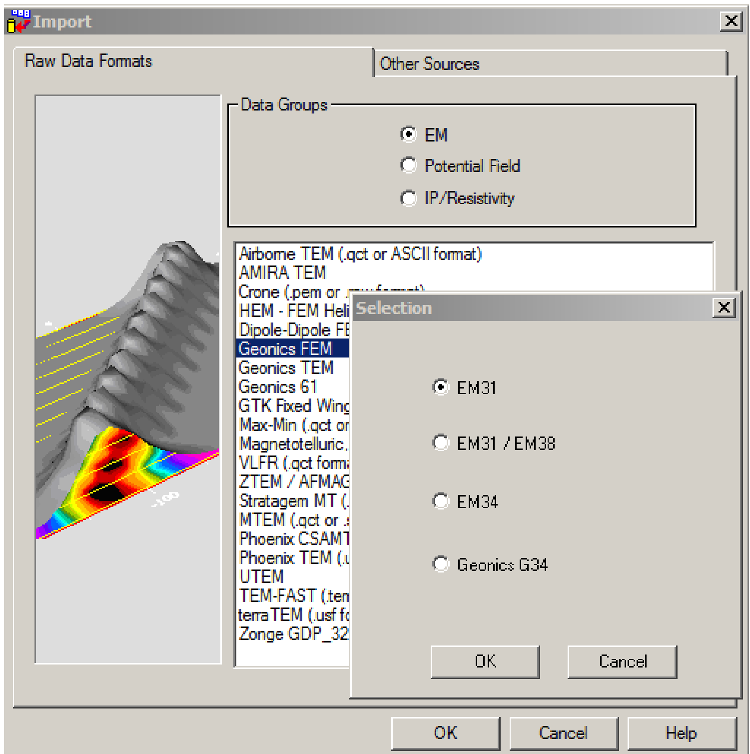
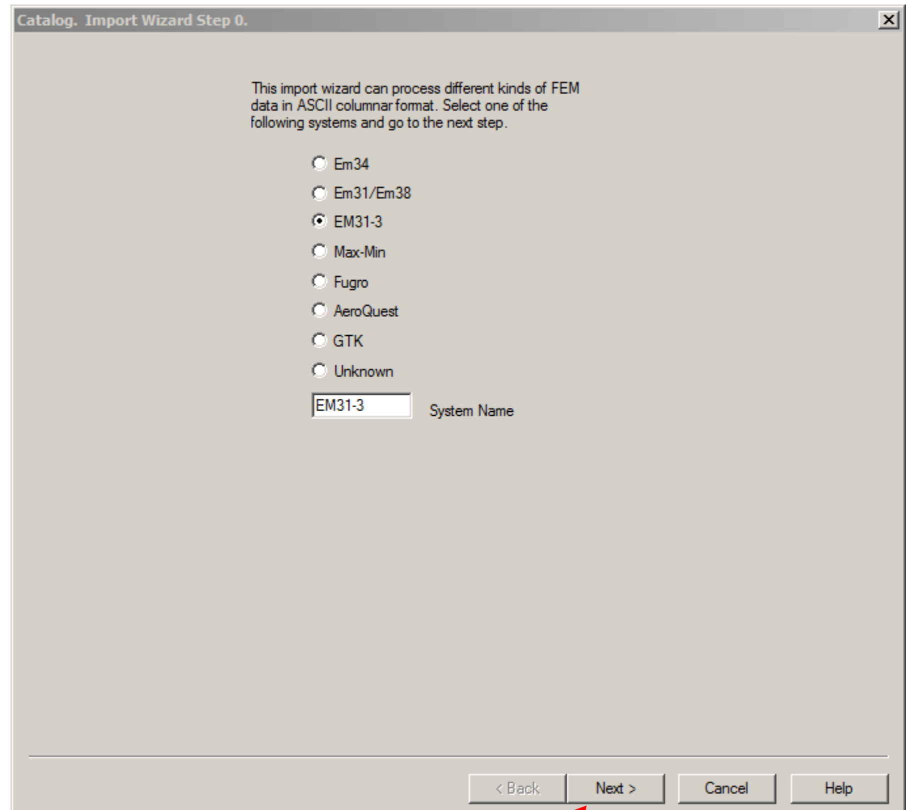
FDEM INVERSION TUTORIAL
ground, helicopter of fixed wing data

Steps: ***Page***

1. Import data
2. Examine data
3. Perform initial modeling
4. Perform controlled under-parametrized Marquardt or over-parametrized Occam Inversions
5. Inversion evaluation





Click “Next” button to proceed to the next step

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Your FEM data is typically of a dipole-dipole nature. This means that the transmitter and receiver are small coils typically represented numerically as dipoles with a defined separation and orientation. The configuration can be of many types. For example, a common type for both ground and airborne is when the coils are horizontal and thus the dipoles are vertical and the separation is along the profile direction. Typical examples are with one type of component of airborne data but also this is the type for ground instruments such as the EM31 or the GEM2. Ground surveys can be utilized by orientating the system perpendicular to the profile with either the dipoles up or pointed in the profile direction. This latter configuration is also utilized in fixed wing dipole-dipole systems.

Your data files could be in instrument formats such as provided by Geonics or as geosoft .gdb files or in ascii columnar files. The easiest means for import is to first import into your QCTool software which provides a wide range of capabilities. In QCTool, you can clean and edit your data and carry out other processing if required. The .qct file is then imported to EMIGMA. However, ascii files can be imported directly to EMIGMA if preferred.

In this example, we will utilize some Dighem 5 multi-frequency, multi-component data which was provided in ascii format.

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This data consists of 3 different data components with 5 different frequencies:

1. Horizontal Coplanar (Mz-Hz) separated by 8m at 900 and 7200 Hz
2. Co-axial (Mx-Hx) – separated by 8m at 1000 and 5500 Hz
3. Horizontal Coplanar (Mz-Hz) separated by 6.3m at 56 Khz

The header section of the file header is given below. The file contains data locations and elevations as well as magnetic and EM data.

```
/ XYZ EXPORT [12/20/2006]
/ DATABASE   [.\prearc-2.gdb]
/ ---------------------------------------------------------------------------
/
/       X       Y      FID       Z      BALT   ALTBIRDM     MAGSP     DIURNAL     MAGLD      IGRF      MAG    CPIR900    CPQR900   CXIR1000   CXQR1000   CXIR5500
CXQR5500  CPIR7200  CPQR7200   CPIR56K   CPQR56K    CPI900    CPQ900   CXI1000   CXQ1000   CXI5500   CXQ5500   CPI7200   CPQ7200    CPI56K    CPQ56K
//Flight 22
//Date 2006/10/02
Line  20010
```

In the header line for the channels, CP indicates coplanar while CX is coaxial. CPI and CPQ indicate, for example, in phase and quadrature . The numbers as in CXI5500 indicate that 5500Hz is the frequency for this data. "R" in the labels likely indicates reduced or processed. The header line has been wrapped here for convenience. The data has the elevation via the barimetric altitude, whereas ALTBIRDM represents the altitude of the data above the surface. The data file also contains raw, base station and processed magnetic channels. The data file can be input to QCTool without editing. If the channel header line is selected as the channel headers then the channels will be automatically labeled during creation of the .qct file. A number of editing procedures were carried out in QCTool. There were several bad station locations which were deleted and about 2 dozen stations with no data which were also deleted. Additionally, the tie lines were not broken into separate lines but were all with one line. We utilized the tools provided in the map tools to break the tie lines into separate lines and then they were renamed. We are now ready to import to EMIGMA.

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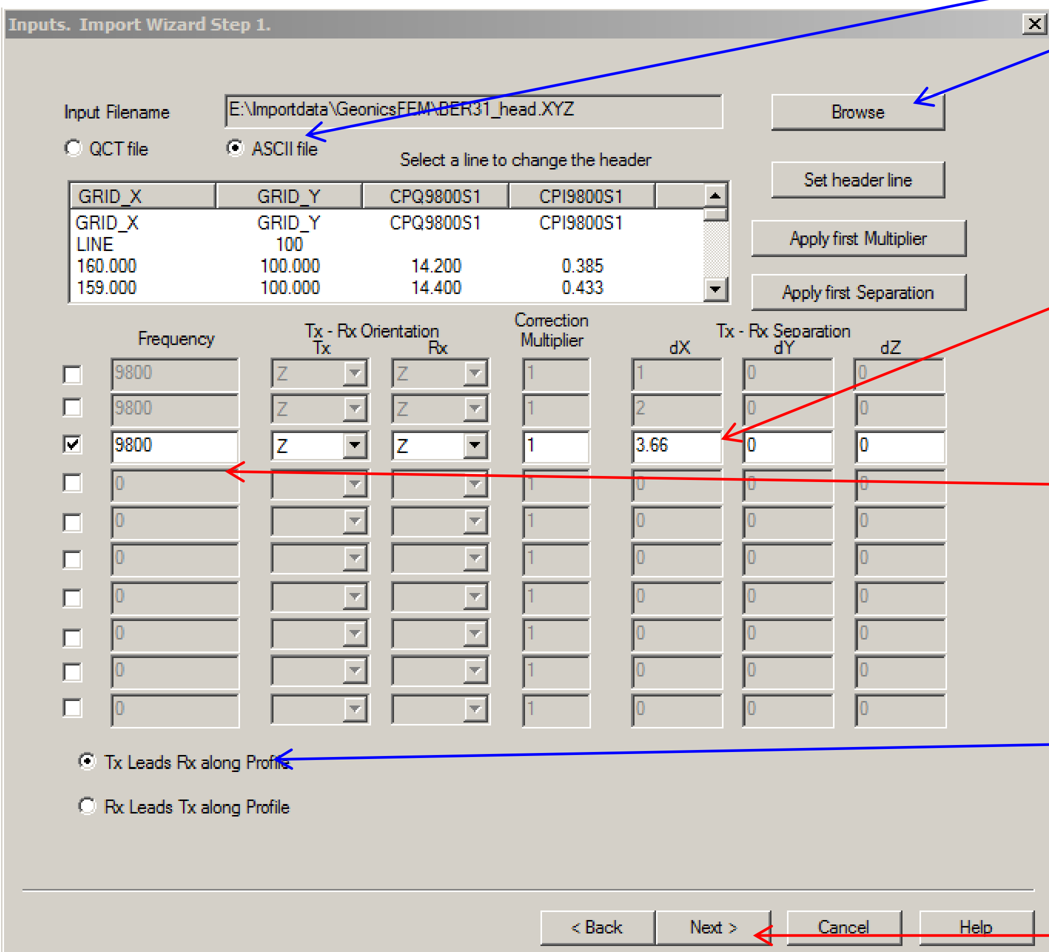
Choose the data file format and click “Browse” button to select data file



Set separations of Tx-Rx in X, Y and Z directions

The frequency shown here will differ with different selection of FEM system

Select whether Tx or Rx is leading

Click “Next” button to process to the next step

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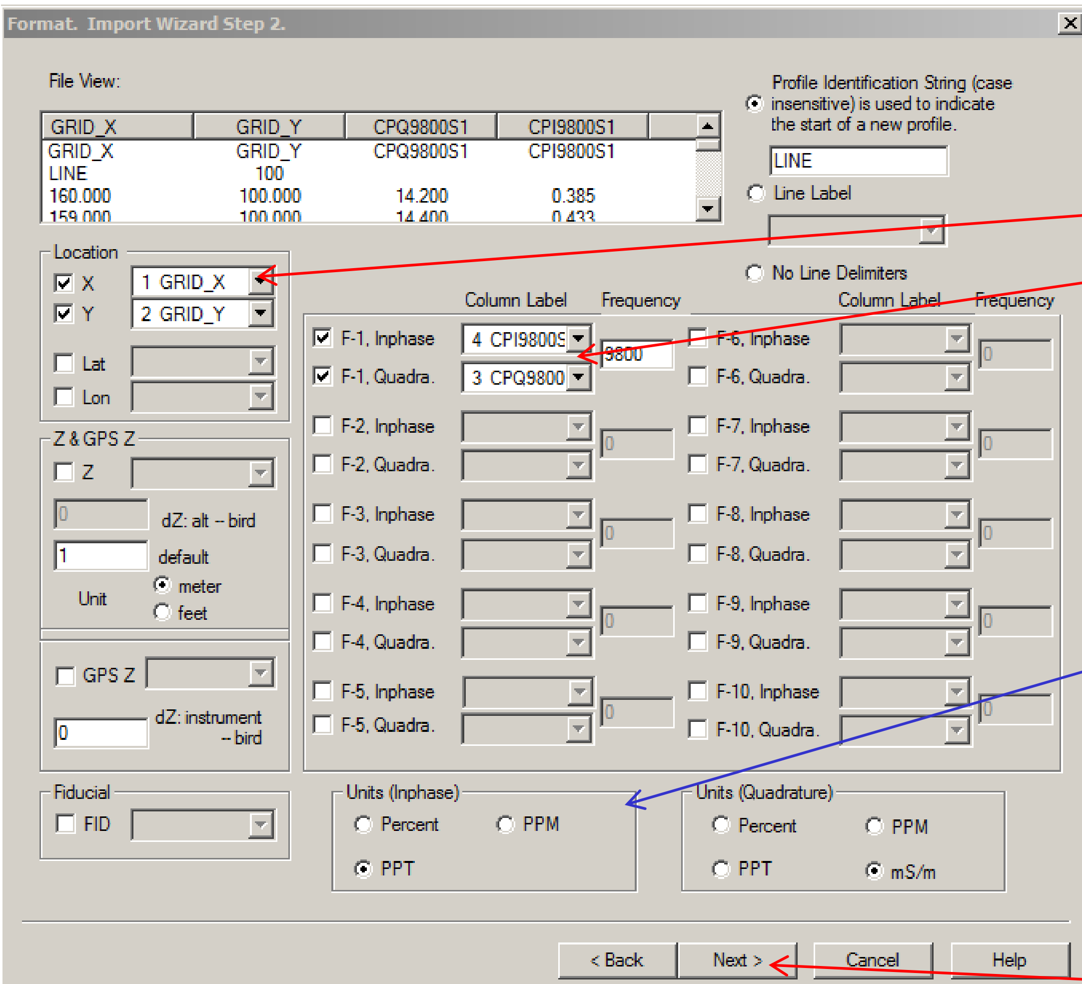

Choose column name corresponding to location and inphase/quadrature signals

Note: this dropdown list will be in accordance with column names of importing file.

Choose units for inphase/quadrature signals

Click "Next" button to process to the next step

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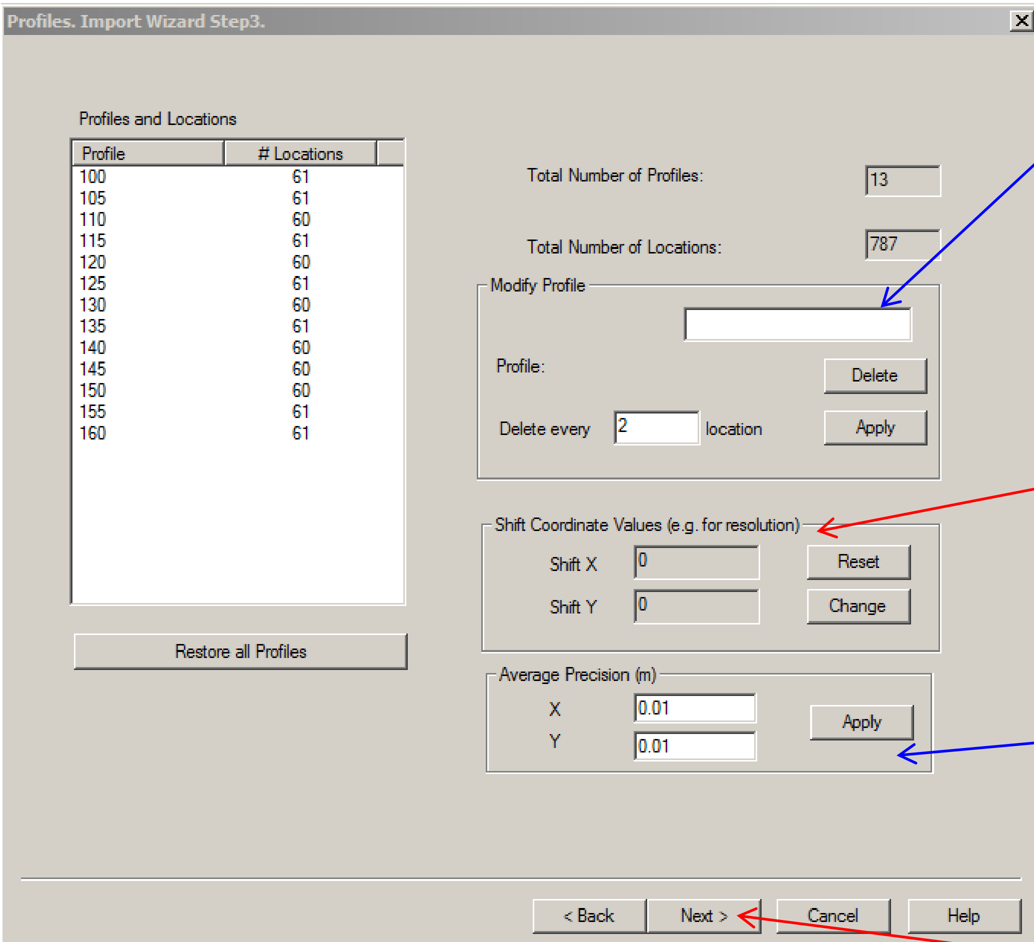

Select the profile you want to delete and its number will appear here. Click "Delete" button to delete this profile from importing file. You can also delete locations by every certain number.

To shift the coordinate for a better positioning accuracy, click "Change" button and made change in the popup dialog. Click "Reset" to restore its original value.

Select within what distance to average data. (e.g. if you enter 2, the duplicate data will be averaged within the 2m interval.)

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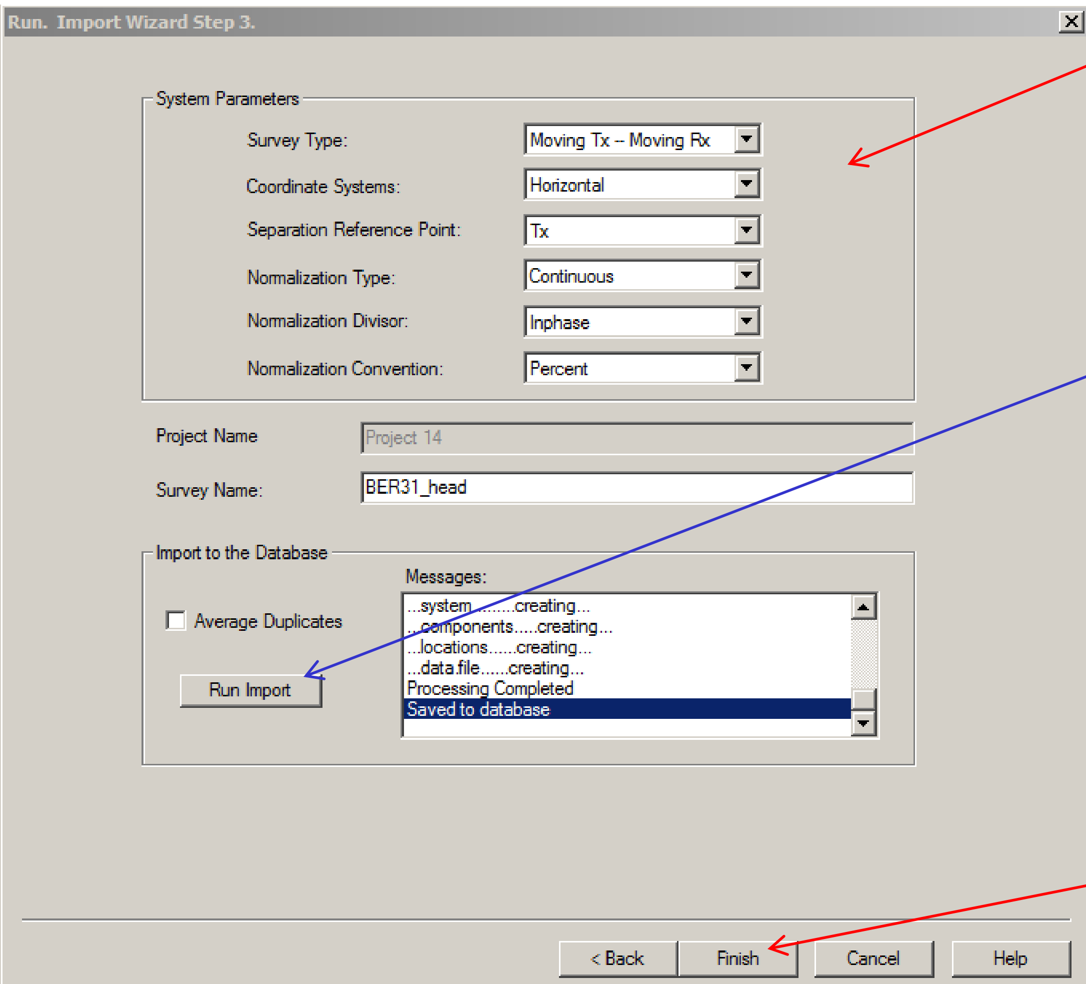

Set system parameters

Click “Run Import” button to start the importing process

Click “Finish” button after import process is done

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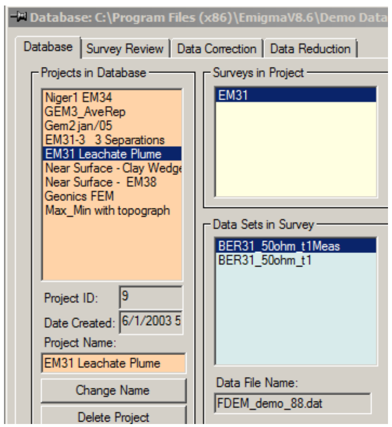
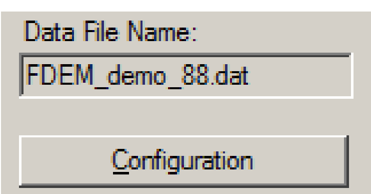
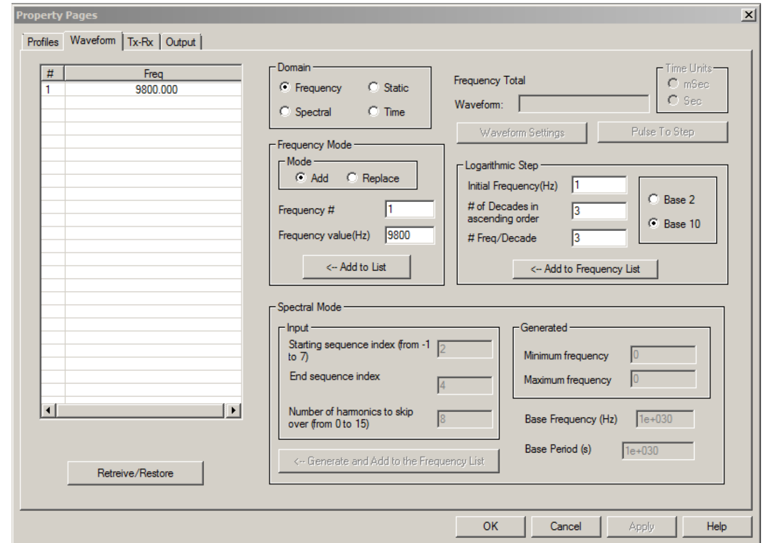
1. Check database for the survey

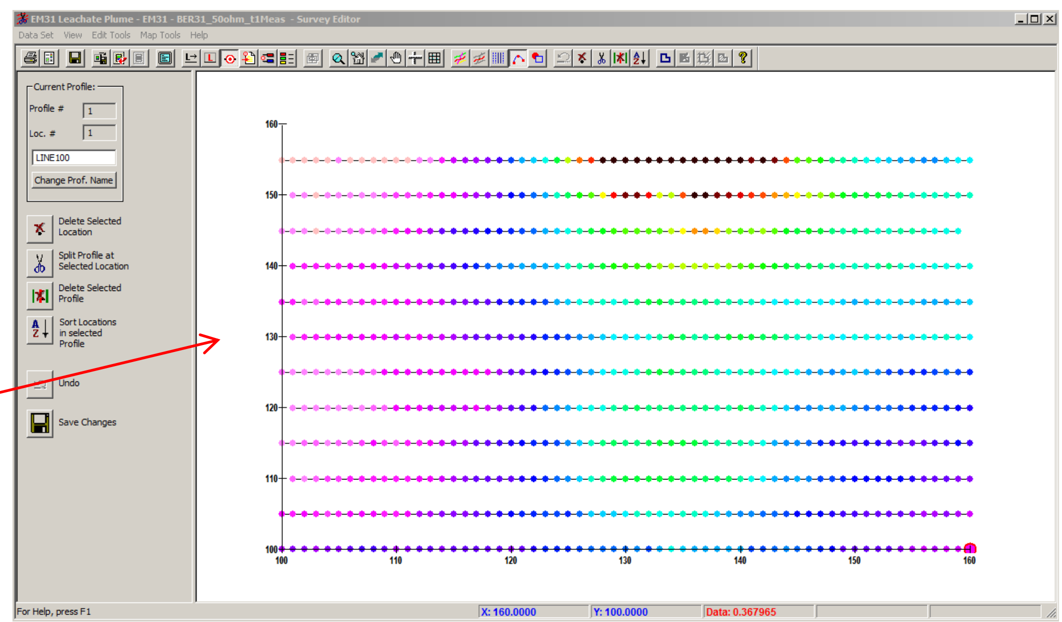


2. Click configuration



3. Check the frequency





4. Check lines and stations by clicking "Survey Editor" button 

1. Import data
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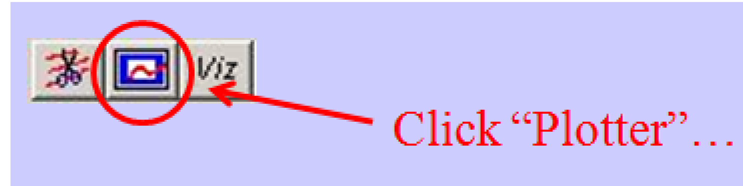
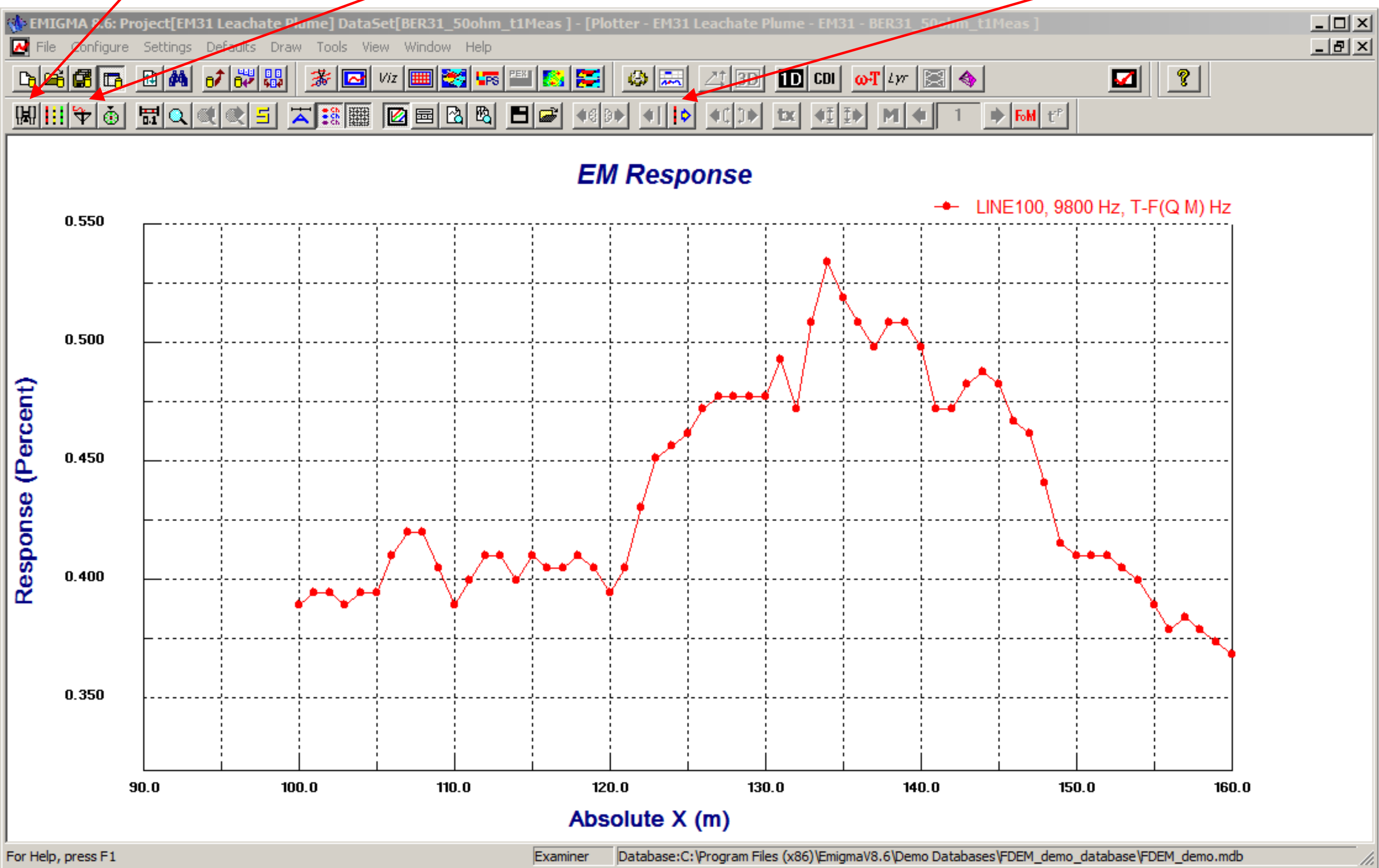


Change data set in Plotter

Switch between profile and spectrum mode

Toggle between profiles



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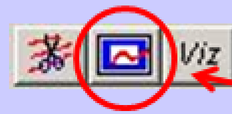
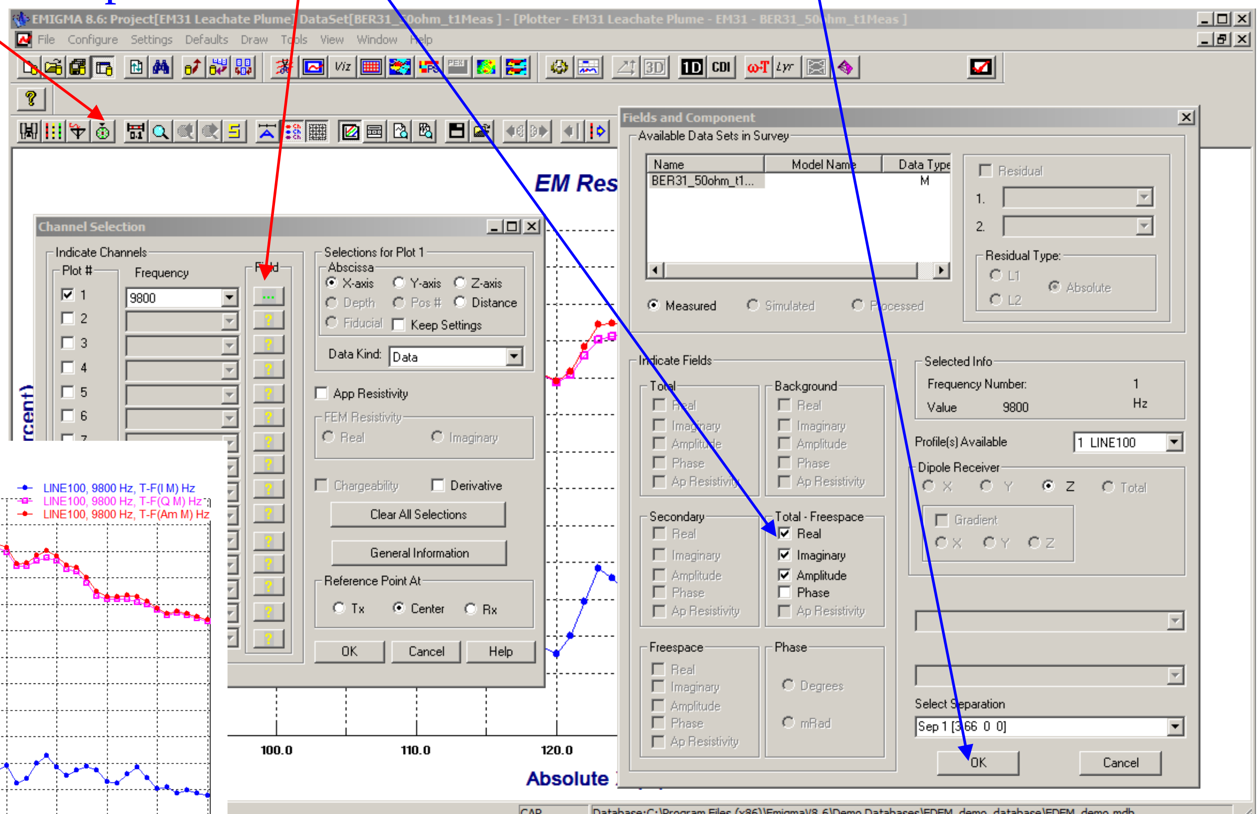


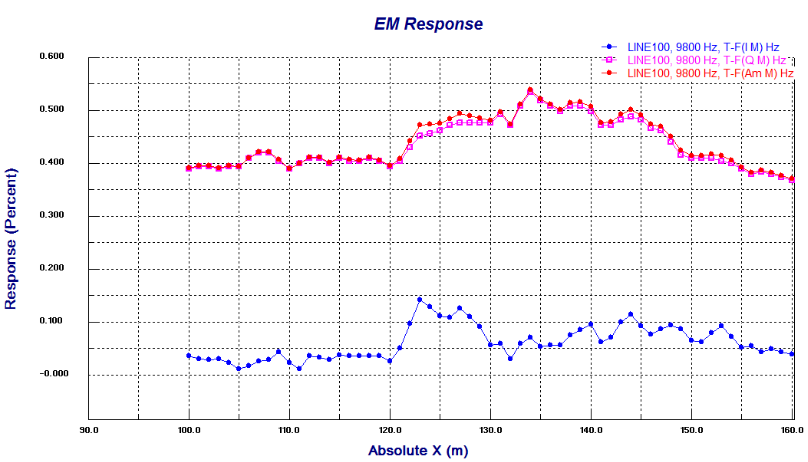
Click "Plotter"…

Click "Channels" button, and select "Field" in popup dialog

Check "Real", "Imaginary" and "Amplitude" options, and click "OK" to bring up real/imaginary/amplitude data plot:



Real/Imaginary/Amplitude data:



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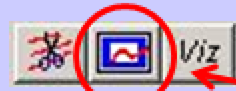
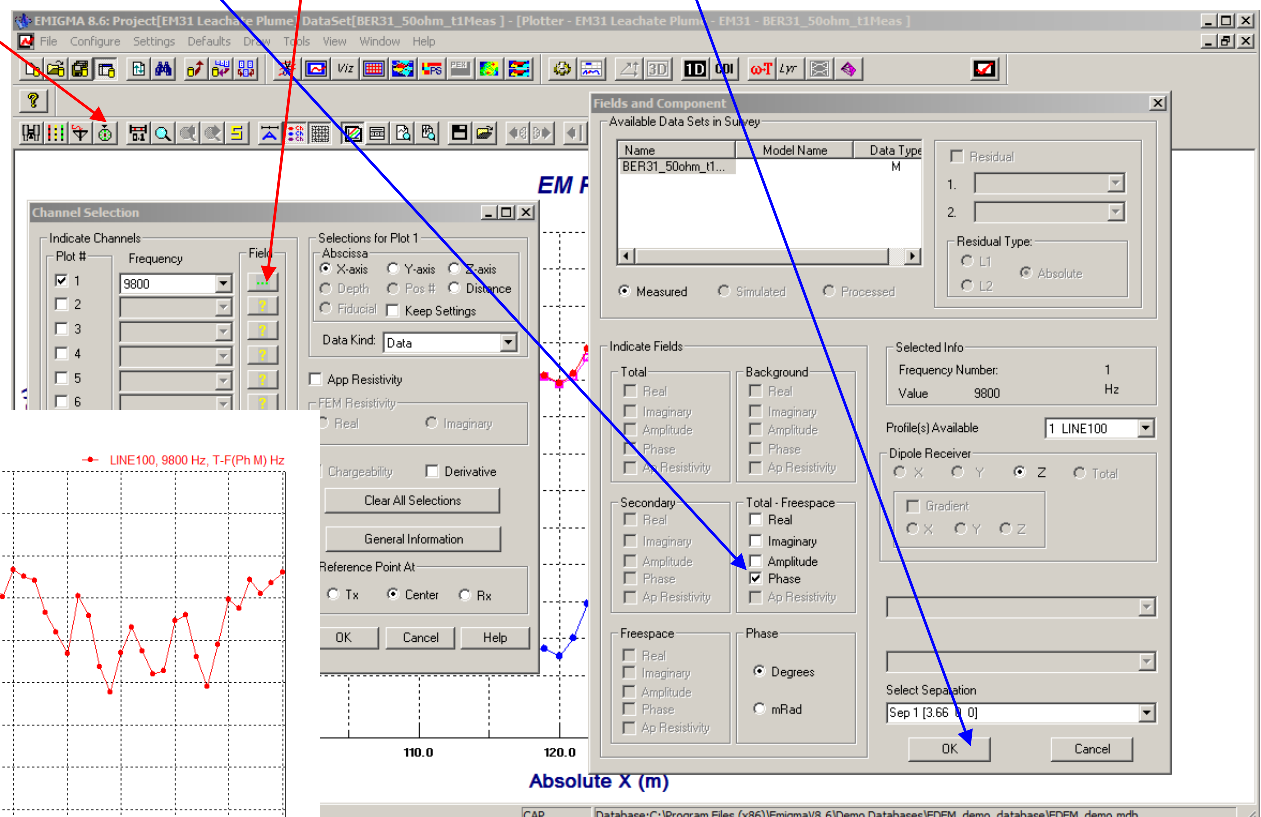


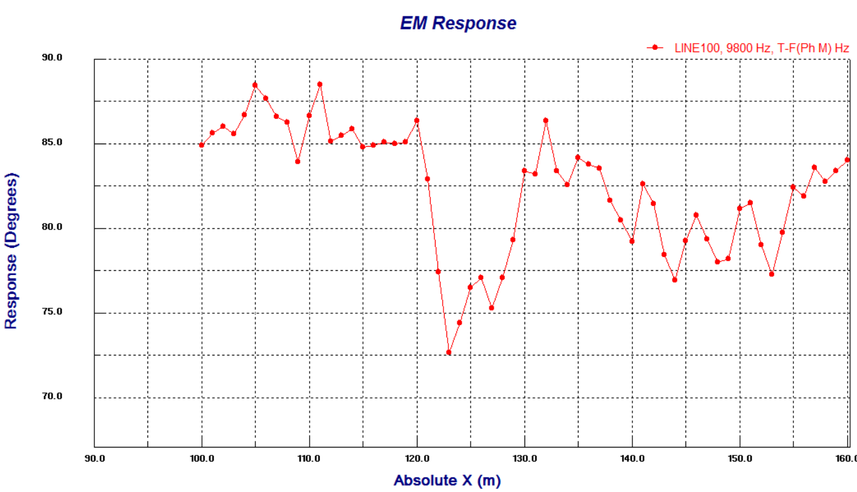
Click "Plotter"…

Click "Channels" button, and select "Field" in popup dialog

Check "Phase" option, and click "OK" to bring up phase data plot:



Phase data:



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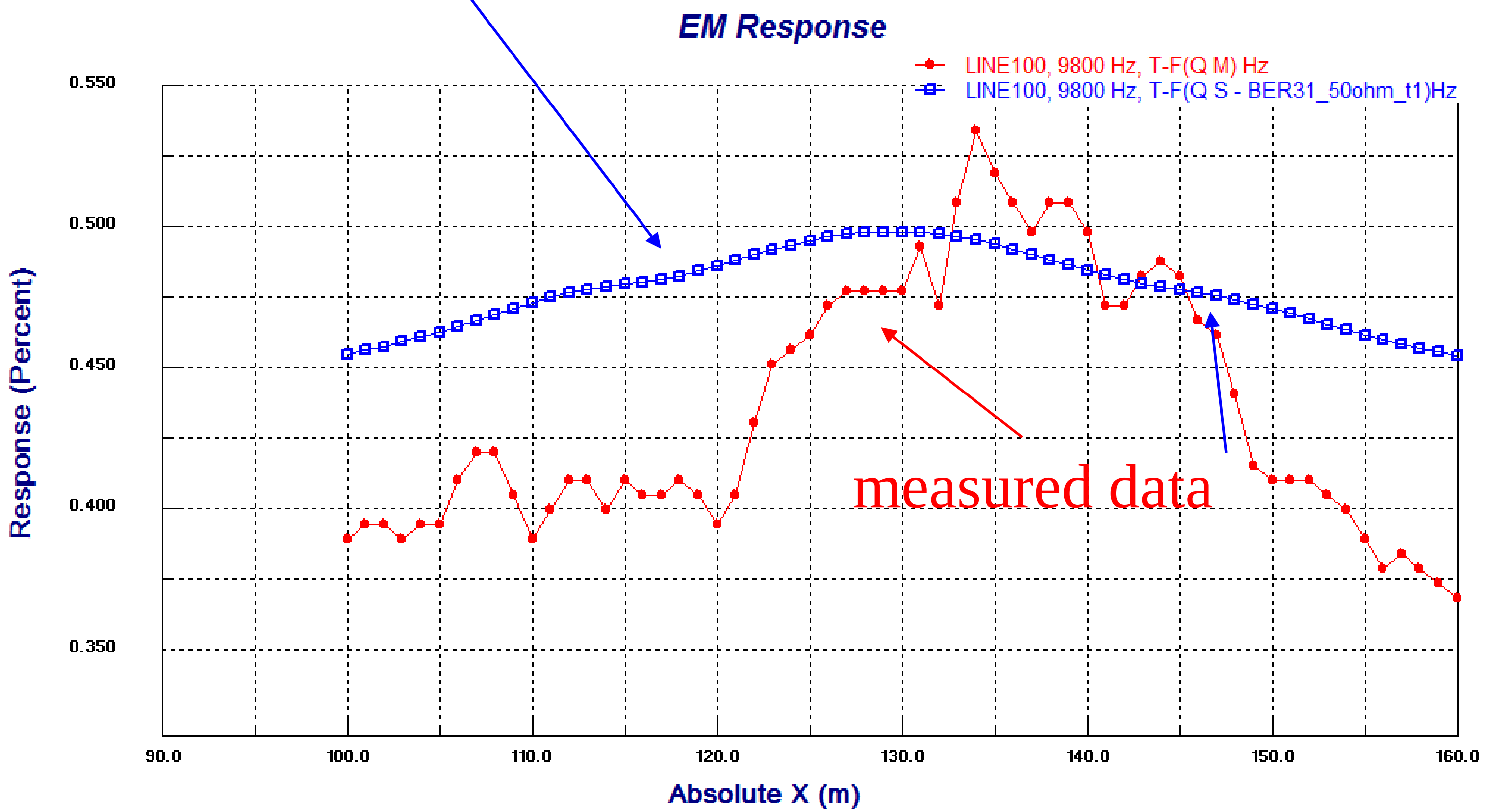
Note: *Performed some initial modeling to get a "feel" of the background resistivity and estimate parameters of initial model for inversion.*

simulated data with a forward model



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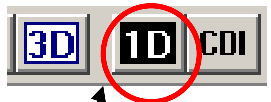
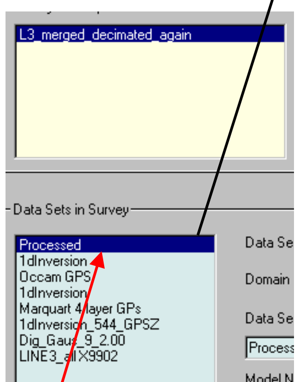
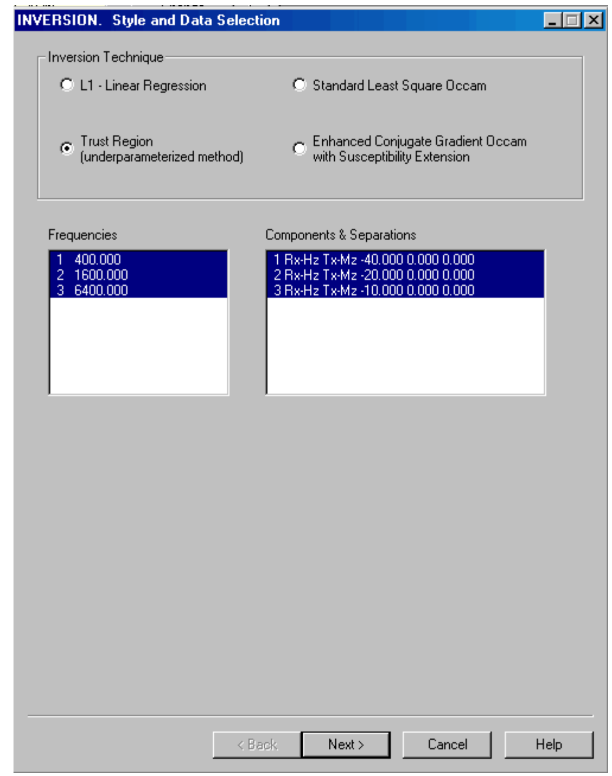
Select project





Select survey data



In this case, we will be utilizing a 3 frequency EM34 dataset, with 3 separations each at its own frequency.

***Note on Quadrature sign convention*: Most FEM data utilizes a convention of *exp*(-iωt). However, EMIGMA utilizes the standard scientific convention of *exp*(+iωt) for all data. However, the 1D inversion assumes the standard data convention , flipping the quadrature for inversion and then placing back flipped to match the simulation convention. This should be transparent for the user.**

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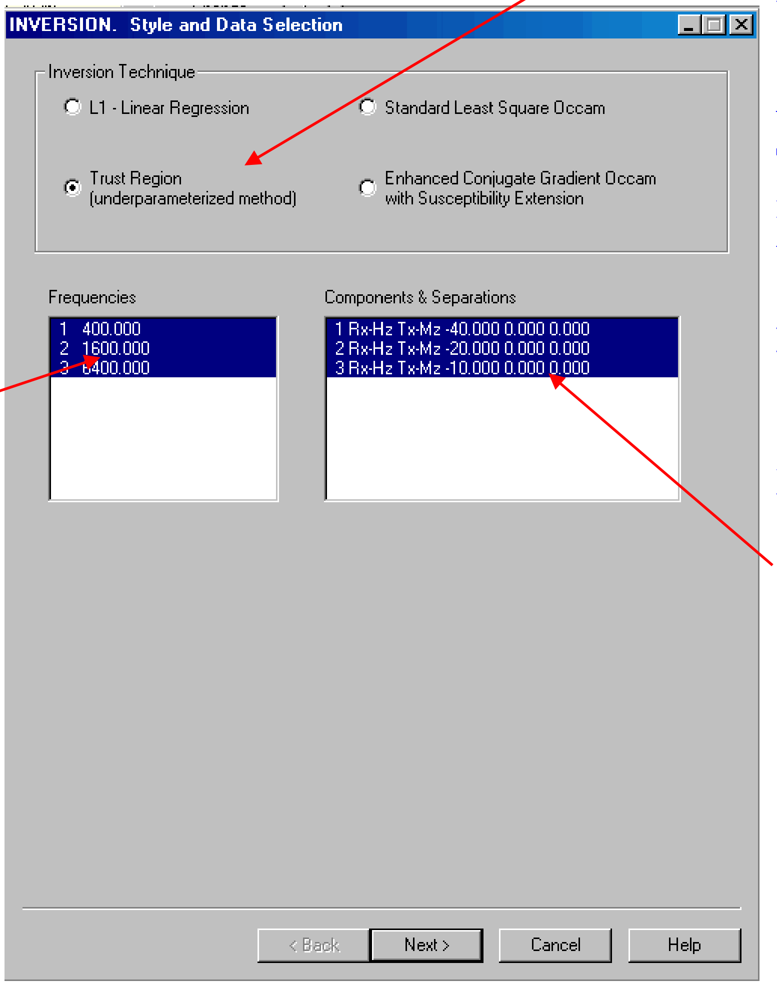

Select frequencies to be inverted

Note: the maximum number of frequencies for an inversion is 50.

Inversion Technique:

L1 – Linear Regression: Norm-1 linear regression model for solving the least-square problem

Standard Least Square Occam: using smoothing Occam inversion which inverts only resistivity with layer thickness fixed

Trust Region: inverts for both layer thickness and resistivity. This technique is a modern evolution of the older Marquardt techniques but uses model gradients

Enhanced Conjugate Gradient Occam with Susceptibility Extension: using conjugate gradient method to solve Occam style inversion problem with susceptibility extension

Select components used for inversion

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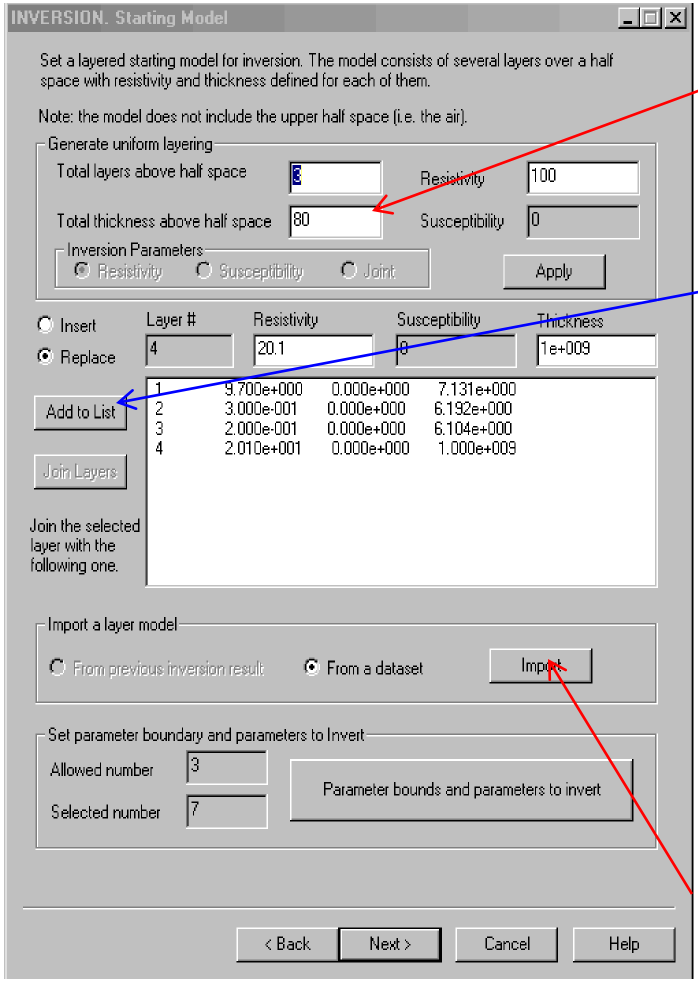
Create a Starting Model

Inversion Parameters:
If selectable, choose which parameter you would like to inverse: resistivity, susceptibility, or both.



Generate a Starting model:
Select how many layers in total that you would like in the model, set the initial resistivity and thickness. Then click "Apply" button.

Editing Starting model:
After making a starting model (whether by importing or generating), the user may edit either the resistivity or the thickness of the layer. Set resistivity and thickness of the layer and check "Insert" radio. Select one layer from the table and click "Add to List" button. The new layer will be added below the selected one. Or simply click on the parameter and make change at "Resistivity" and "Thickness" boxes above the table. Select "Replace" option and click "Add to List" button. The user may also join two adjacent layers by selecting one layer and clicking "Join Layers" button to merge this one with the layer below.

Import Layers:
If you already have a forward model that you like to use, you may import it as the starting model by clicking "Import" button and select from appeared dialog. We use this option here.

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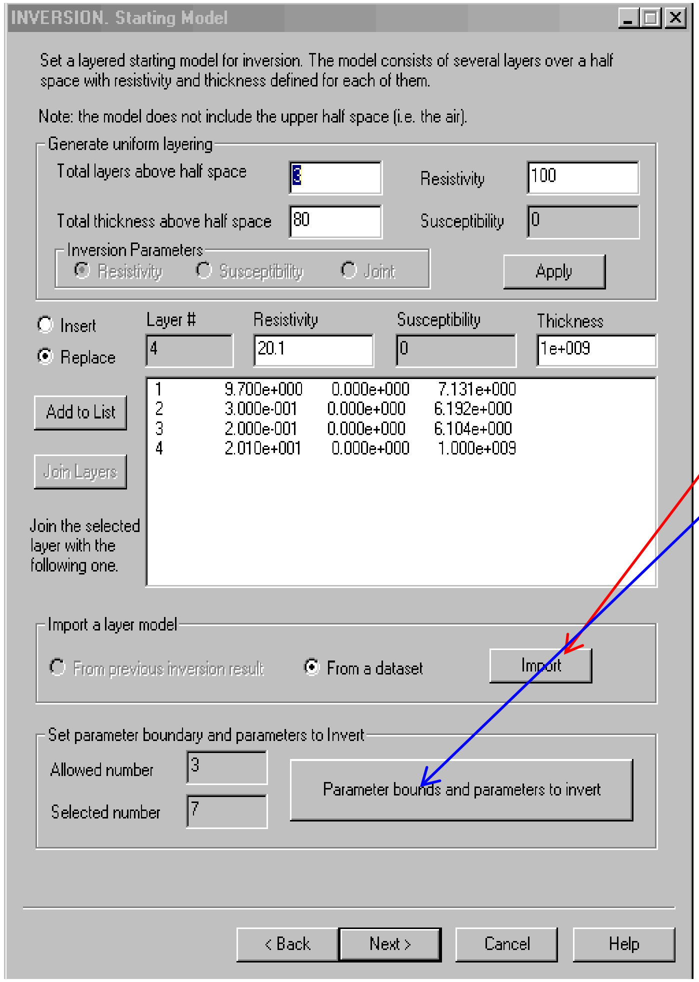
Create a Starting Model



Import Layers:
If you already have a forward model that you like to use, you may import it as the starting model by clicking "Import" button and select from appeared dialog. We use this option here.

Parameter bounds and parameters to invert:
If you already have a forward model that you like to use, you may import it as the starting model by clicking "Import" button and select from appeared dialog. We use this option here.

1. Import data
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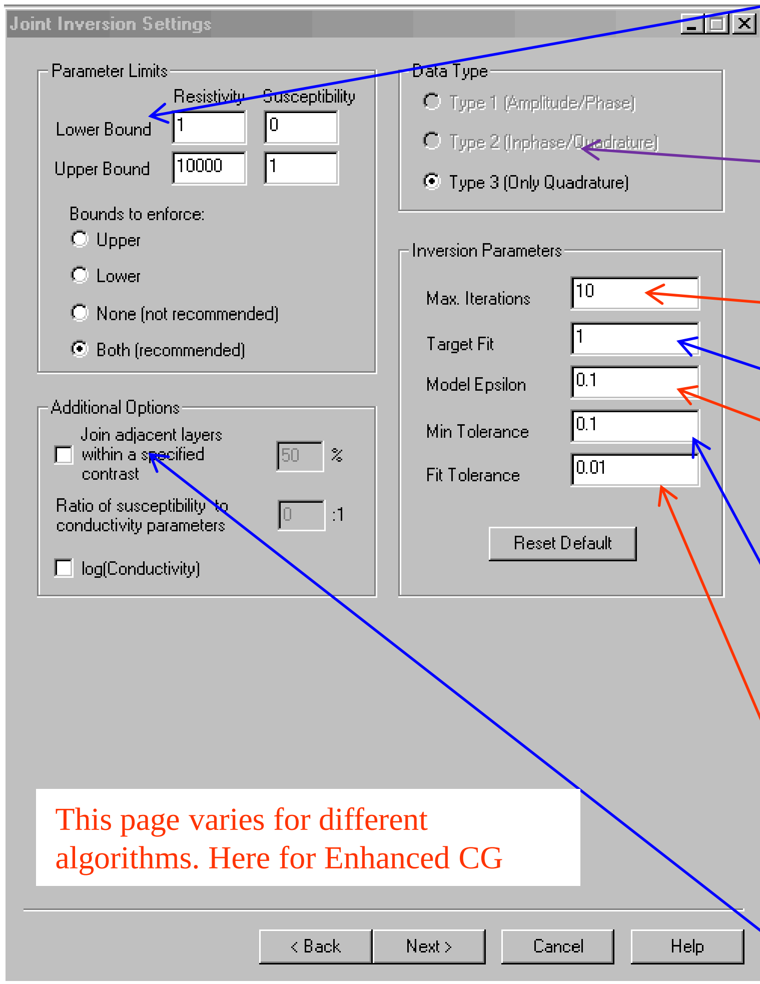
4. **Perform controlled Trust Region or <u>Occam Inversions</u>**
5. Inversion evaluation



This page varies for different algorithms. Here for Enhanced CG

Model and Simulation Parameters Settings

Parameter Limits:
It is useful to constrain model parameters to ranges that are possible in the geological environment.

DataType:
Depending on data, different data are available for inversion

Max. Iterations:
A higher value will help ensure accuracy but execution times increases

Target Fit:
The residual between the estimated data under the best model and the measured data.

Model Epsilon:
Once the target fit has been met, if subsequent inversion produce an rms change in model parameters less than epsilon then inversion is deemed to be accomplished.

Min Tolerance:
Determines how accurately the search algorithms determine minima in the fit.

Fit Tolerance:
Determines how close to determine the final fit

Join Layers:
When the contrast between neighboring layers is within a certain percentage (20% in this case), join these two layers together.

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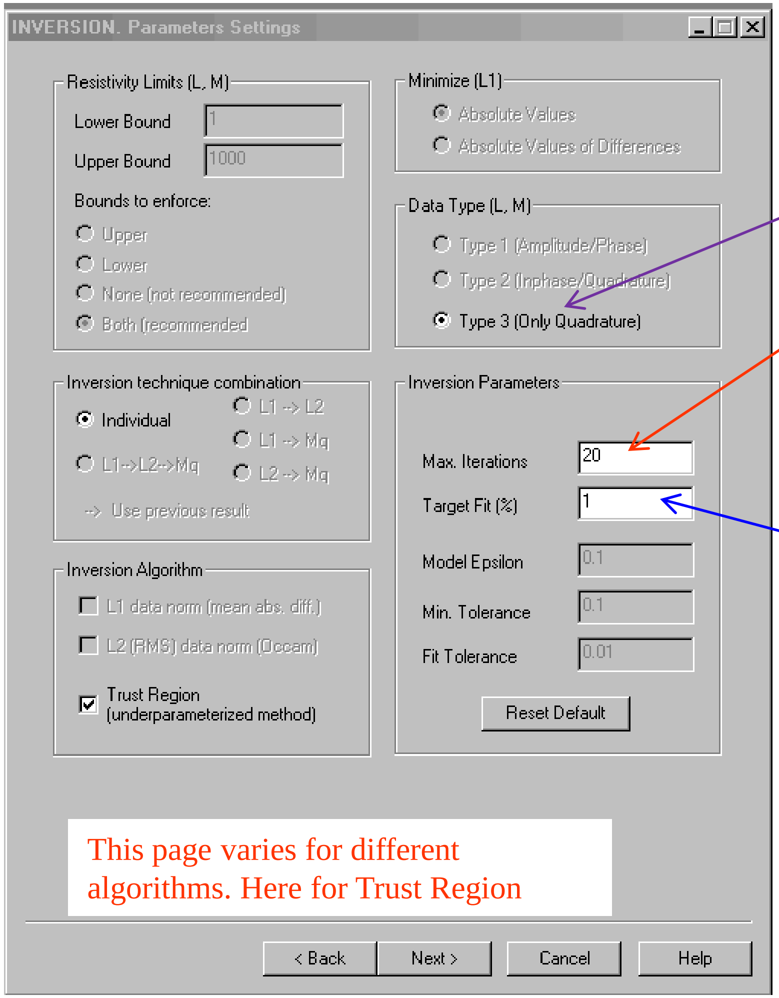
Model and Simulation Parameters Settings



This page varies for different algorithms. Here for Trust Region

DataType:
Depending on data, different data are available for inversion

Max. Iterations:
A higher value will help ensure accuracy but execution times increases

Target Fit:
The residual between the estimated data under the best model and the measured data.

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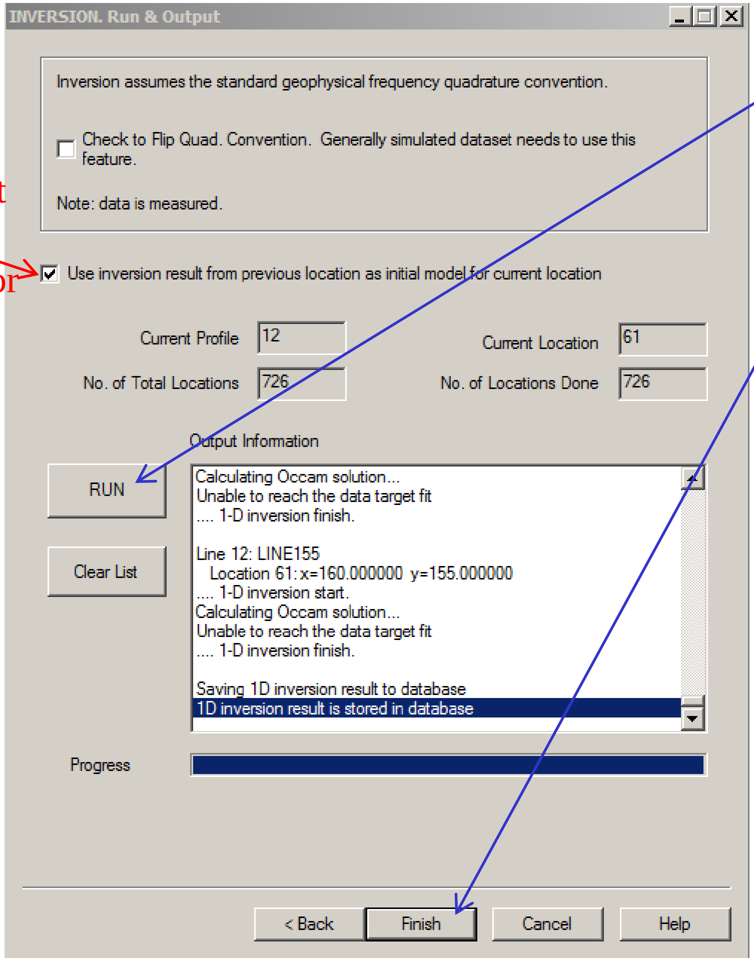
Executing the Inversion

Choose inversion result from previous location as the initial model for current model will create smooth spatial model. Suggested for large datasets.



Finally, click the "Run" button. The right window (in white) shows each data point's progress. Click "Finish" button to complete inversion procedure.

NOTE: When the inversions are running, you may minimize the window and the processing will run in the background allowing you to continue to work on the computer. Any extra CPU cycles will be used by the inversion process. For some datasets containing 10's of thousands of data points, the process may take several hours.

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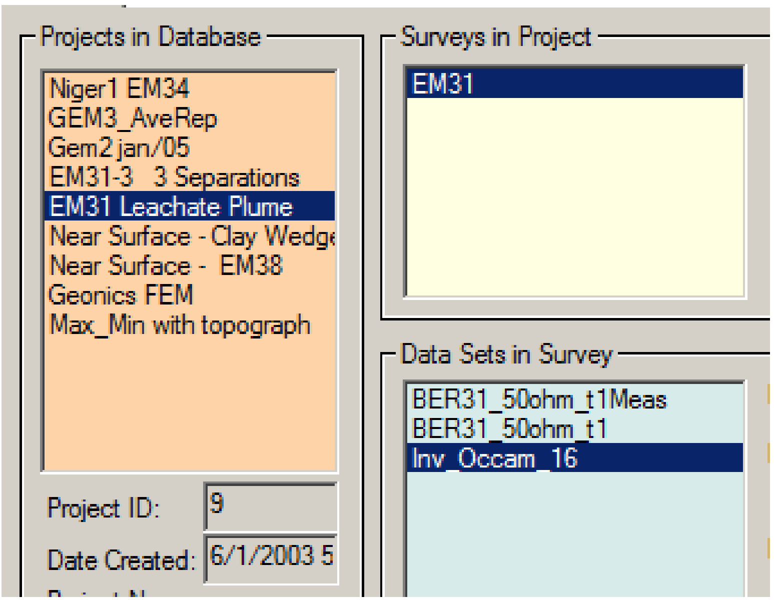
5. **Inversion evaluation**

Inversion Evaluation



In each survey, there will be several data sets after modeling, inversion and processing. In this case, we have 1 forward model and 1 inversion model. The forward model has a new data set containing the simulated data under the model. Similarly, each inversion contains a new dataset containing the simulated data set under the inversion model (for each point) and attached to that data set is the inversion model.

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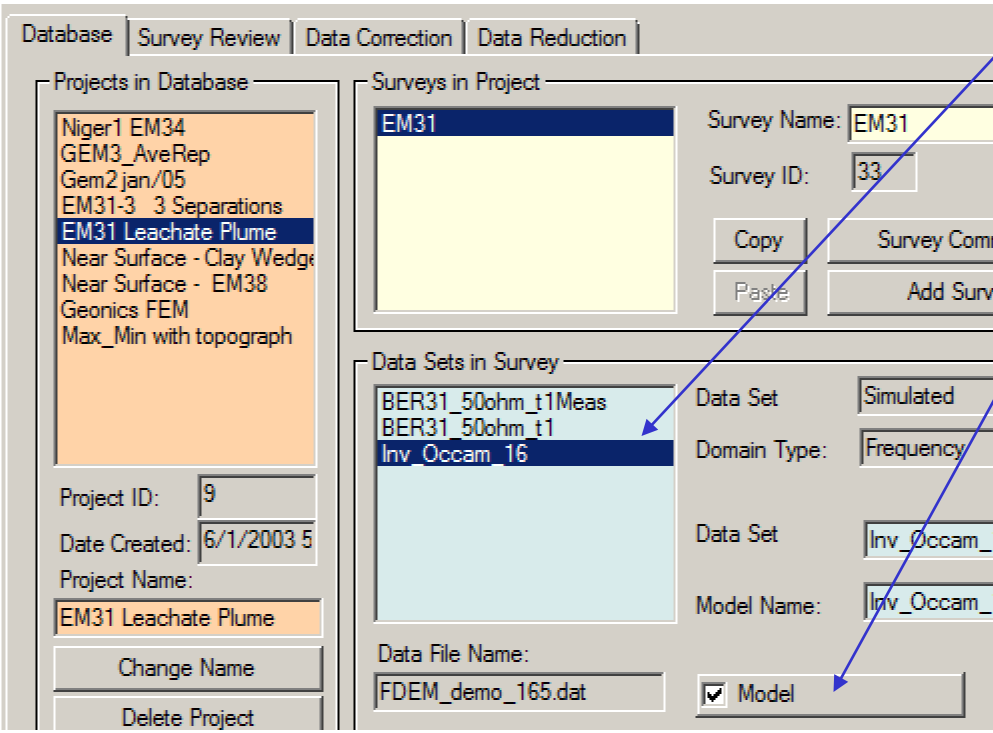
5. **Inversion evaluation**

Inversion Evaluation



An inversion is selected. You will note the “Model” button is checked.

If the model button is clicked…

1. Import data
2. Examine data
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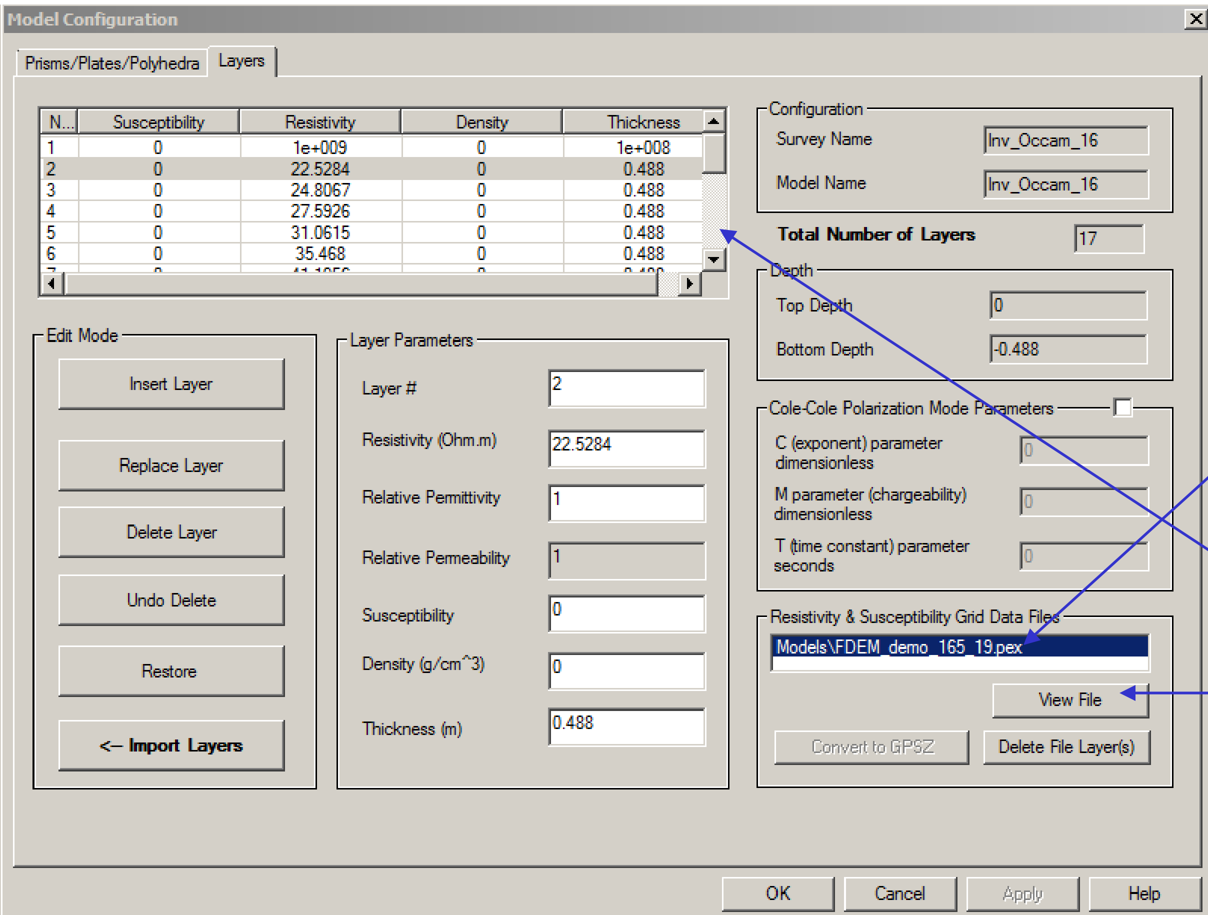
5. **Inversion evaluation**

Inversion Evaluation

a window will open



Attached to the database in a subdirectory called "Models" is the inversion results in a simple ASCII XYZ file (*.pex) which may be viewed here. This file may easily be imported to another application although graphical viewing tools are provided within EMIGMA.

The 1D model for the final data point is also included.

Click "View File" button to view the data file of the saved 1D layered model.

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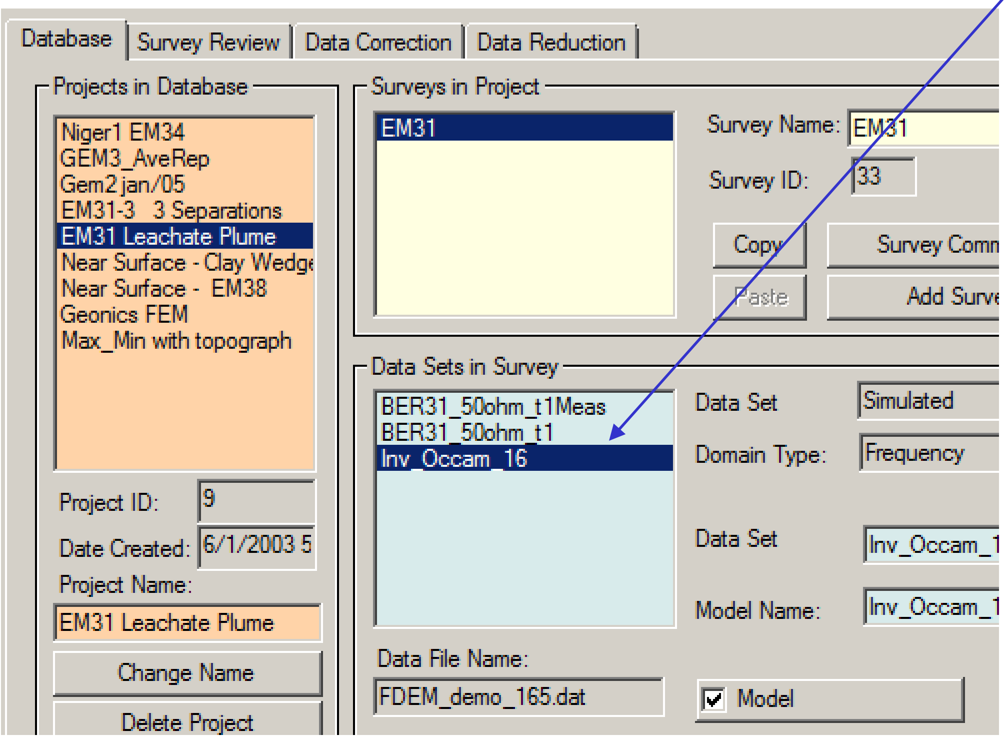
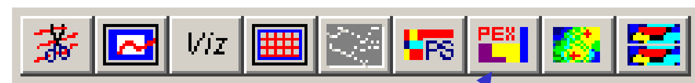
5. **Inversion evaluation**

Inversion Evaluation

Select the inversion.





Choose CDI Viewer to view a stacked section of the results

1. Import data
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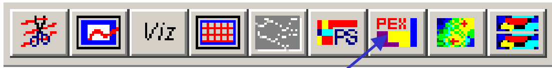
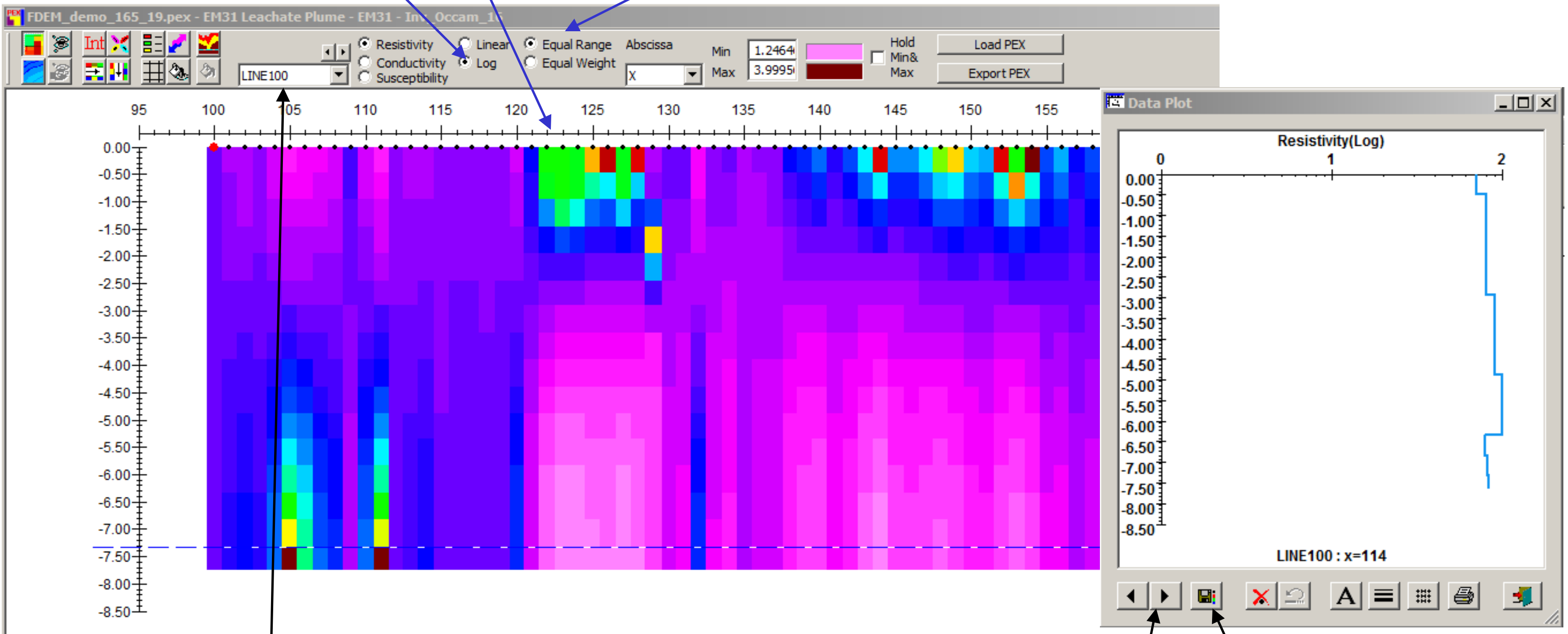
Inversion Displays



Choose CDI viewer to graphically view the results. See Help inside this tool

The results for each **data point** are shown (without interpolation) initially in **log(Resistivity)** with **Equal Range** display.



If there is more than one line then **other lines** may be selected.

A **simple line drawing** is also provided and you may **step** along the profile. You may also save the layered model of the current point by clicking 

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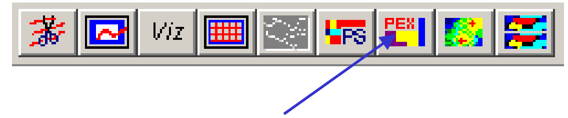
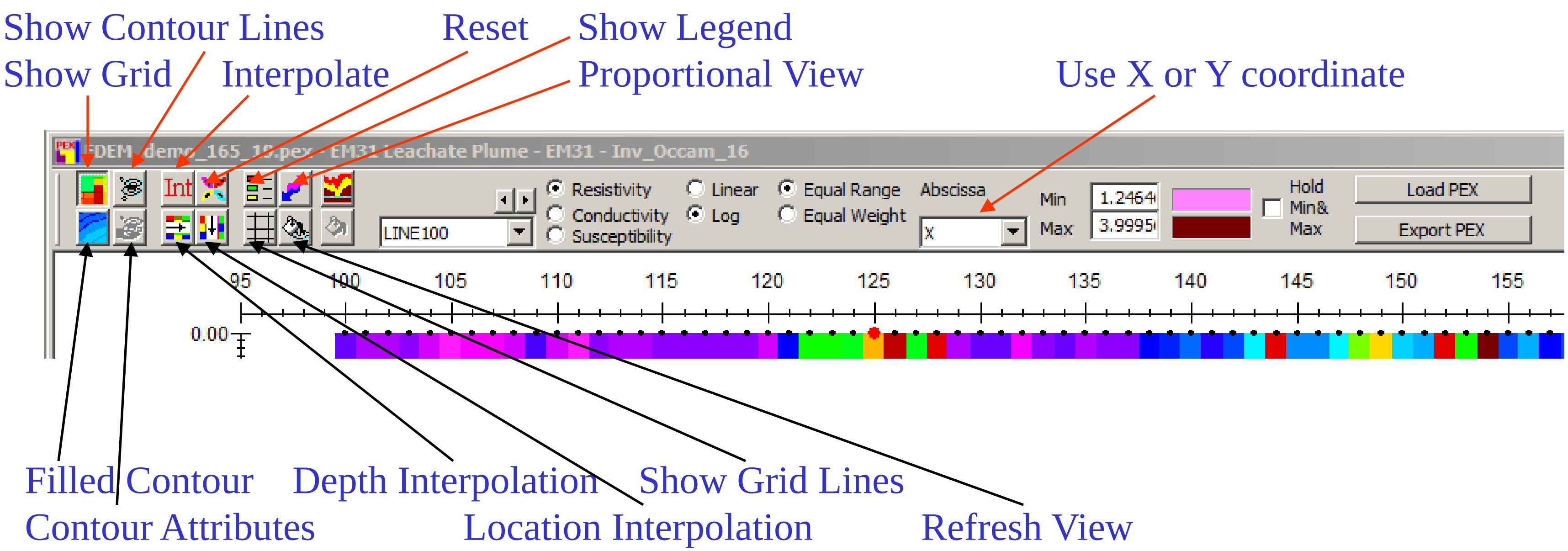
Inversion Displays



Choose CDI viewer to graphically view the results



Equal Range: assign different colors to different ranges which are equal independently of the number of data falling within these ranges

Equal Weight: assign colors to different ranges which are unequal but covering the same number of data

Min: Any data values below Min will be displayed as the color to the right of the edit field

Max: Any data values above Max will be displayed as the color to the right of the edit field

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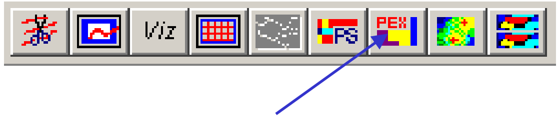
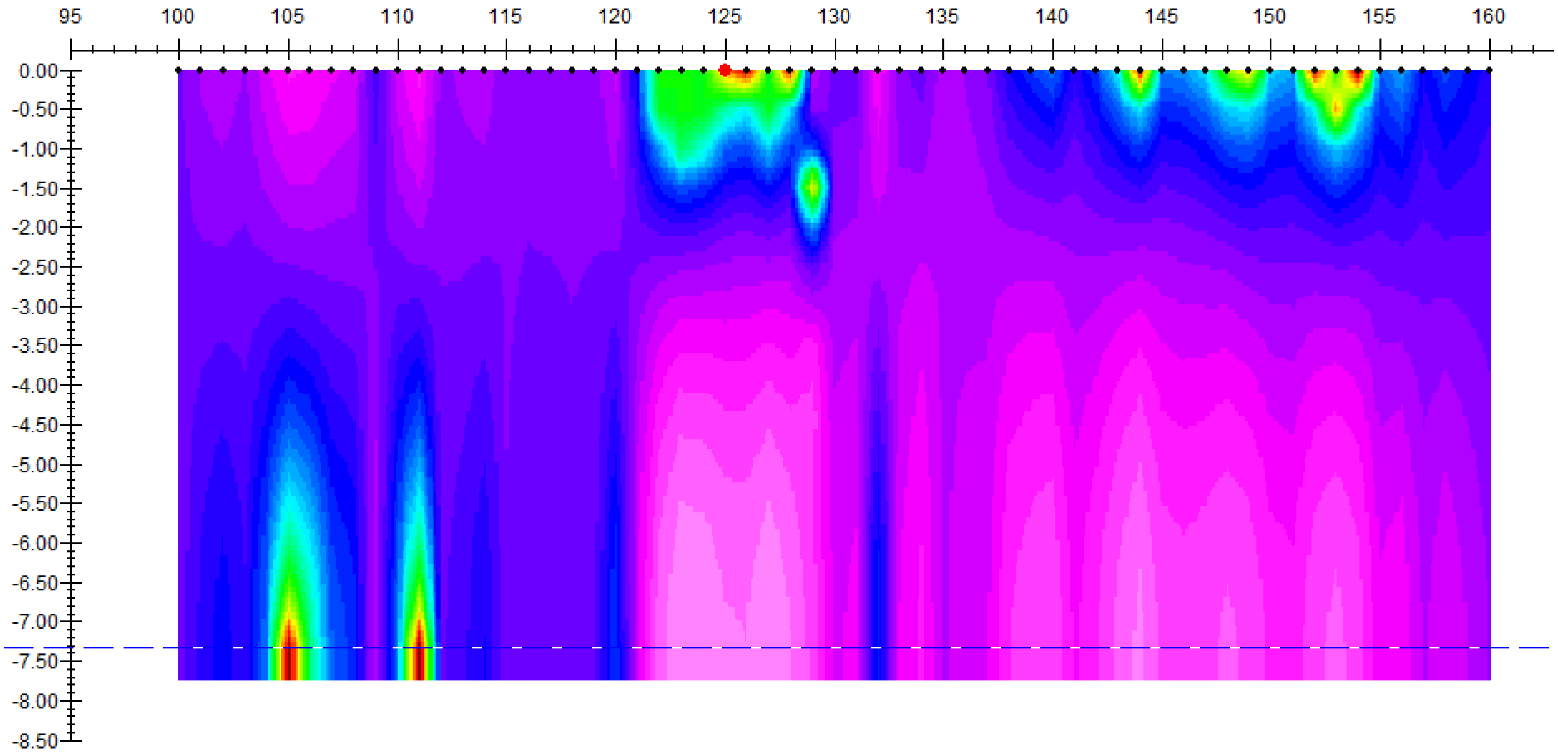
Inversion Displays



Choose CDI viewer to graphically view the results



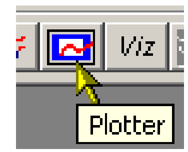
Axes may be edited by double-clicking on it, and you can change Max, Min, Labels and Titles etc. on the popup dialog

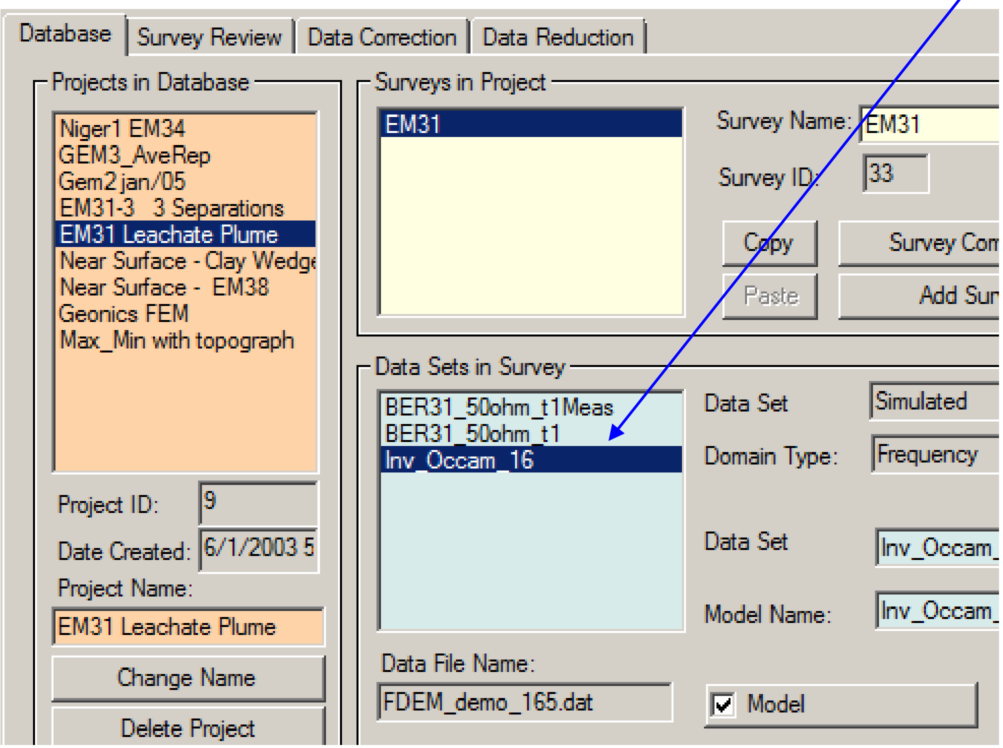
Depth and location interpolated may be repeated (note: the results of previous interpolations are used in the next interpolation so use with care)

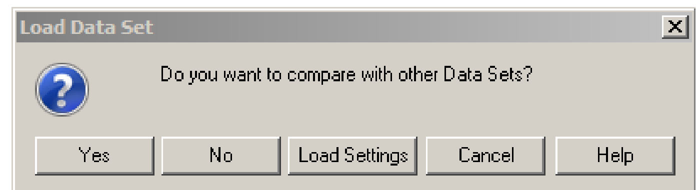
1. Import data
2. Examine data
3. Perform initial modeling
4. Perform controlled Marquardt or Occam Inversions
5. **Inversion evaluation**

Inversion Evaluation

To assess how well the inversion model fits the data at each station, select the inversion data set and then select the plotter.





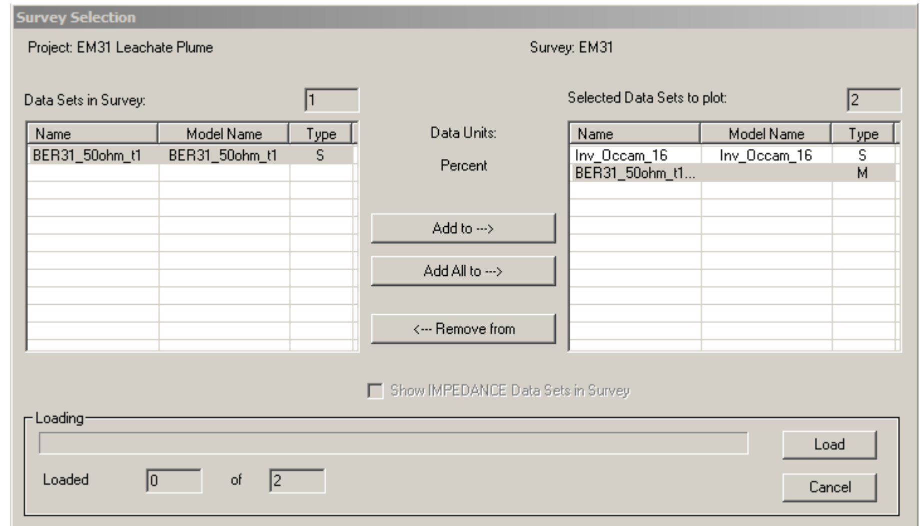


Select “Yes”, if this dialog is appeared

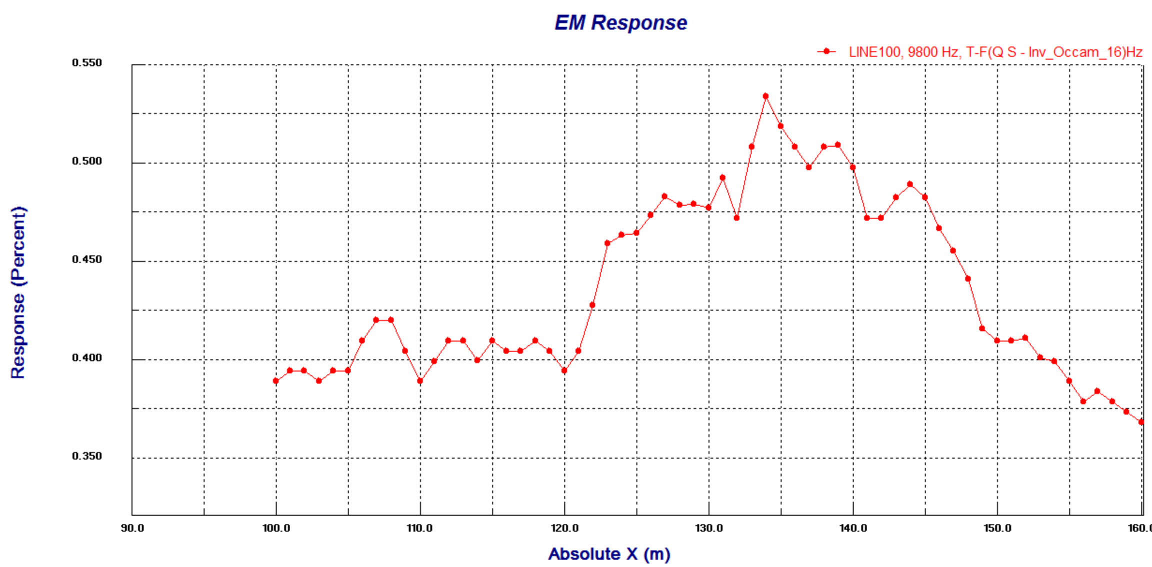
1. Import data
2. Examine data
3. Perform initial modeling
4. Perform controlled Marquardt or Occam Inversions
5. **Inversion evaluation**

Inversion Evaluation

Select the data sets required for comparison and then "Load"



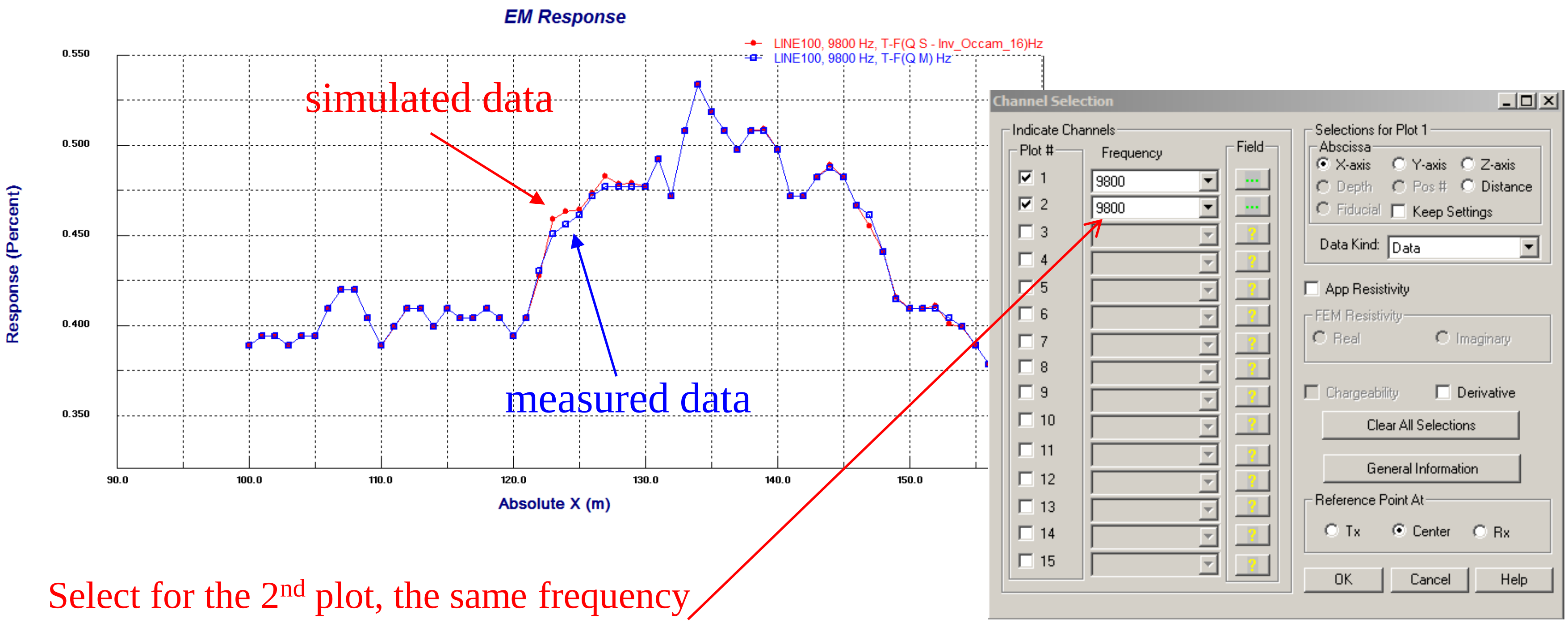
All selected data sets are then loaded to the Plotter application and the plot appears showing the first channel of the simulated data.



1. Import data
2. Examine data
3. Perform initial modeling
4. Perform controlled Marquardt or Occam Inversions
5. **Inversion evaluation**

Inversion Evaluation

The user may select other data sets to plot by simply double clicking on the plot



Select for the 2nd plot, the same frequency and then measured data.

1. Import data
2. Examine data
3. Perform initial modeling
4. Perform controlled Marquardt or Occam Inversions
5. **Inversion evaluation**

Inversion Evaluation

Multiple plots can be shown for various inversions and models in "Profile" mode. The user may step through profiles by simply clicking the arrow.