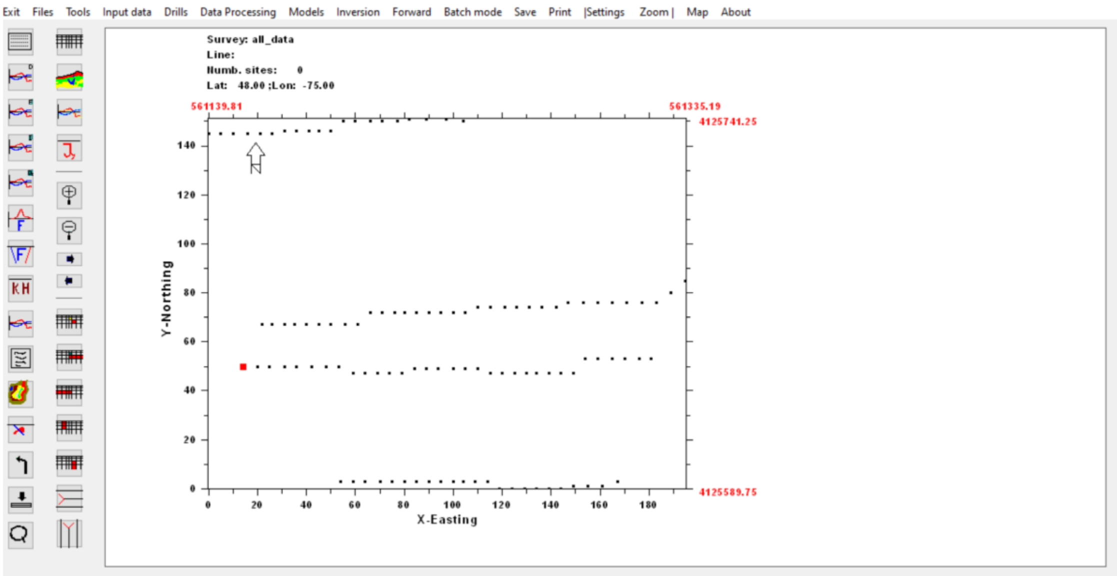
If all these values are accepted as correct the program will save a WAD file that can be input with the right option. The WAD file for this case is,

```
0022E
Line 2
  24.0000000
         9
  0.00000000     -16.5000000     -25.3999996
  21.4750004    -0.300000012     -28.5000000
  42.9500008     19.0000000     -28.1000004
  64.4250031     37.7999992     -22.7000008
  85.9000015     46.4000015     -37.4000015
  107.375000     77.1999969     -58.0999985
  128.850006     154.500000     -86.5999985
  150.324997    -133.500000      131.000000
  171.800003     -22.5000000    -0.300000012
Line 3
  24.0000000
        11
  216.899994     -21.7000008     -2.29999995
  195.209991     46.5000000     -163.600006
  173.519989    -110.400002      28.7000008
  151.830002     -75.6999969     42.0999985
  130.139999     -49.7000008     23.8999996
  108.449997     -29.6000004     23.2000008
  86.7600098     -18.1000004     27.7999992
  65.0700073     1.70000005      29.1000004
  43.3800049     7.00000000      32.0000000
  21.6900024     14.3000002      23.0000000
  0.00000000     -24.3999996     -26.6000004
Line 4
……
```

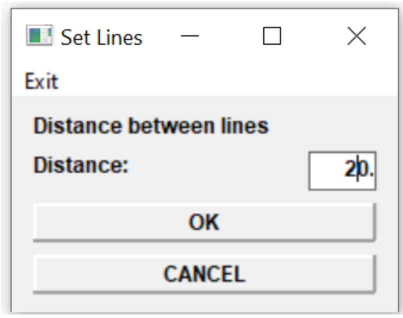
NOTE that the X,Y and Z values are lost.

12.3. Set Lines

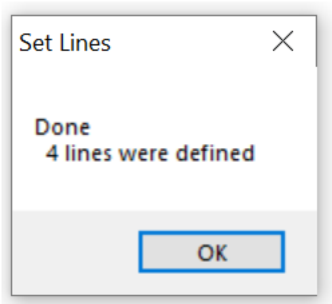
This tool allows to define the lines in a survey, which data (lines) where saved sequentially in a file (lines not separated). Let's consider the example of the following survey with four lines. Because the lines were not identified, it is not possible to process the data.



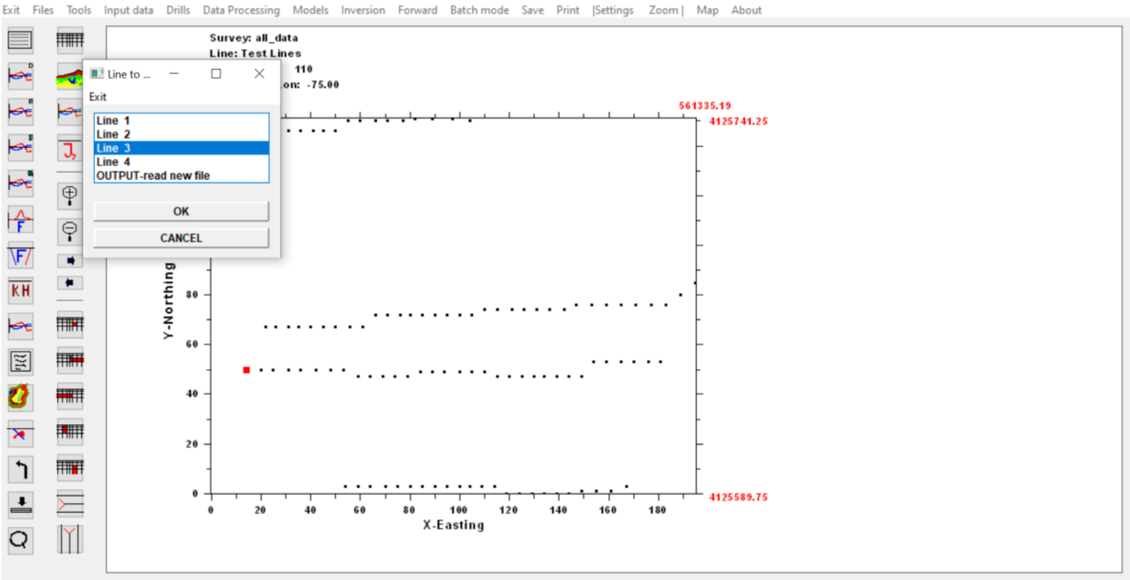
To apply Set Lines, the user needs to give the minimum distance between lines (a little less but greater than the distance between stations in the lines). A value of 20 m is good for this example.

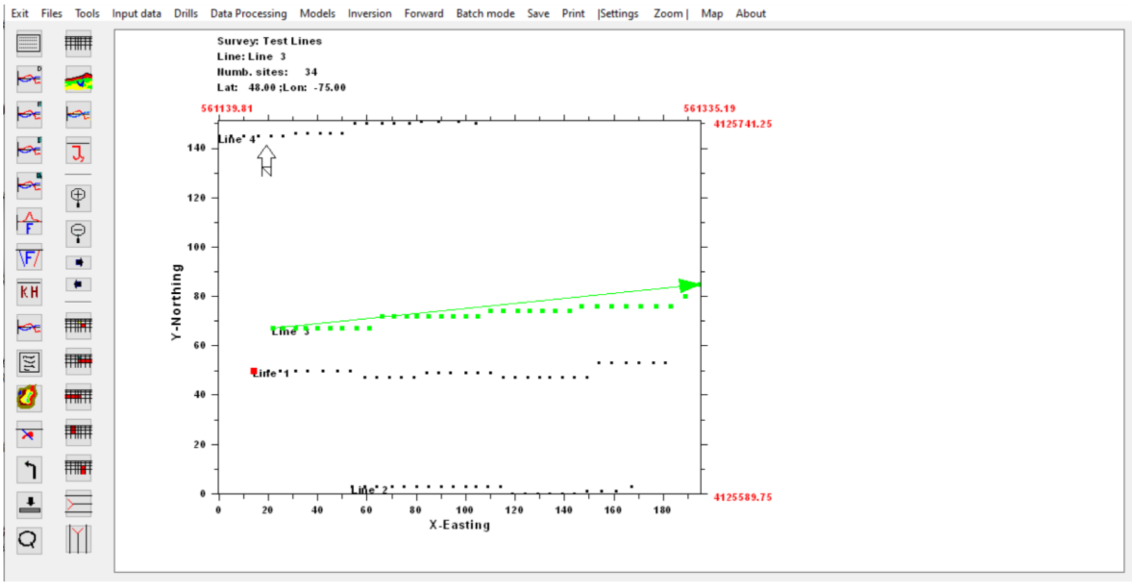


The results is,



And the lines can now be selected,

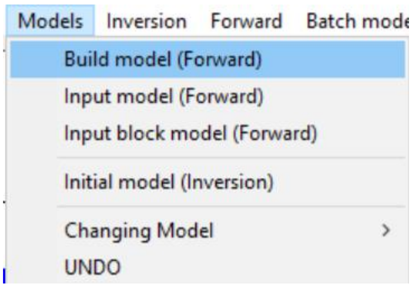


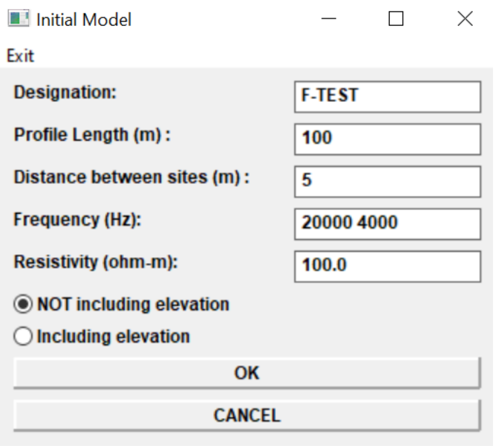


13. Forward calculations

Building a model for forward calculations

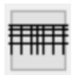
Clicking in this option, the following menu (that allows the setup of the model) will open.

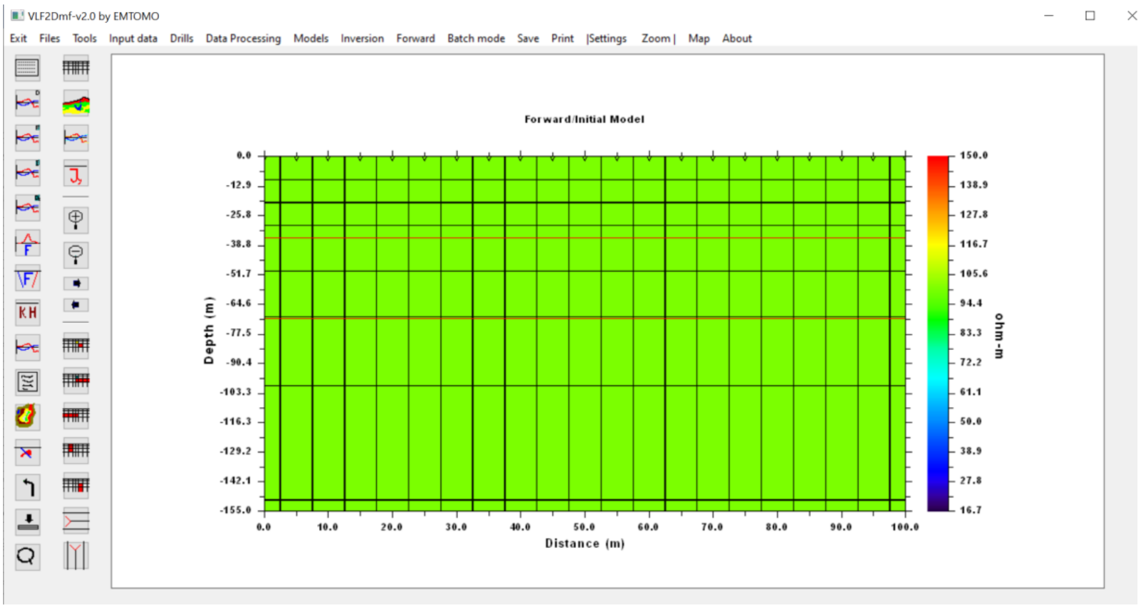




Setup of a model for forward calculations.

By default, the topography (elevation) is not included in the model. However, it can be considered, importing a file with the appropriated values (see Format section).

The model can be viewed by clicking in the "Plot Initial Model" action button . Figure below shows a possible initial model. The red and magenta lines represent the skin depth considering the highest and lowest frequencies and the environmental resistivity. The vertical and horizontal white lines make a mesh of rectangular blocks (cells) that can be used to build structures of different resistivity, simulating geological structures. The user can then calculate the response of such "conceptual" earth.



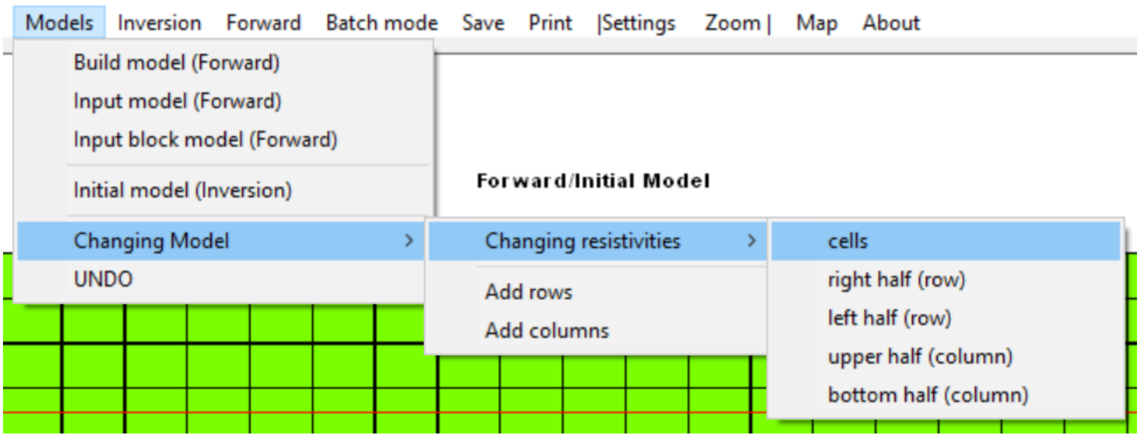
Displaying the initial model.

There is also the possibility to input an existent 2D model previously saved with the option "save initial model" in the Save menu. These files do not have any predefined extension. Use the option "Input model (Forward)".

NOTE: In the models (inversion or forward), the elevation is always referred to its minimum value. However, the correct elevation (altitude) will be displayed in the figures of the final model.

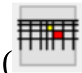
Changing model

Any initial model can be changed. It is allowed to change the resistivity of blocks and the number of blocks adding new rows and columns to the model (Figures).



Menu for changing the model.

Clicking in "Changing resistivities" a new menu opens with several options that allows you to change the resistivity value of individual cells; change the resistivity of a group of cells in the same row and localized on right or left of a selected cell or the resistivity of the cells localized in a column upper or down of a selected sell. Selecting one option will open a menu and answering yes, the mouse cursor will change to a cross (+). Select the cells you want to have the same resistivity, clicking with the left mouse button. Stop the selection by clicking with the right button. Type the wanted resistivity. The process can continue or not. Use the button (plot initial model) to see the new model.

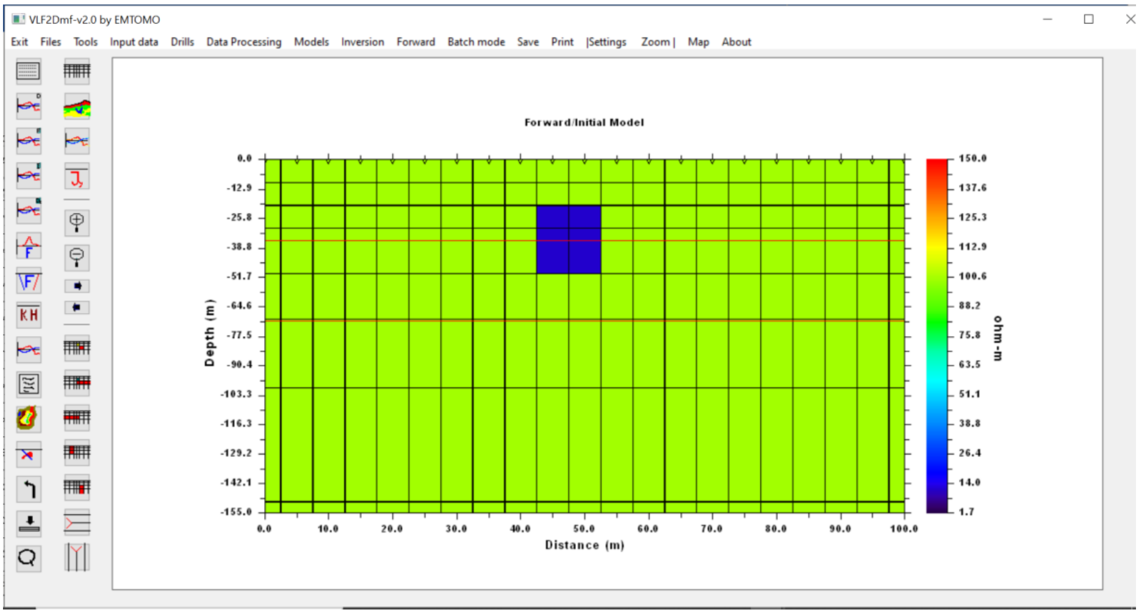
The modifications can be performed using the buttons on left ( …). A similar procedure is used to add row or columns to the model.

NOTE: When adding columns or rows do not cut a block (cell) more than once. If you want to have a fine mesh, repeat the procedure for every cell you want to divide.

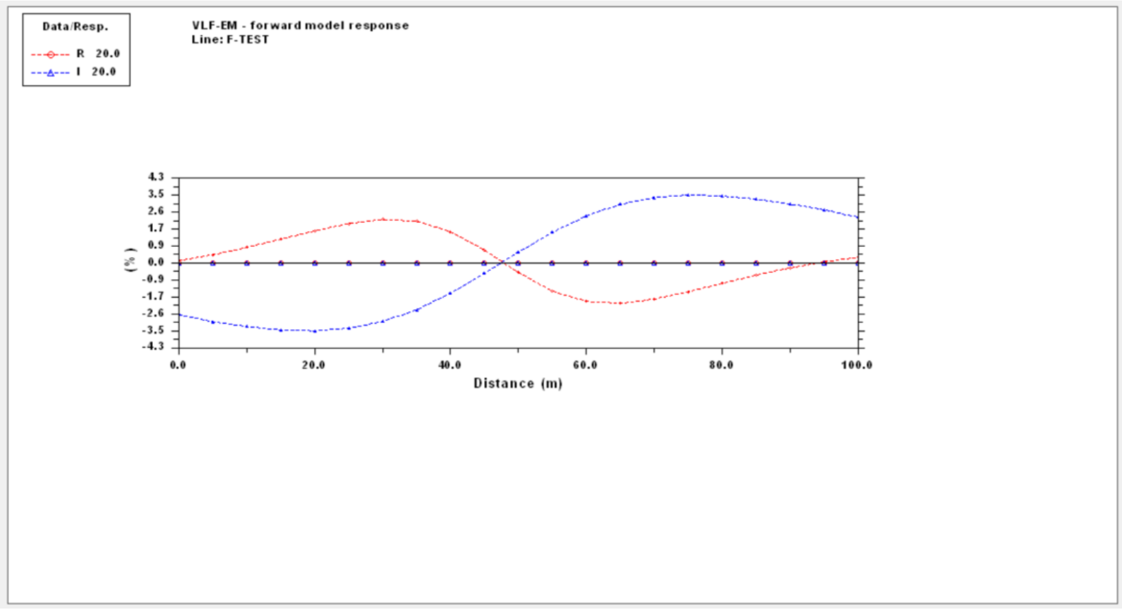
NOTE: Accuracy of the calculations depends on the mesh. However, computational effort greatly depends on the number of cells, too. Therefore, do not increase the number of cells unnecessarily. A good balance between accuracy and computational time should be the target.

NOTE: The undo option allows you to reverse the last modification.

Figure shows a modified initial model prepared for forward calculations, which result is shown in Figure below.

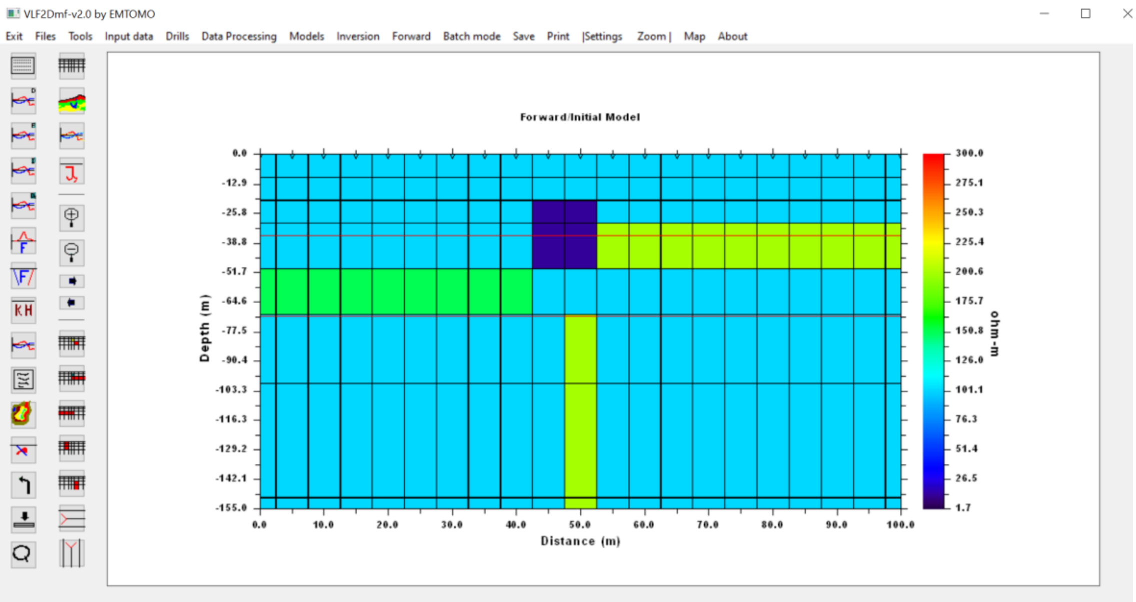


Example of a model with two anomalous bodies of 10 ohm-m (on left) and 10 ohm-m (on right) in a 100 ohm-m environment.



Response of the model shown in previous Figure.

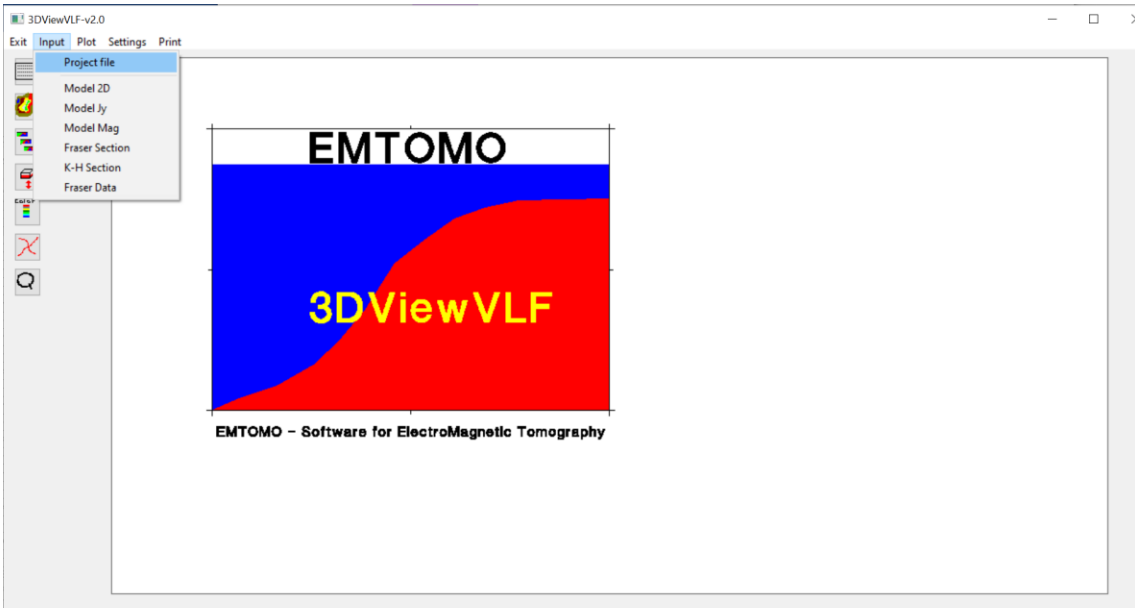
Other possibilities to change the model are available.



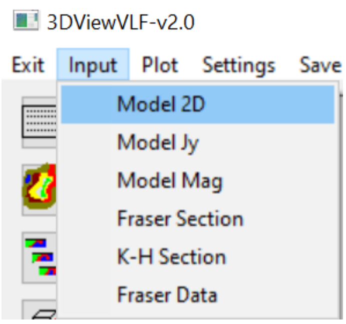
Changing the resistivity value of individual cells, right half of a row and bottom half of a column.

The 3DViewVLF

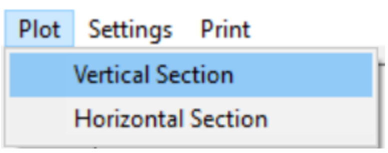
This program allows to display **VLF2DMF** results in a 3D view, or maps. The results can be input reading XYZ files (from 2D or J models, Fraser sections or K-H sections) (**this version does not allows reading the project files (PRoJ)**.



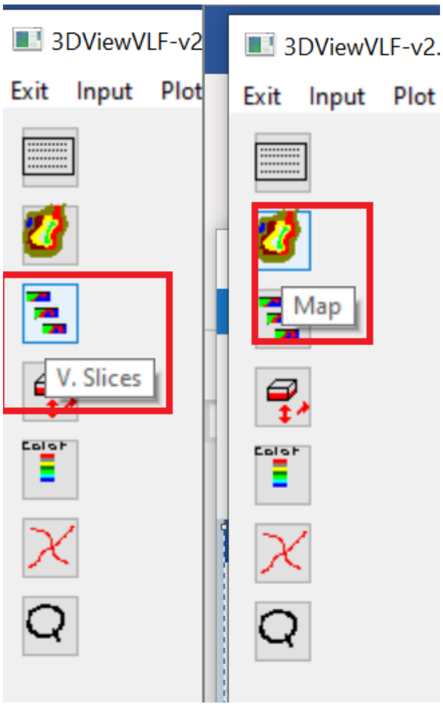
Input the files you want to see,

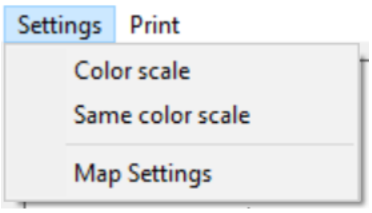


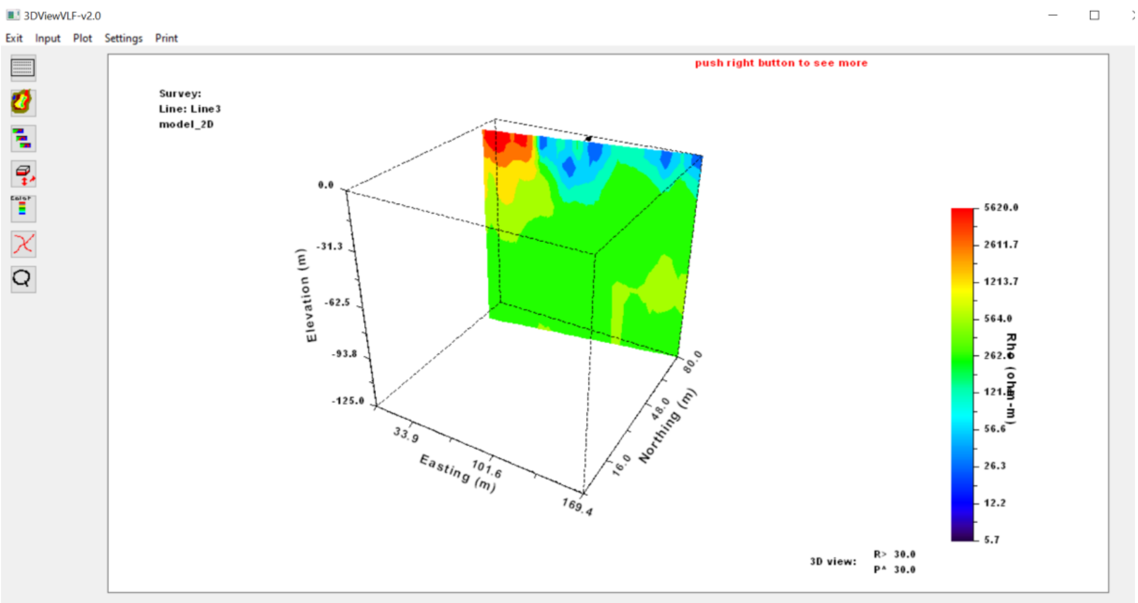
Select how do you want to see the results, using the Plot option,



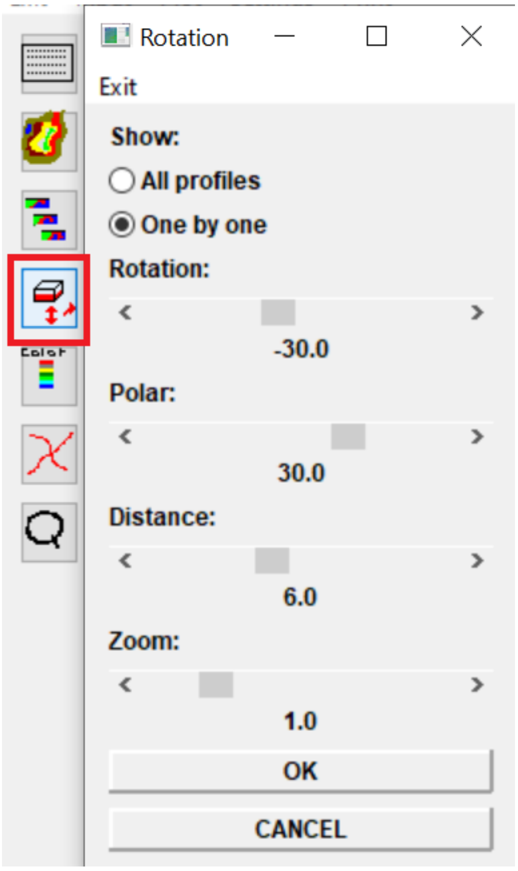
Or using the buttons,

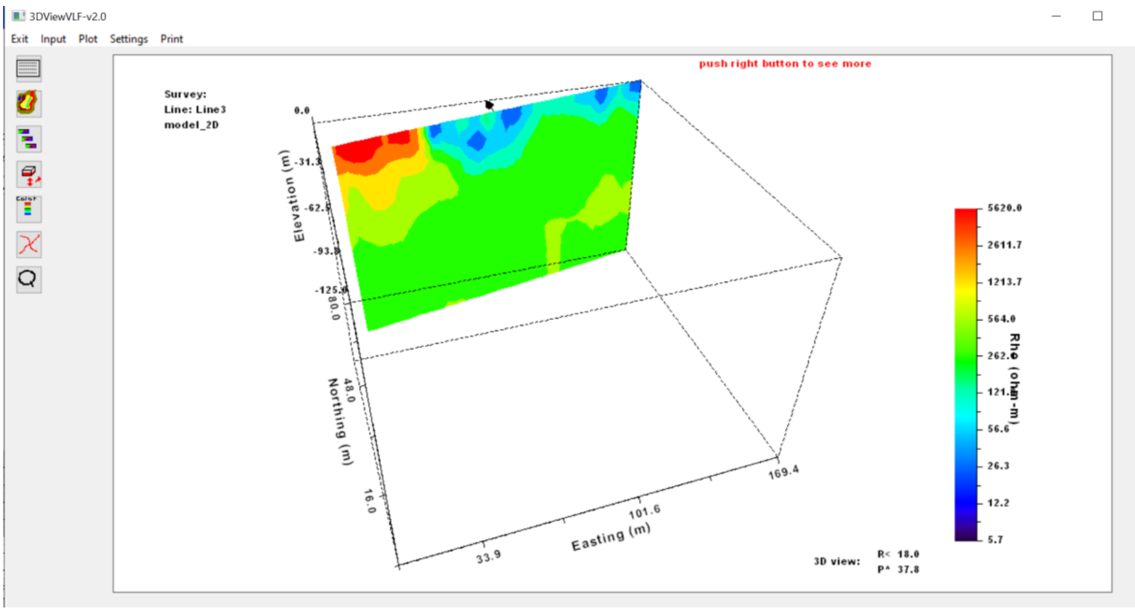


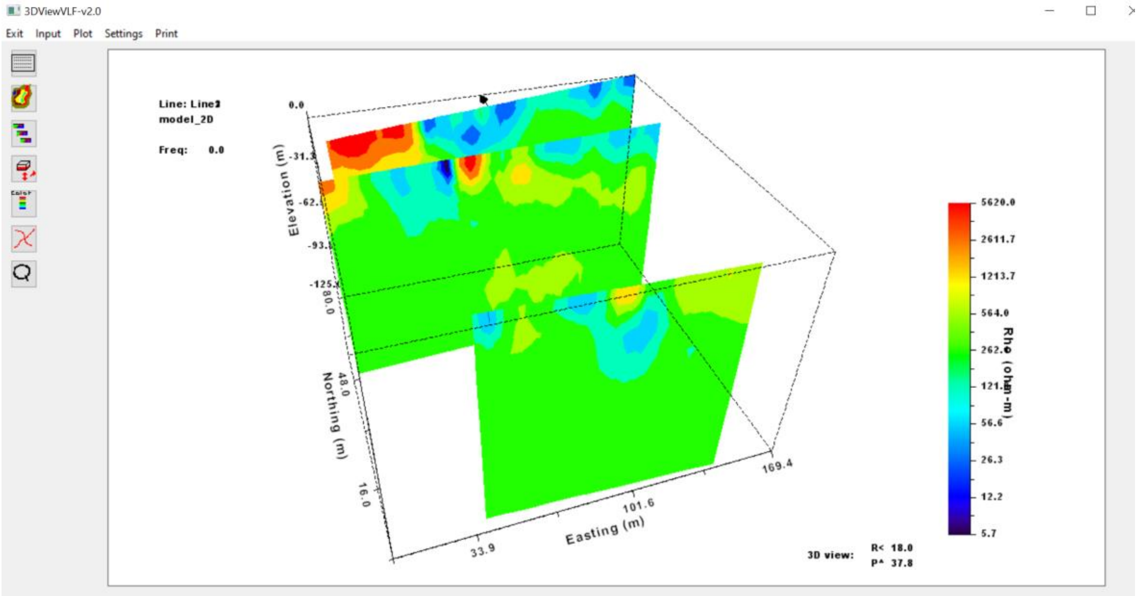




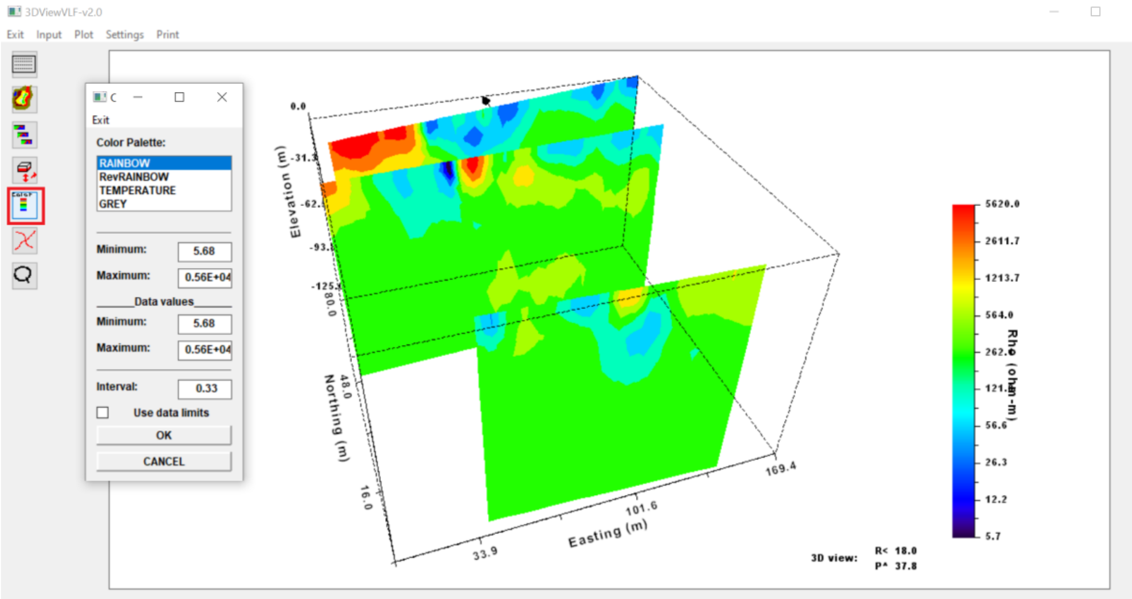
The left button  allows you to rotate the 3D view of your results,

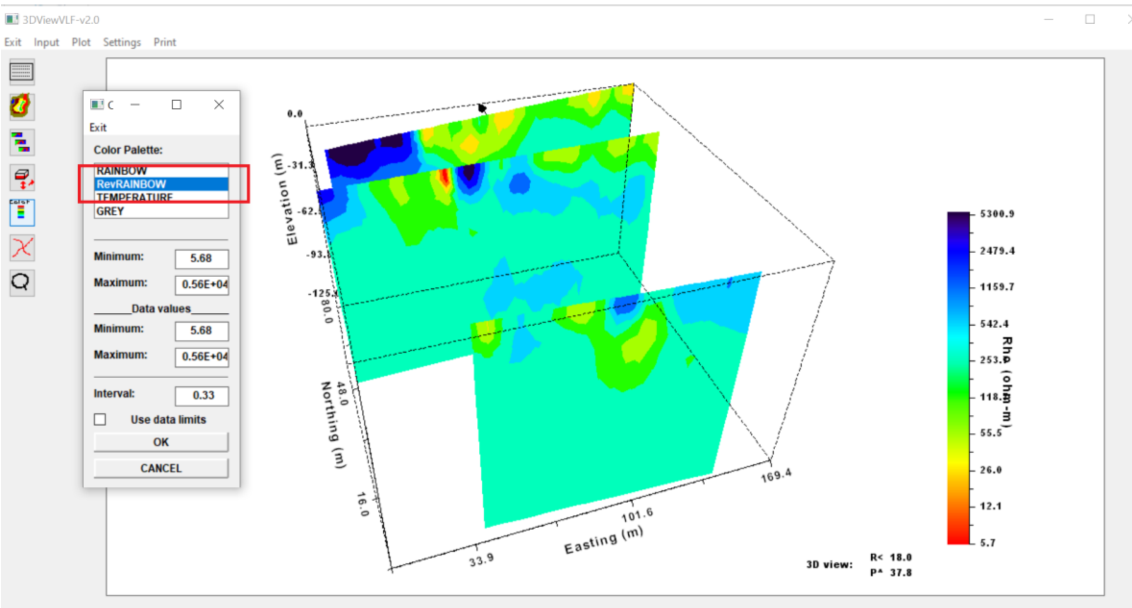




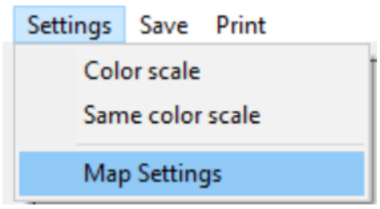


The colour scale can be modified clicking in the 





Some map features can be controlled using Map Settings including the depth of the horizontal slices,



Before you input results from a new survey the existing files must be deleted pushing

APPENDICE A. Processing the data

The data can be filtered using a three-point moving average method. This averaging action removes the high frequency components present in the data.

The data can be interpolated using a linear approximation. In the majority of the cases a linear interpolation is more realistic than more sophisticated method like those based on splines or polynomial techniques. The interpolation factor (*n*) represents the number of values that will be "created" between two contiguous ones on the original data set. The interpolated data will have (N+n(N-1)) values, where N is the number of values in the original data.

Fraser filter is a four-point weight average filter. The weights are defined in accordance with the reference system. In this package they are +1, +1, -1, -1. This filter operates over real and imaginary components of the tipper.

Karous-Hjelt filter operates over the real part of the data (inphase component) to obtain a pseudo-section of the equivalent current distribution responsible for producing the measure magnetic field. The magnitude of the output depends on the apparent current density, which is unknown. The values in the pseudo section are then arbitrary. Its interpretation is generally as follows: a) areas of positive values correspond to good conductors; b) areas of negative values correspond to high resistive zones; c) the trend of the contour pattern gives indications about the dip of the conductors. In this package the K-H weights are: 0.102, -0.059, 0.561, -0.561, 0.059, -0.102.

APPENDICE B. Topography

The topography is incorporated through a distortion of the finite element mesh.

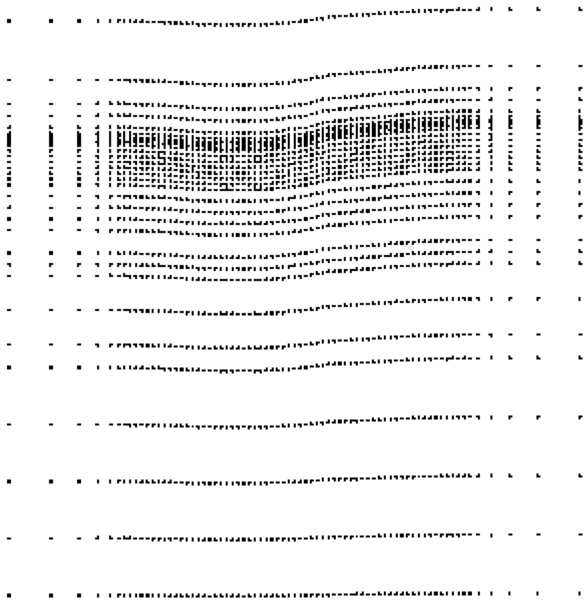


Figure B1. Example of a distorted mesh to incorporate a smooth elevation (a hill).

The original elevation is shifted taking as reference the lowest value, which assumes the value 0.

NOTE: steep elevation should be avoided (or smoothed) to prevent numerical errors.

APPENDICE C. Inversion algorithm

The nonlinear, smoothness-constrained inversion algorithm described by Monteiro Santos (2004) was adopted. The optimization equations are represented as follows (Sasaki, 1989; named algorithm S89 in this package):

$$\left[\left(\mathbf{J}^{\mathrm{T}}\mathbf{J}+\lambda\mathbf{C}^{\mathrm{T}}\mathbf{C}\right)\right]\delta\mathbf{p}=\mathbf{J}^{\mathrm{T}}\mathbf{b} \qquad \text{[C-1]}$$

or (Sasaki, 2001; named algorithm S01 in this package),

$$[(\mathbf{J}^{\mathrm{T}}\,\mathbf{J}+\lambda\mathbf{C}^{\mathrm{T}}\,\mathbf{C})]\,\delta\mathbf{p}=\mathbf{J}^{\mathrm{T}}\,\mathbf{b}-\lambda\mathbf{C}^{\mathrm{T}}\,\mathbf{C}\,(\mathbf{p}-\mathbf{p}_{\mathrm{o}}) \qquad \text{[C-2]}$$

where $\delta\mathbf{p}$ is the vector containing the corrections applicable to the parameters (logarithm of block conductivities, p_j) of an initial model, $\mathbf{p}_{\mathrm{o}}$ is a reference model, **b** is the vector of the differences between the observed and calculated tipper components [$\mathbf{b} = (\mathbf{T}^{\mathrm{o}}) - (\mathbf{T}^{\mathrm{c}})$], **J** is the Jacobian matrix whose elements are given by $(\sigma_j)(\partial T_i^{c}/\partial\sigma_j)$, the superscript T denotes the transpose operation, and λ is a Lagrange multiplier (Damping factor) that controls the amplitude of the parameter corrections and whose best value is determined empirically. The value can be determined empirically by comparing the models calculated using different values with the available information. The elements of the matrix **C** are the coefficients of the values of the roughness in each parameter, which is defined in terms of the four neighbours parameters. The elements of **C** are -4, 1, or 0. An iterative process allows the final model to be obtained, with its response fitting the data set in a least square sense.

The misfit between data and model response is calculated by:

$$rms=\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(d_i^{o}-d_i^{c}\right)^2} \qquad \text{[C-3]}$$

where N is the number of data values, σ the error on the data and d the data (real and imaginary components).

APPENDICE D. Empirical Mode Decomposition

There are several tools to analyse a signal. The most known is (probably) the Fourier decomposition, where a signal is decomposed into components which are monochromatic sinus and/or cosines. The Empirical Mode Decomposition (EMD) is a technique introduced by N.E. Huang (Huang 1998) that decomposes a signal $x(t)$ into functions, the called Intrinsic Mode Functions (IMF) $c_i(t)$ that are not single frequency components, and into a residue $r(t)$,

$$x(t) = \sum_{i=1}^{N} c_i(t) + r(t) \qquad \text{(D1)}$$

where N is the number of IMF functions. IMF functions are signals with the following characteristics (Trnka and Hofreiter, 2011):

- The number of extremes and the number of zero-crossing must either be equal or must differ by a maximum of one.
- Each point, that is defined as mean value of envelopes defined by local maxima and local minima is zero.

The EMD method was applied to VLF-EM data by Jeng et al. (2007, 2012) and the user is referred to these papers for a more detailed discussion.

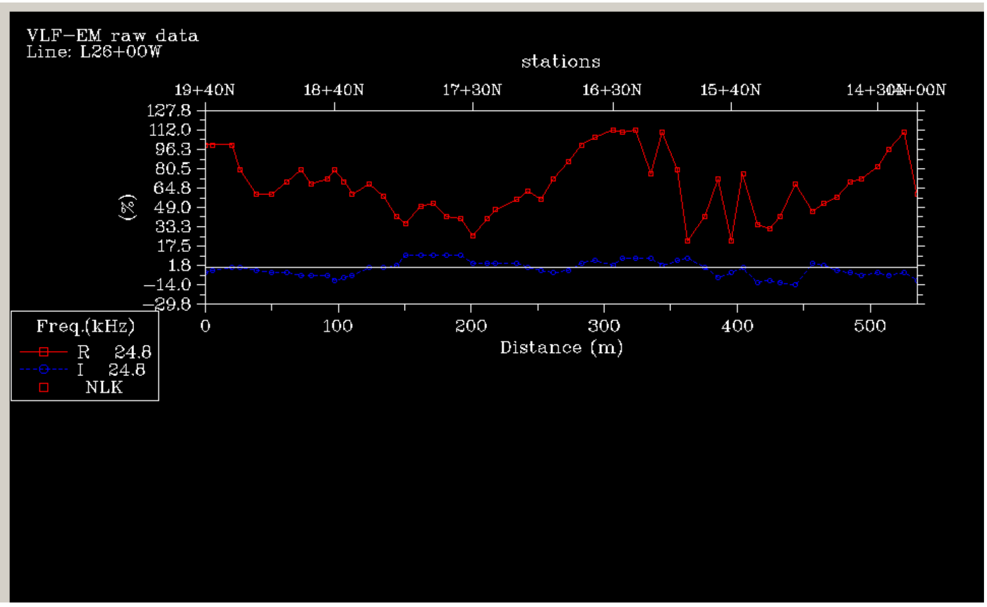


Figure D1. Example of a VLF-EM signal.

An example of EMD application is presented in Figures D2 and D3.

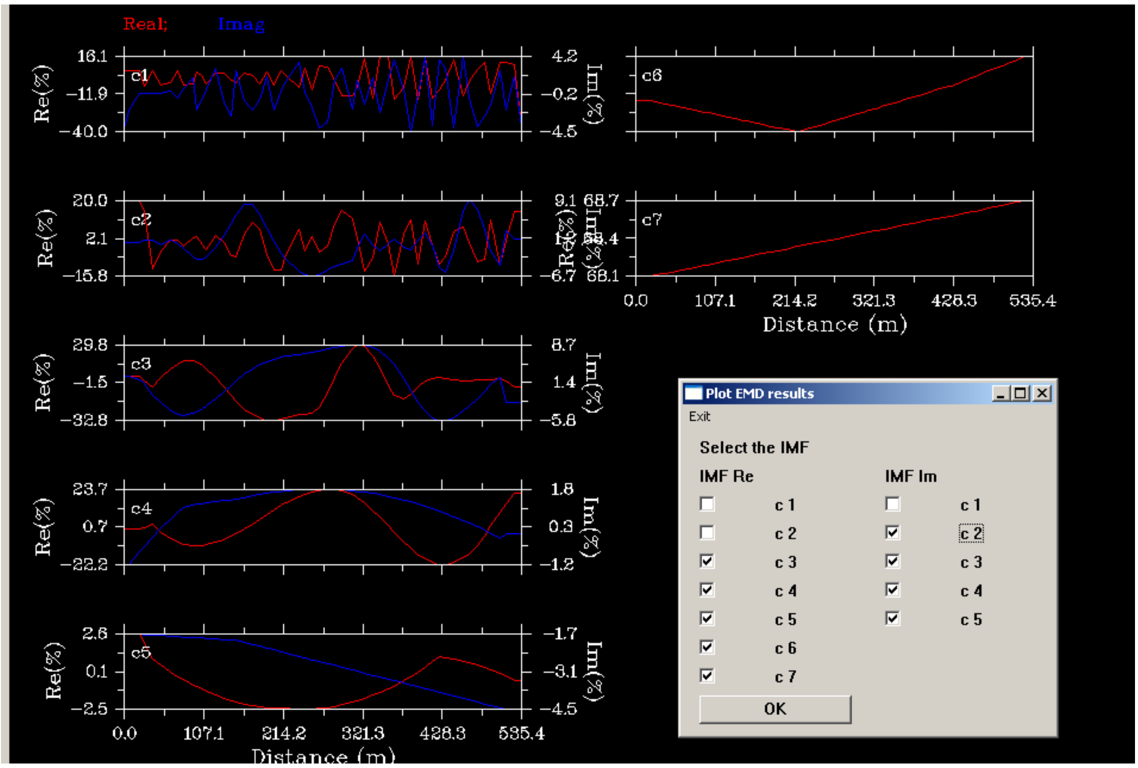


Figure D2. EMD of the VLF signals shown in Figure D1. The Re part of the signal was decomposed in seven IMF and the Im part only in five IMF functions. The last IMF represents the residue.

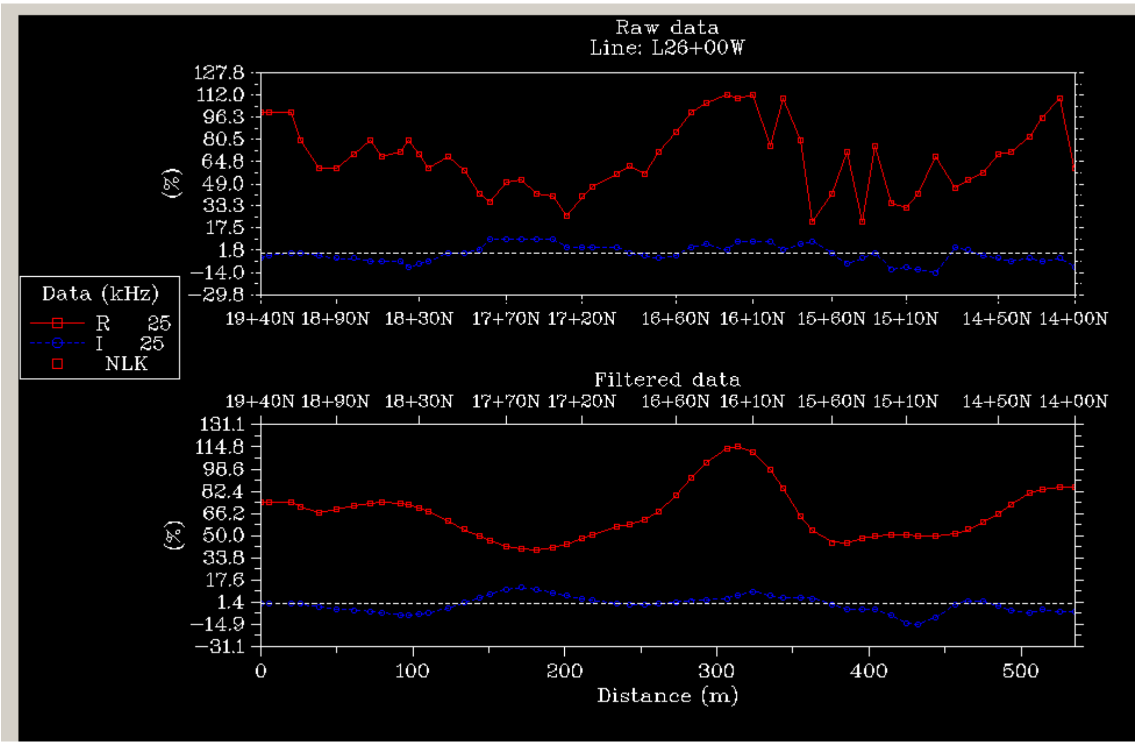
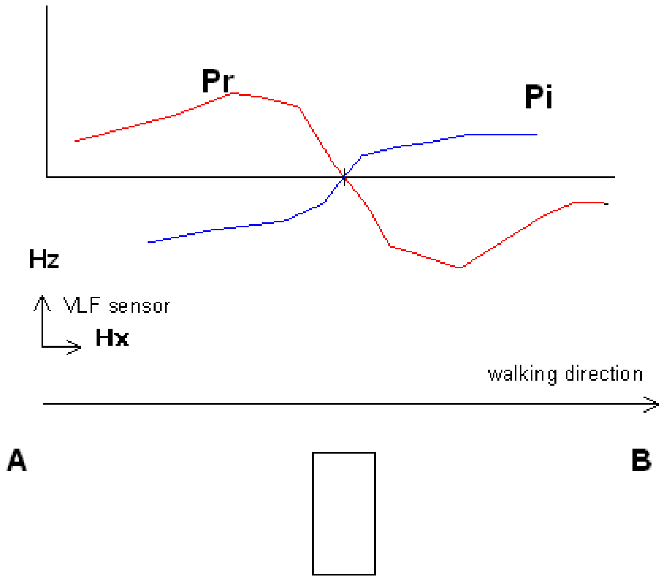


Figure D3. The filtered signal considering that it is composed by some selected IMF functions (as shown in Figure D2).

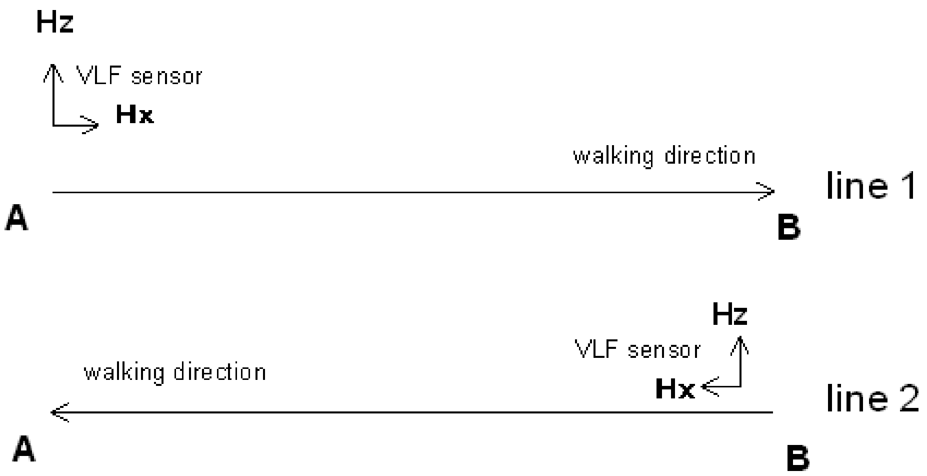
APPENDICE E. Inverting VLF lines

VLF2Dmf software assumes the "normal" VLF signal, over a conductive isolated body, is that described in the following figure. Usually, A and B represent South and North or to West and East, respectively.



In this case the data (in sequential order from A to B) can be imported and inverted, and the model will display A on left and B on right.

It is common to acquired data in parallel lines. In such case it is also usual to reverse the VLF signal to have consistency between the signals of the different lines. Let's consider the situation in the following figure, where the signal in line 2 was reversed (it is assumed the data file are contains the values ordered sequential according to the acquisition).



Inversion of the line 1 is made "normally". However, for line two there are two options according to the final output.

1- Model displayed from B to A (that is B will appear on left and A on right). Because the vlf signal was reversed it needs to be reversed again (use the tool reverse signal and reverse both components), and then the inversion can be done.

2- Model displayed from A to B (A on left and B on right). In VLF2Dmf program this can be done in 2 steps: i) reverse both signal and ii) reverse the model. After that the inversion can be calculated.

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