

Setting Moving FDEM systems in EMIGMA

The coordinate system

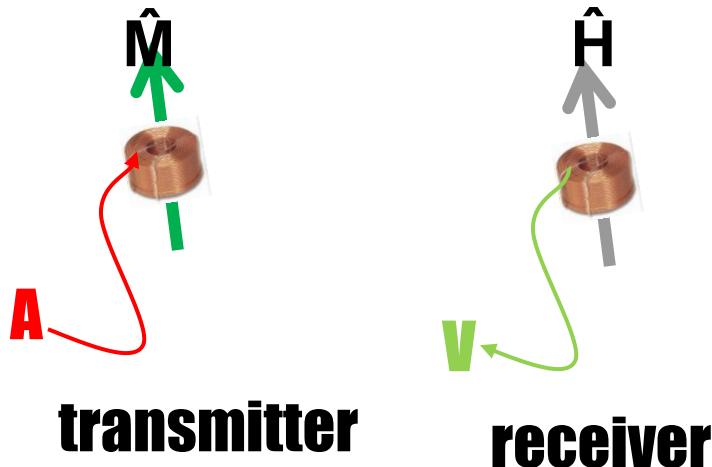
Normally, the Horizontal coordinate system is used for such systems in EMIGMA.



Horizontal Coordinate System

- *direction of unit vectors change with profile direction*
- *\hat{X} and \hat{Y} are horizontal and \hat{Z} is up.*
- *\hat{X} is directed parallel to the tangent of the profile at each station.*
- *\hat{Y} is perpendicular to the tangent at each station*
- *the station locations are your normal GPS or grid values*

Transmitters and Receivers

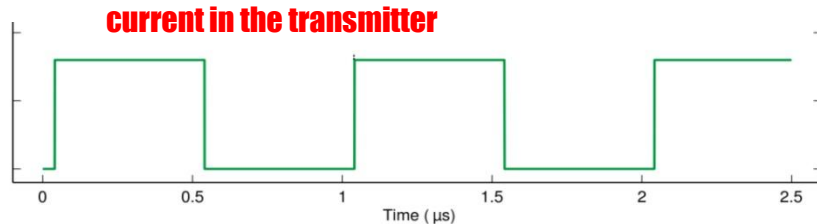


System Components

- *the transmitter and receiver are both wound coils*
- *a current is injected into the transmitter coil and this produces a magnetic moment.*
- *the magnetic field caused by the transmitter and the ground running through the receiver coil produces a voltage which is output*
- *the voltage output can be converted to a value of magnetic field coupling with the coil if desired*
- *the measured magnetic field is aligned with the moment of the receiver coil*
- *mathematically the source and receiver are defined as point electric dipoles – this is satisfactory as the coils are small with respect to the tx-rx separations*

Setting Moving FDEM systems in EMIGMA

Data Processing



Instrument Aspects

- a square wave current of a certain frequency is injected into the transmitter
- the fundamental harmonic of this boxcar is extracted in the receiver which produces a real part and an imaginary part
- the real part is inphase with the current in the transmitter
- the imaginary part is out of phase with the current

output voltage (ω) or (f)

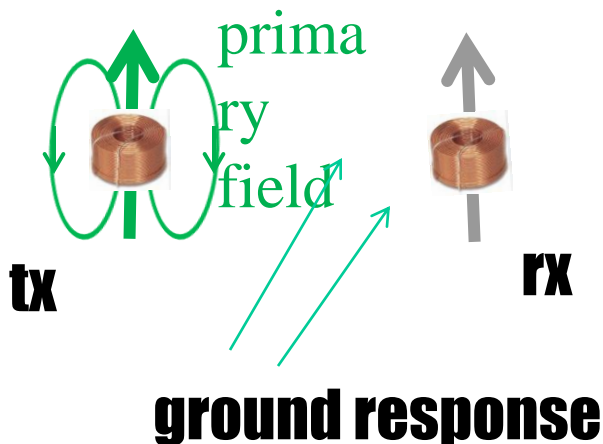
Imag

Re

complex plane

Inphase – a common name for the real part of the output
Quadrature – a common name for the imaginary part of the output

Normalization



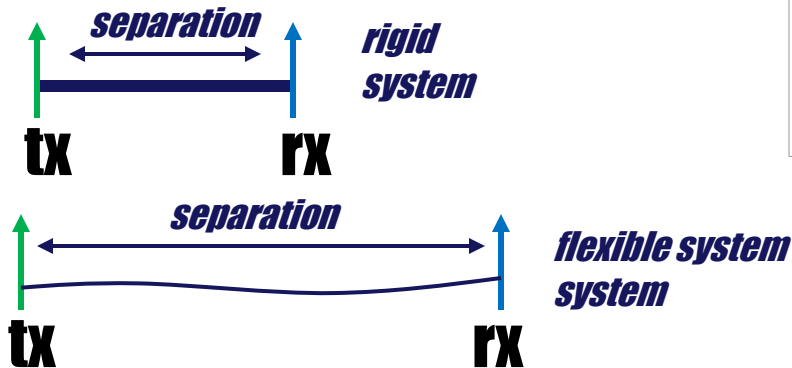
Normalization

- the strongest field is that directly from the transmitter which contains no part of the ground response
- this direct (primary) field is inphase and can be computed if the coil strength and the current are known
- this primary field is removed from the output voltage either by computation or by the use of a bucking coil (e.g. airborne systems)
- the remaining voltage is the ground response
- the remaining or secondary voltage is then divided by the primary voltage which was previously subtracted
- the resulting voltage output is then dimensionless
- depending upon the manufacturer the resulting voltage can be adjusted to different units

Setting Moving FDEM systems in EMIGMA

Data Processing

Normalization 2



Normalization

- there are two types of systems – rigid and flexible
- in a rigid system, the tx and rx are housed in a rigid structure so that the separation of tx and rx is fixed – e.g. EM38, EM31, GEM2
- in a flexible system, the tx and rx are independent and connected via a cable of some sort – e.g. Promis, MaxMin, EM34
- in a flexible system care must be taken to ensure the cable is at the prescribed length and the coils are coplanar

Additional Comments

- in an airborne system, the tx and rx are housed in a bird which is flexible during flight and thus normally a bucking coil is used to reduce and normalize to the primary response
- in the PROMIS system, 3 components of the secondary field are measured simultaneously and so the coil orientation of tx and rx should be made accurately
- in the older MaxMin system, one can measure Hx as well as Hz but the orientation of the receiver coils in both cases must be made accurately

Setting Moving FDEM systems in EMIGMA

Data Units

Data Units

- the raw response is always calculated according to the formula below
- *this ratio, however, can be expressed in various units as below*

$$\text{Response (Re, Im)} = \frac{\left\{ \text{Measured Voltage (Re,Im)} - \text{Primary Field} \right\}}{\text{Primary Field}}$$

InPhase Units – Percent (%), PPT, PPM

Quadrature Units – Percent (%), PPT, PPM, apparent conductivity

Data Units Apparent Conductivity

- *it should be noted that the word "apparent" is extremely important for understanding these units*
- *this does mean actual conductivity, but rather the ratio expressed in terms of an approximate formula which represents an equivalent halfspace for the ground and not the actual ground conductivity*
- *the formula assumes a halfspace for the ground and then only one (1) term in the accurate representation from physical principles of such a system*

Setting Moving FDEM systems in EMIGMA

Data Units – apparent conductivity

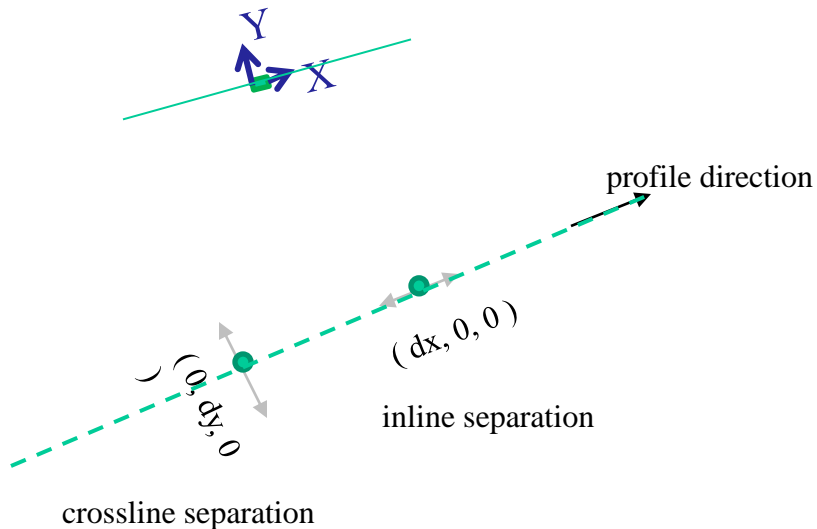
Data Units Apparent Conductivity

- *it should be noted that the word "apparent" is extremely important for understanding these units*
- *this does mean actual conductivity, but rather the ration expressed in terms of an approximate formula which represents an equivalent halfspace for the ground and not the actual ground conductivity*
- *the formula assumes a halfspace for the ground and then only one (1) term in accurate representation of such a system from physical principles*
- *in the formula below "s" is the distance between transmitter and receiver. This formula assumes no effect from the (1/s) term in the response*
- *if indeed the ground is a halfspace then the expression is most accurate when the induction number,
[$\sigma \omega \mu_0 s^2$] is small*

$$\sigma_{\text{app}} = \frac{4}{\omega \mu_0 s^2} \frac{(H)_{\text{quadrature}}}{H_{\text{primary}}}$$

Setting Moving FDEM systems in EMIGMA

Tx-Rx separations in EMIGMA



Horizontal Coordinate System

- direction of unit vectors change with profile direction
- \hat{X} and \hat{Y} are horizontal and \hat{Z} is up.
- \hat{X} is directed parallel to the tangent of the profile at each station.
- \hat{Y} is perpendicular to the tangent at each station
- the station locations are your normal GPS or grid values
- these conventions are for the source and receiver dipoles as well as the TX-RX separations
- separations may be defined as any (dx, dy, dz) with respect to the profile direction

Setting Moving FDEM systems in EMIGMA

Tx-Rx separations in EMIGMA

Some Examples

- *standard horizontal coplanar inline system configuration (HCP):*
 $Tx - M_z ; Rx - H_z ; \text{separation} (dx, 0, 0)$
[EM38 – (1,0,0) , EM31 – (3.66,0,0)
- *standard horizontal coplanar crossline system configuration (HCP):*
 $Tx - M_z ; Rx - H_z ; \text{separation} (0, dy, 0)$
- *standard vertical coplanar in line system configuration (VCP):*
 $Tx - M_y ; Rx - H_y ; \text{separation} (dx, 0, 0)$
- *standard vertical coplanar crossline system configuration (broadside VCP):*
 $Tx - M_x ; Rx - H_x ; \text{separation} (0, dy, 0)$

Setting Moving FDEM systems in EMIGMA

Configuration Page Example in EMIGMA – EM38

System Name: System Type:

1. System Mode: Transmitter: Separation(s) (moving system) input -->

☐ Fixed ☒ Moving

2. Transmitter Type: ☒ Coil ☐ Current Dipole ☐ Loop ☐ Pole

Dipole Moment (Amp*m^2):

Transmitter Input -->

Tx/Rx Replacement Mode: ☒ Add ☐ Replace ☐ Multiple Tx/Generator

3. Receiver Type: ☒ Coil ☐ Voltage Dipole ☐ Loop ☐ Pole

Receiver Input -->

Ip/Res System Wizard

Transmitter Coord. System:

1. TX-DIPOLE Mz
2. TX-DIPOLE My
3. TX-DIPOLE Mx

SEP-REF-POINT AT CENTER

#	X	Y	Z
1.	1.000e+000	0.000e+000	0.000e+000
2.	0.000e+000	1.000e+000	0.000e+000

Receiver Coord. System:

Component: Select All Create Comp

Tx	Rx	Sep
1	3	1
2	2	1
1	3	2
3	1	2

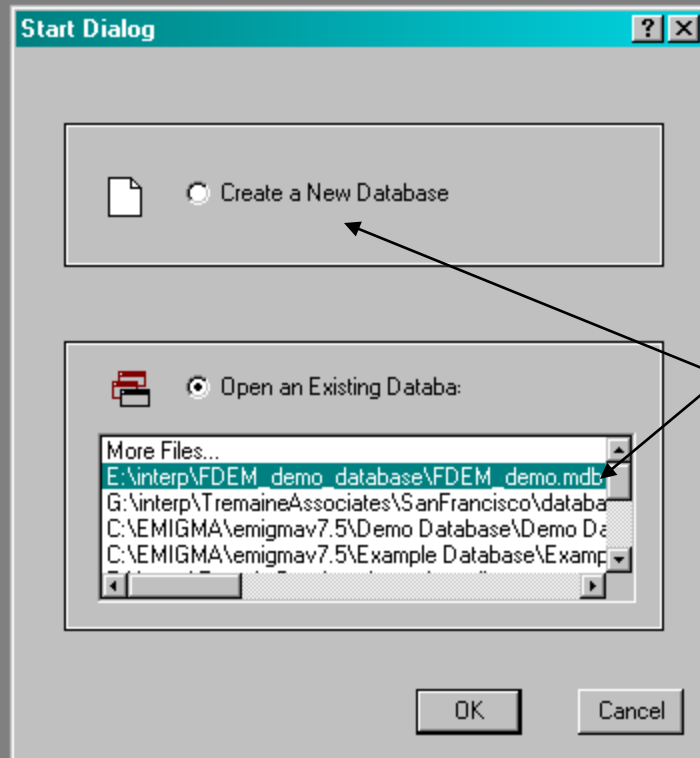
1. Mz, Hz, (1,0,0)
2. My, Hy, (1,0,0)
3. Mz, Hz, (0,1,0)
4. Mx, Hx, (0,1,0)

< Back Next > Cancel Help

System Configurations

- 1: *standard HCP*
- 2: *standard VCP*
- 3: *standard HCP crossline*
- 4: *standard VCP crossline, broadside*

Opening a database



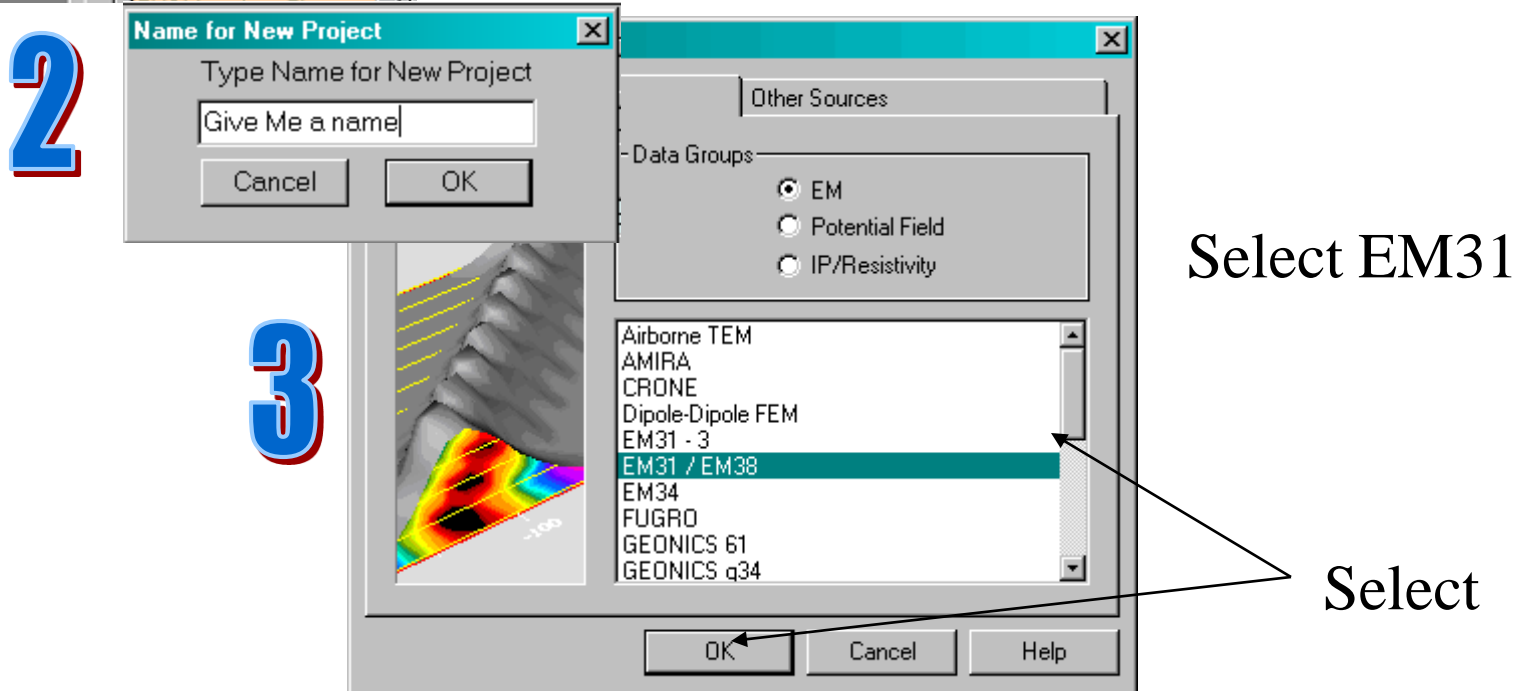
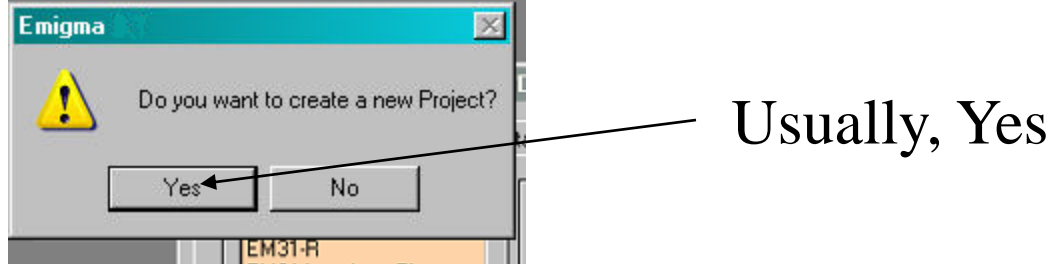
Select a Database

Or

Create a New Database

Note: If Creating a new database, it is recommended to put the new database in a new subdirectory

Importing Data - 1



Importing Data - 2

1

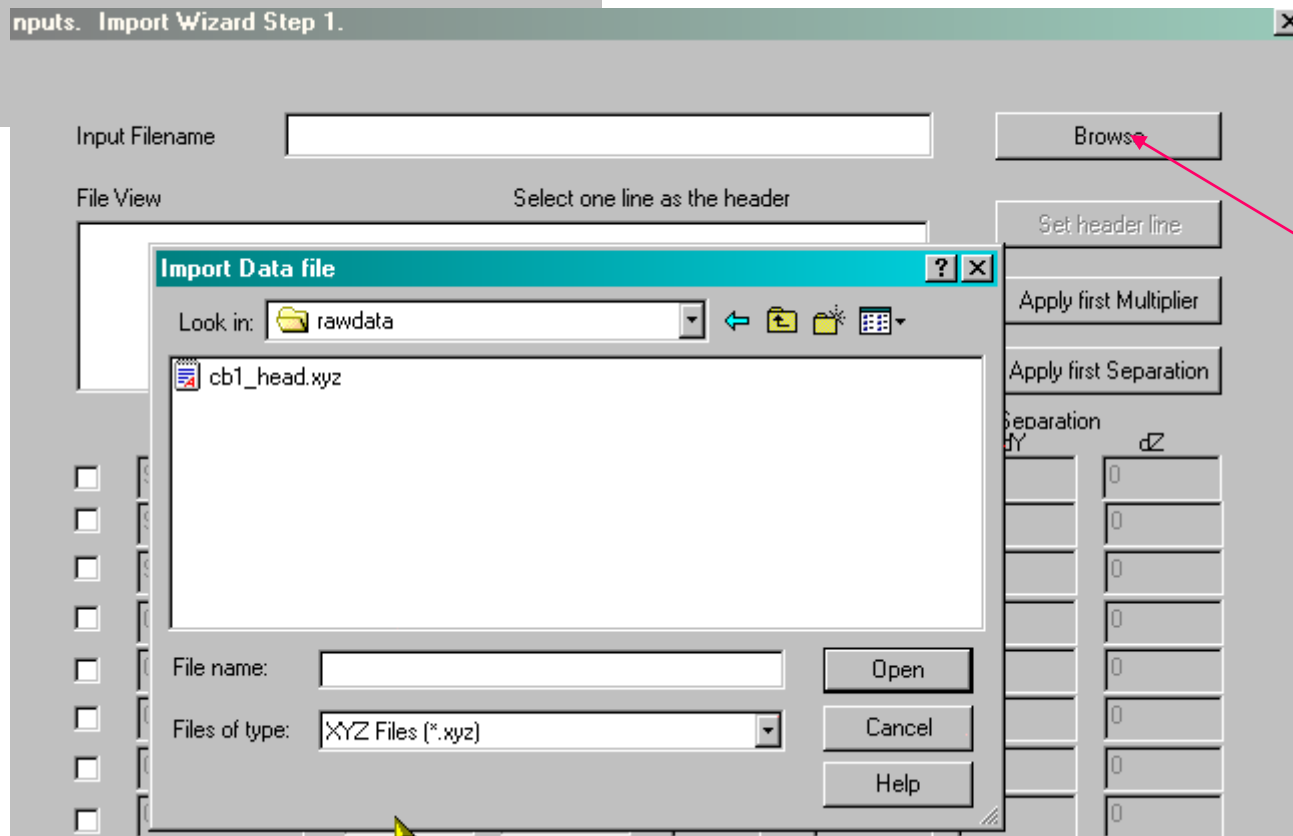
- ☐ Em34
- ☐ Em31/Em38
- ☒ EM31-R
- ☐ Max-Min
- ☐ Fugro
- ☐ AeroQuest
- ☐ Unknown

EM31-R System Name

Select System

For other systems select Unknown and give it a name

2



Browse
for
XYZ
columnar
datafile

Importing Data - 3

Imports. Import Wizard Step 1.

Input Filename:

File View: Select one line as the header

//	UTM X	UTM Y	CPQ9800S1	CPI9800S1	CPQ9800S2	CPI9800S2	CPQ9800S3
LINE1							
553262.654311	4180924.072563	97.750000	15.900000	154.250000	20.4781		
553262.654004	4180924.072665	101.000000	15.880000	159.000000	20.4781		
553262.653462	4180924.072846	94.500000	15.860000	159.250000	20.4781		

	Frequency	Tx - Rx Orientation		Correction Multiplier	dX	Tx - Rx Separation	
		Tx	Rx			dY	dZ
<input checked="" type="checkbox"/>	9800	Z	Z	1	1	0	0
<input checked="" type="checkbox"/>	9800	Z	Z	1	2	0	0
<input checked="" type="checkbox"/>	9800	Z	Z	1	3.66	0	0
<input type="checkbox"/>				1	0	0	0
<input type="checkbox"/>	0			1	0	0	0

If your file does not contain a Header line with our specific annotation then use 'Set Header line' to set the header. Use the provided example file for assistance.

Importing Data - 3b

outs. Import Wizard Step 1.

Input Filename:

File View: Select one line as the header

//	UTM X	UTM Y	CPQ9800S1	CPI9800S1	CPQ9800S2	CPI9800S2	CPQ9800S3
LINE1							
553262.654311	4180924.072563	97.750000	15.900000	154.250000	20.4781		
553262.654004	4180924.072665	101.000000	15.880000	159.000000	20.4781		
553262.653462	4180924.072846	94.500000	15.860000	159.250000	20.4781		

	Frequency	Tx - Rx Orientation Tx	Rx	Correction Multiplier	dX	Tx - Rx Separation dY	dZ
<input checked="" type="checkbox"/>	9800	Z	Z	1	1	0	0
<input checked="" type="checkbox"/>	9800	Z	Z	1	2	0	0
<input checked="" type="checkbox"/>	9800	Z	Z	1	3.66	0	0
<input type="checkbox"/>				1	0	0	0
<input type="checkbox"/>	0			1	0	0	0

Note 1: Dipole orientations may be X,Y, or Z. These are in reference to the ‘Horizontal’ co-ordinate system (Manual). For example, Z-Z is horizontal co-planar and Y-Y or X-X or vertical coplanar. Y is perpendicular to line and X is tangential to the line.

Note 2: Separations may be dX, dY or dZ. dX is along line while dY is across line. For example, a dipole configuration with X-X and a separation of (0,dy,0) is vertical co-planar ‘broadside’.

Importing Data - 4

Format. Import Wizard Step 2.

File Header View: Select the suitable line to define data format

LINE	UTM X	UTM Y	CPQ9800S1	CPI9800S1	CPQ9800S2	CPI9800S2	CPQ9800
553262.654311	4180924.072563	97.750000	15.900000	154.250000	20.47800		
553262.654004	4180924.072665	101.000000	15.880000	159.000000	20.4780		
553262.653462	4180924.072846	94.500000	15.860000	159.250000	20.47800		

Profile identification string (case insensitive) is used to indicate the start of a new profile

LINE

Line Label

Location (column#, name)

☒ UTM ☐ Lat/Lon

☒ X 1 UTM_X

☒ Y 2 UTM_Y

Z & GPS Z

☐ Z

dZ: alt -- bird

.45 default

Unit ☒ meter ☐ feet

☐ GPS Z

dZ: instrument --

Fiducial

☒ FID 9 FIDS3

Frequency	Column#	Frequency	Column#	name	Frequency
<input checked="" type="checkbox"/> F-1, Inphase	4	CPI9800S	9800	<input type="checkbox"/> F-6, Inphase	0
<input checked="" type="checkbox"/> F-1, Quadra.	3	CPQ9800S	9800	<input type="checkbox"/> F-6, Quadra.	0
<input checked="" type="checkbox"/> F-2, Inphase	6	CPI9800S	9800	<input type="checkbox"/> F-7, Inphase	0
<input checked="" type="checkbox"/> F-2, Quadra.	5	CPQ9800S	9800	<input type="checkbox"/> F-7, Quadra.	0
<input checked="" type="checkbox"/> F-3, Inphase	8	CPI9800S	9800	<input type="checkbox"/> F-8, Inphase	0
<input checked="" type="checkbox"/> F-3, Quadra.	7	CPQ9800S	9800	<input type="checkbox"/> F-8, Quadra.	0
<input type="checkbox"/> F-4, Inphase			0	<input type="checkbox"/> F-9, Inphase	0
<input type="checkbox"/> F-4, Quadra.			0	<input type="checkbox"/> F-9, Quadra.	0
<input type="checkbox"/> F-5, Inphase			0	<input type="checkbox"/> F-10, Inphase	0
<input type="checkbox"/> F-5, Quadra.			0	<input type="checkbox"/> F-10, Quadra.	0

Units (Inphase)

☐ Percent ☒ PPT ☐ PPM

Units (Quadrature)

☐ Percent ☐ PPT ☐ PPM ☒ mS/m

< Back Next > Cancel Help

Check that the import has recognized the columns correctly.

Set the height of the instrument.

Check the data units.

Note:

mS/m is not an actual data unit. The data has been converted by the instrument manufacturer through an approximation to this unit. EMIGMA converts it back to the original data units. You may later display in these approximate units.

Importing Data - 5

Files. Import Wizard Step3.

Profiles and Locations

Profile	# Locations
LINE1	417
LINE2	557
LINE3	606
LINE4	604
LINE5	557
LINE6	531
LINE7	130
LINE8	420
LINE9	616
LINE10	628
LINE11	261
LINE12	202
LINE13	233
LINE14	218

Total Number of Profiles: 14

Total Number of Locations: 5980

Modify Profile

Profile:

Delete every: 2

Delete

Apply

Shift Values

	Sample Value	Shift Value
X Coordinate	553262.625	-550000
Y Coordinate	4180924	-4100000

OK

Cancel

Shift Coordinate Values (e.g. for resolution)

Shift X: 0

Shift Y: 0

Reset

Change

Average Precision (m)

X: 1

Y: 10

Apply

You may choose not to import all profiles or decimate the data.

In addition, if you require sub-metre accuracy in your data positioning you may wish to strip off the leading numbers of the UTM positions

Importing Data - 6

n. Import Wizard Step 3.

System Parameters

Survey Type: Moving Tx -- Moving Rx

Coordinate Systems: Horizontal

Separation Reference Point: Tx

Normalization Type: Continuous

Normalization Divisor: Inphase

Normalization Convention: Percent

Project Name: Give Me a name

Import to the Database

Run Import

Messages:

- ...frequencies....creating...
- ...system.....creating
- ...components....creating...
- ...locations.....creating...
- ...data.file.....creating...
- Processing Completed

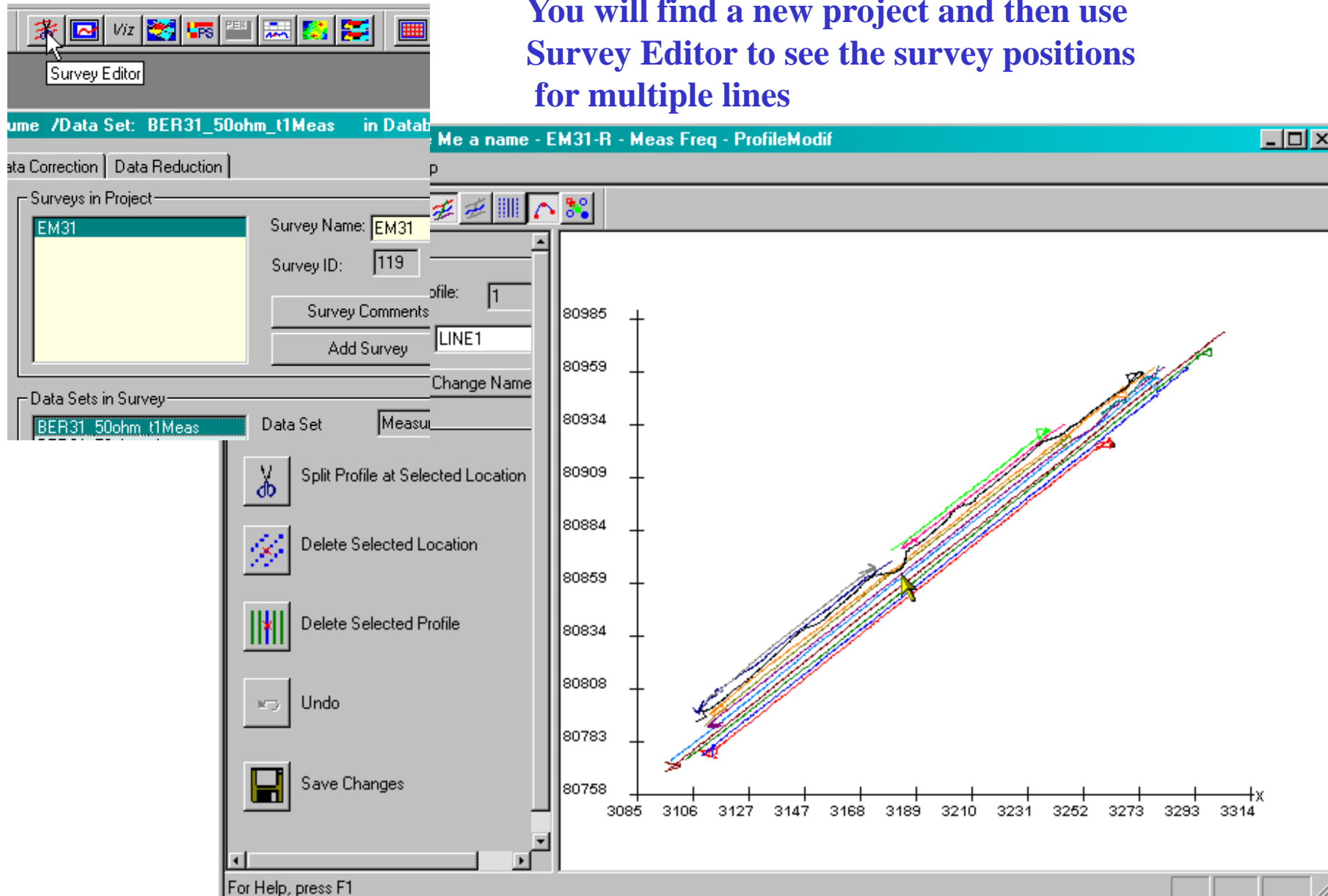
If using an EM31-R, then your data is probably positioned at a common Tx reference point. This is because the data is collected from a common Tx antennae

Note: The centre point of the 3 Rx-Tx data are not the same.

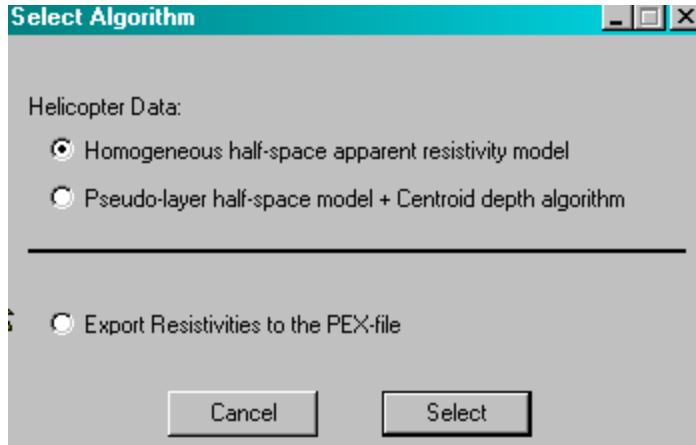
Run Import:

Importing Data - Final

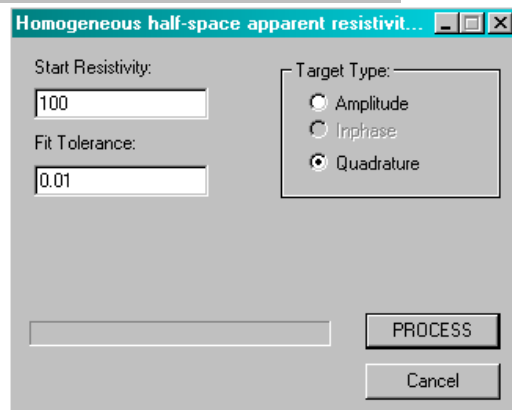
You will find a new project and then use Survey Editor to see the survey positions for multiple lines



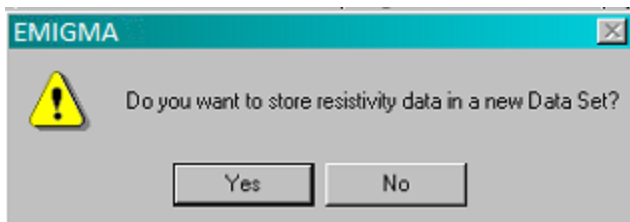
Calculating Apparent Resistivity



Calculate the best fitting half-space app rho for any dipole-dipole frequency EM data airborne or ground



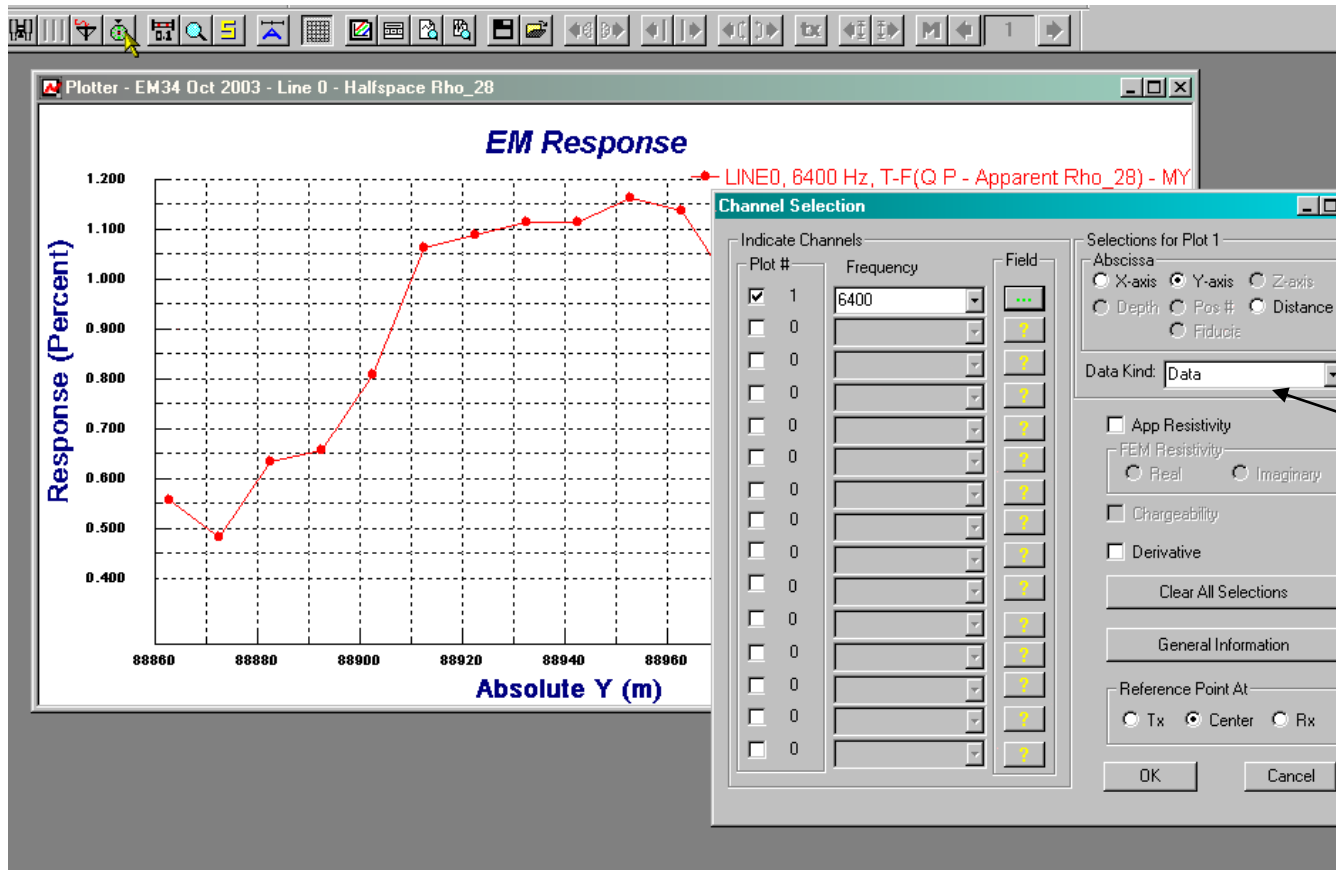
Calculate the best fitting half-space app rho choose which data elements to use e.g. for EM34 then Quadrature is default



Store to new dataset or attach to original data

Plotting Data - 1

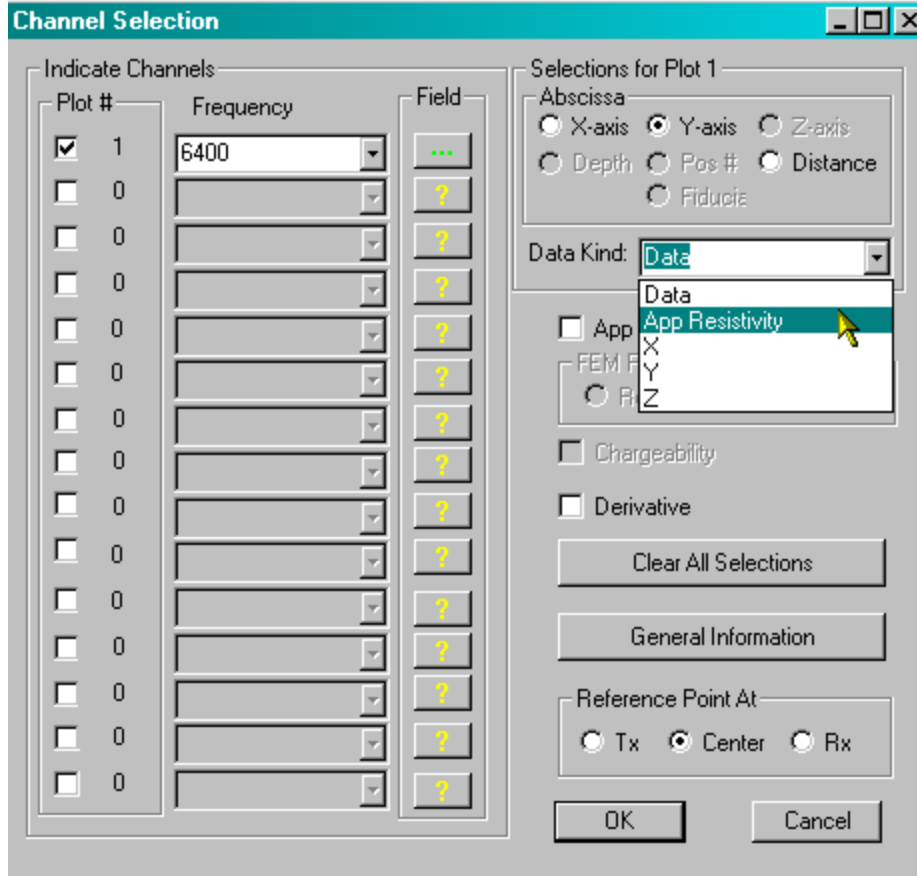
(V90_tutorial .pdf for more details)



app rho display
converts normalized
data to app rho
through short separation
algebraic formula

For apparent conductivity:
Settings -> Custom -> App Cond

Plotting Data - 2



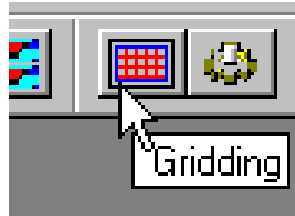
app rho display
use calculated best fit
apparent resistivity

for apparent conductivity
Settings -> Custom -> App Cond

Gridding data - 1

Interpolate to Grid

interpolate to regular grid



3D interpolation

Survey Bounds:

Data Number: 279 Min X: 8468.72 Min Y: 88741.6 Min Z: 0.2

Profile Number: 11 Max X: 8954.61 Max Y: 89190.3 Max Z: 0.2

Select Data for Interpolation: Select Components for Interpolation: ☒ All Component

Data: App Resistivity

Method: Natural Neighbour

Max Iteration: 0

Resolution factor: 1000

Derivative Information:

☒ Set to zero

☐ Estimate

☐ Use Input

☐ dX ☐ dY ☐ dZ

Channel Interpolation:

Progress:

Status:

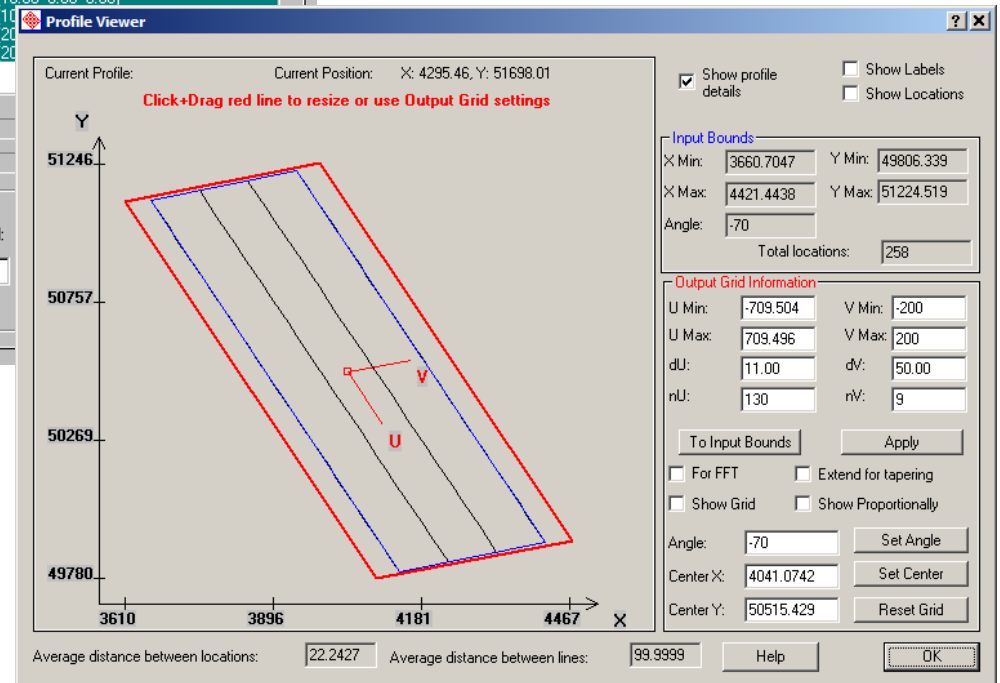
Grid:

Grid Setting

Load Grid

Z - level: 0.2

Select Components



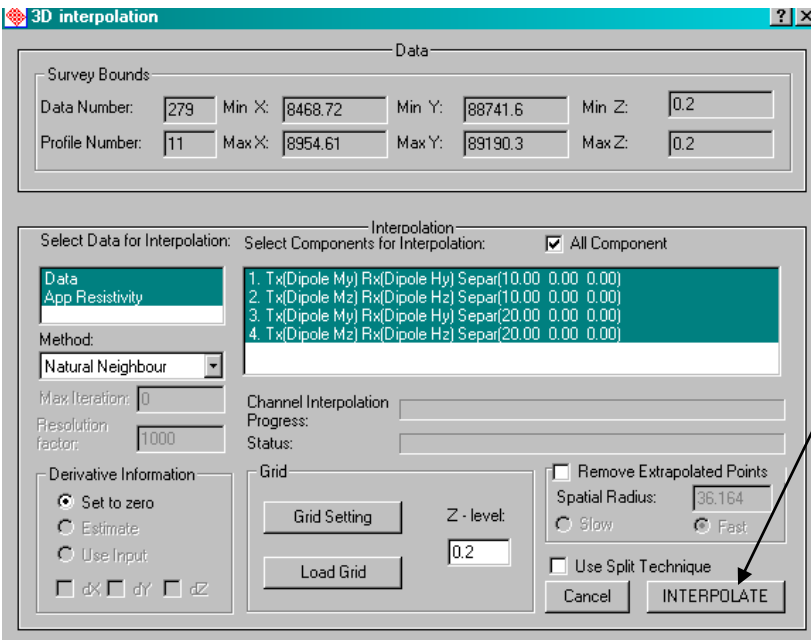
Set Grid Settings

Gridding data - 2

Interpolate to Grid

View Grids

View Grid Characteristics



3D interpolation

Survey Bounds:

Data Number: 279 Min X: 8468.72 Min Y: 88741.6 Min Z: 0.2

Profile Number: 11 Max X: 8954.61 Max Y: 89190.3 Max Z: 0.2

Select Data for Interpolation: Select Components for Interpolation: ☒ All Component

Data: App Resistivity

Method: Natural Neighbour

Max Iteration: 0

Resolution factor: 1000

Derivative Information:

☒ Set to zero

☐ Estimate

☐ Use Input

☐ dX ☐ dY ☐ dZ

Channel Interpolation:

Progress:

Status:

Grid:

Grid Setting

Z - level: 0.2

Load Grid

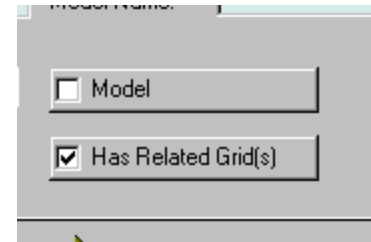
☐ Remove Extrapolated Points

Spatial Radius: 36.164

☐ Slow ☒ Fast

☐ Use Split Technique

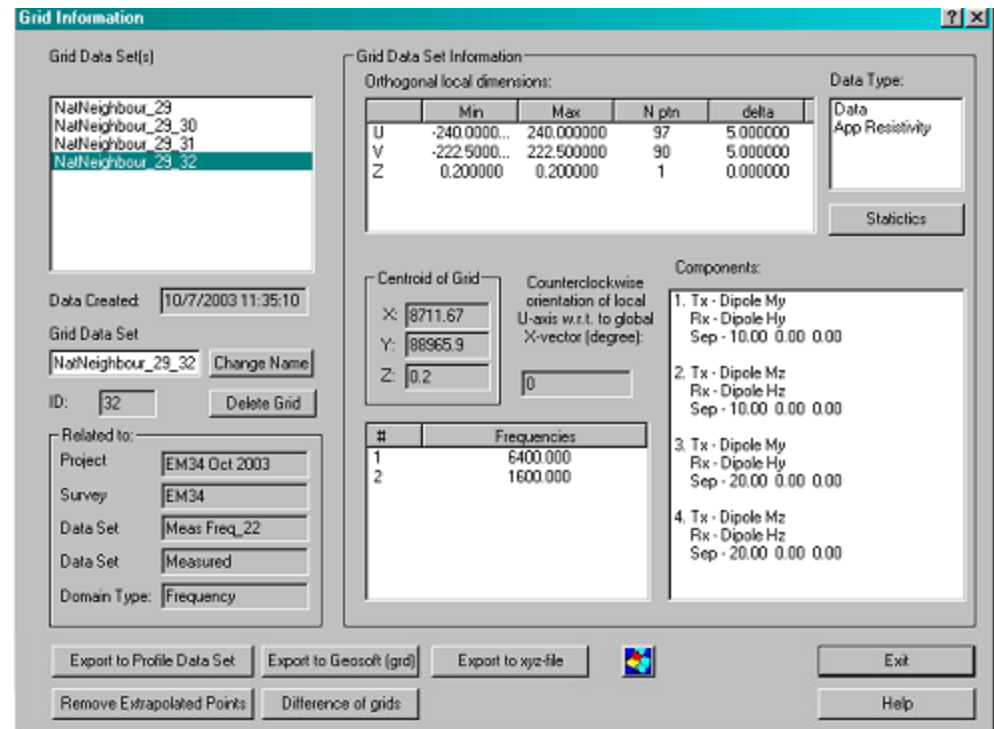
Cancel INTERPOLATE



Model Name:

☐ Model

☒ Has Related Grid(s)



Grid Information

Grid Data Set(s):

NatNeighbour_29

NatNeighbour_29_30

NatNeighbour_29_31

NatNeighbour_29_32

Data Created: 10/7/2003 11:35:10

Grid Data Set: NatNeighbour_29_32 Change Name

ID: 32 Delete Grid

Related to:

Project: EM34 Oct 2003

Survey: EM34

Data Set: Meas Freq_22

Data Set: Measured

Domain Type: Frequency

Grid Data Set Information:

Orthogonal local dimensions:

	Min	Max	N ptn	della
U	-240.0000...	240.000000	97	5.000000
V	-222.5000...	222.500000	90	5.000000
Z	0.200000	0.200000	1	0.000000

Data Type: Data App Resistivity

Statistics

Centroid of Grid:

X: 8711.67

Y: 88965.9

Z: 0.2

Counterclockwise orientation of local U-axis w.r.t. to global X-vector (degree): 0

Components:

1. Tx - Dipole My
Rx - Dipole Hy
Sep - 10.00 0.00 0.00

2. Tx - Dipole Mz
Rx - Dipole Hz
Sep - 10.00 0.00 0.00

3. Tx - Dipole My
Rx - Dipole Hy
Sep - 20.00 0.00 0.00

4. Tx - Dipole Mz
Rx - Dipole Hz
Sep - 20.00 0.00 0.00

Frequencies

#	Frequencies
1	6400.000
2	1600.000

Export to Profile Data Set

Export to Geosoft (.grd)

Export to xyz-file

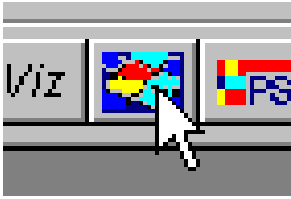
Remove Extrapolated Points

Difference of grids

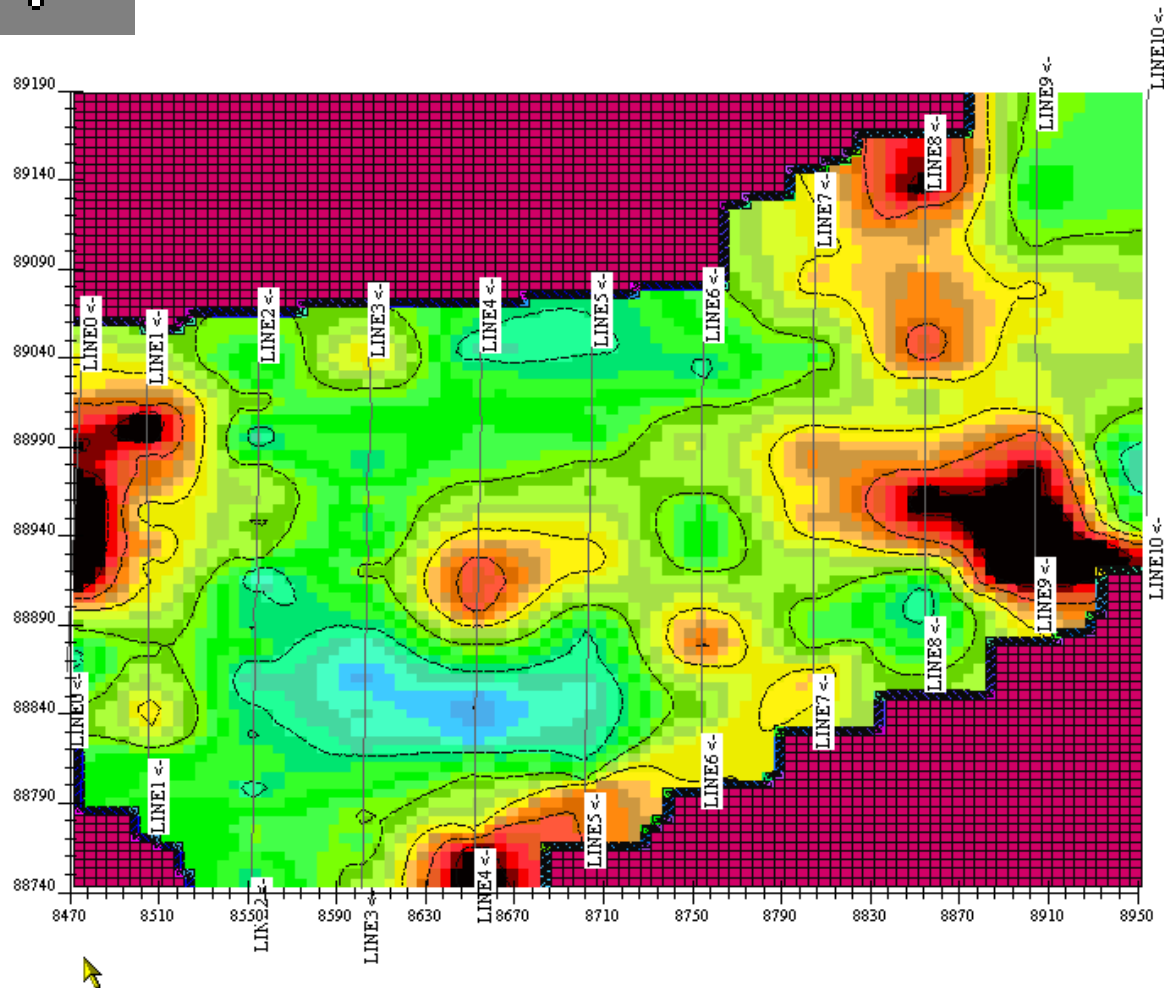
Exit

Help

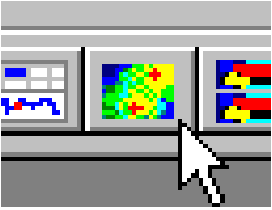
Viewing Gridded Data - 1



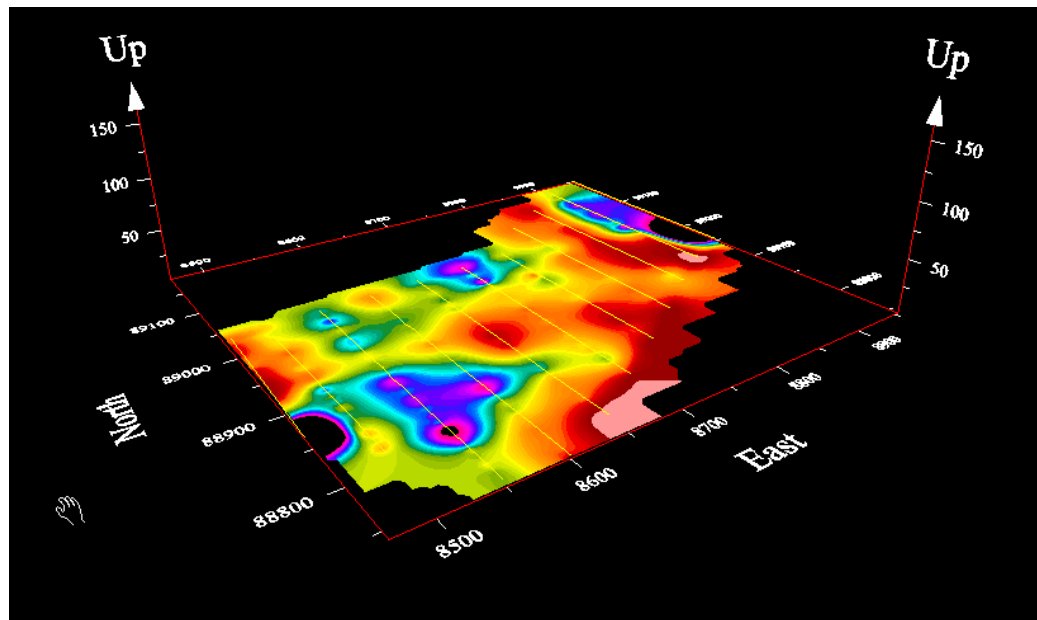
Grid Presentation



Viewing Gridded Data - 2



Contour



1D FEM Inversion - 1

INVERSION. Style and Data Selection

Inversion Technique

☐ L1 - Linear Regression ☐ Standard Least Square Occam

☐ Marquardt - Least Square ☒ Enhanced Conjugate Gradient Occam with Susceptibility Extension

☐ Use old method

Forward Method

☐ Old ☒ New ☐ Emigma

Frequencies

1	9800.000
---	----------

Components & Separations

1	Rx-Hz	Tx-Mz	3.66	0.00	0.00
---	-------	-------	------	------	------

Profiles and Locations

☒ Batch Mode Checked --> Run the 1-D inversion for a series of profiles and locations.
☐ Unchecked --> Only the data at a single location will be inverted.

Profiles

4	LINE115
5	LINE120
6	LINE125
7	LINE130
8	LINE135
9	LINE140
10	LINE145
11	LINE150
12	LINE155

Locations

Profile 9: LINE140

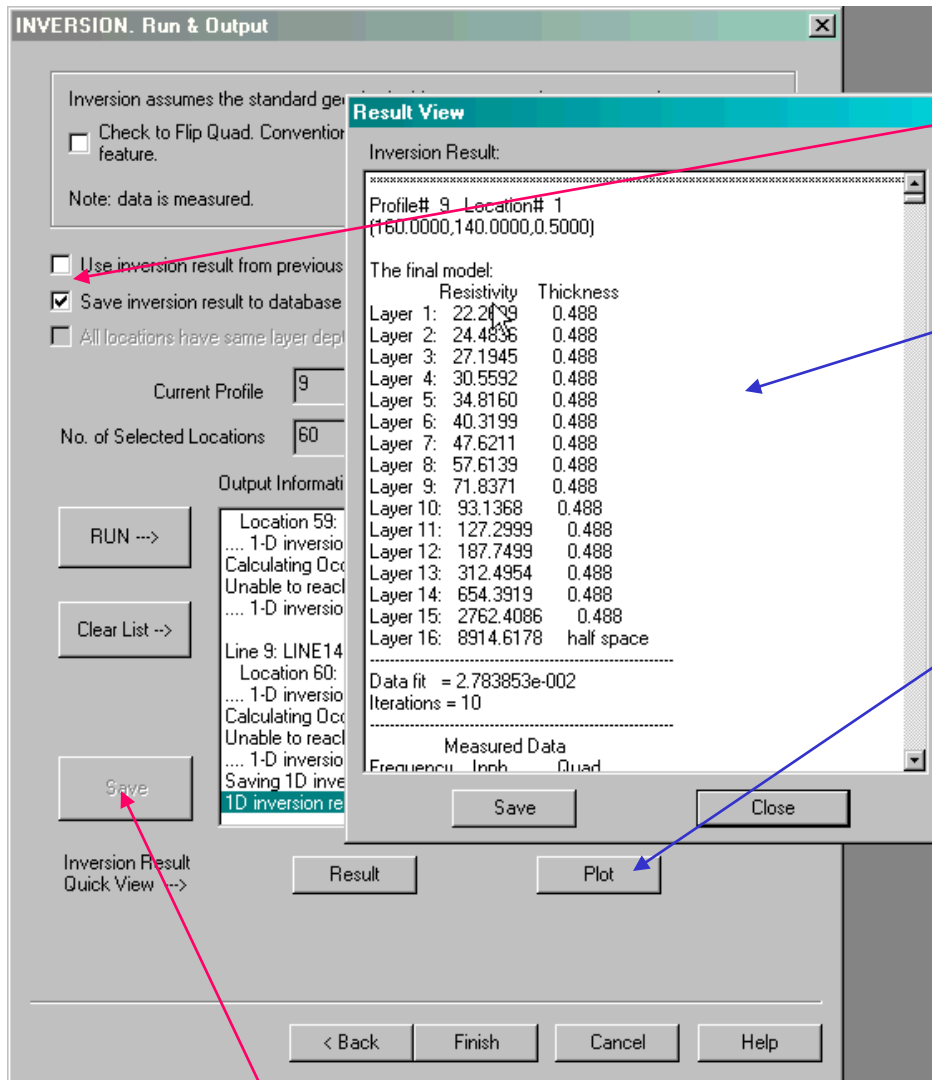
1	160.0	140.0	0.5
2	159.0	140.0	0.5
3	158.0	140.0	0.5
4	157.0	140.0	0.5
5	156.0	140.0	0.5
6	155.0	140.0	0.5
7	154.0	140.0	0.5
8	153.0	140.0	0.5

Optimized conjugate-gradient or Occam, Linear Regression and Marquardt

data points for selected profile

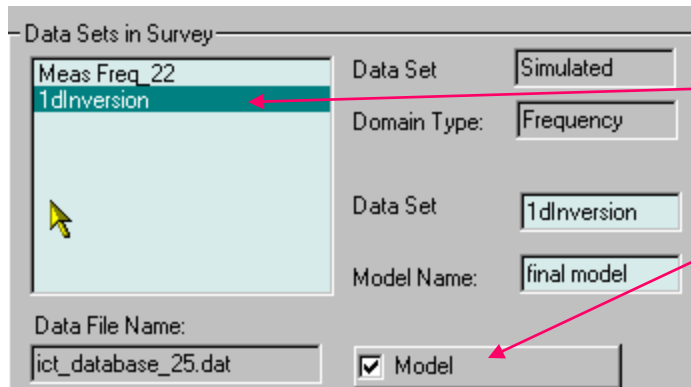
Invert single profile or All profiles

1D FEM Inversion - 2

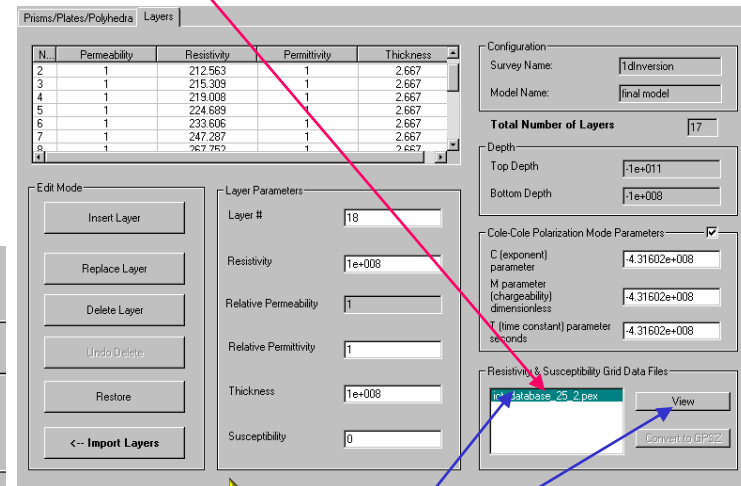
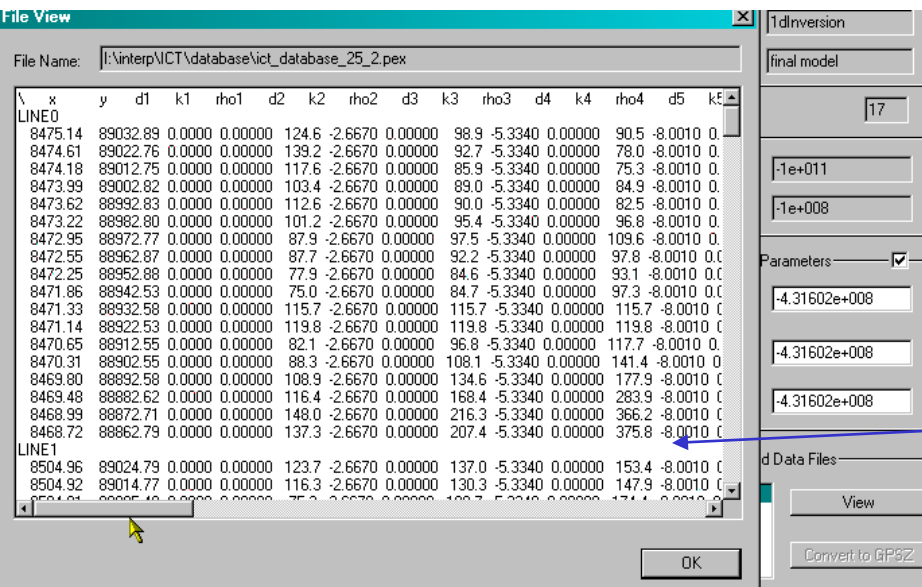


**Save to database
after completion**

1D FEM Inversion - 3



inversion results saved to database
contains synthetic data under the model
with the model attached – (*.pex)



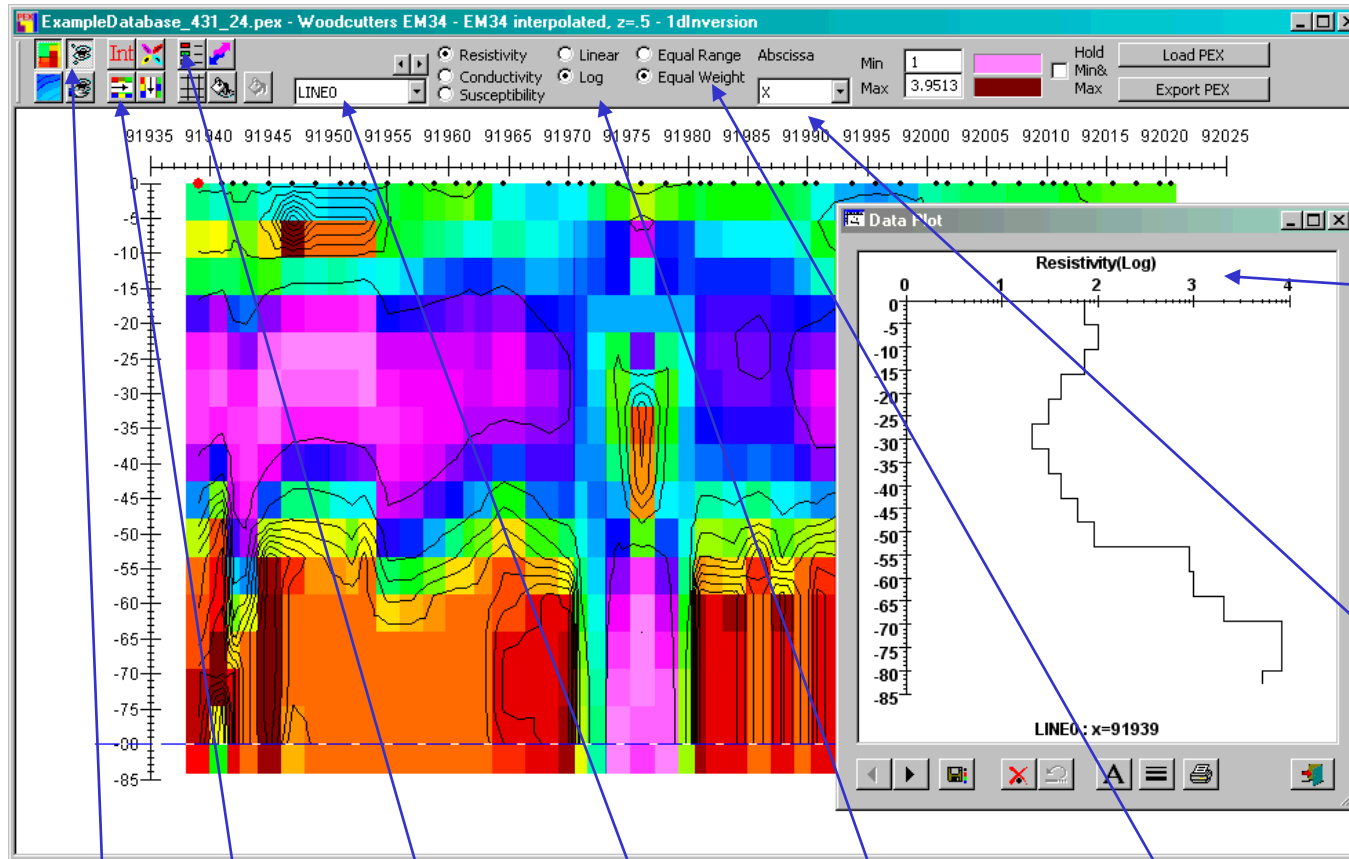
The *.pex file is a columnar ASCII file
inside your database directory

Use CDI Viewer for viewing models



1D FEM Inversion - 4

CDI Viewer



Plot of
Resistivity vs.
Depth for
single point

Horizontal Axis
selection

Apply
Contour

Legend

Select Line

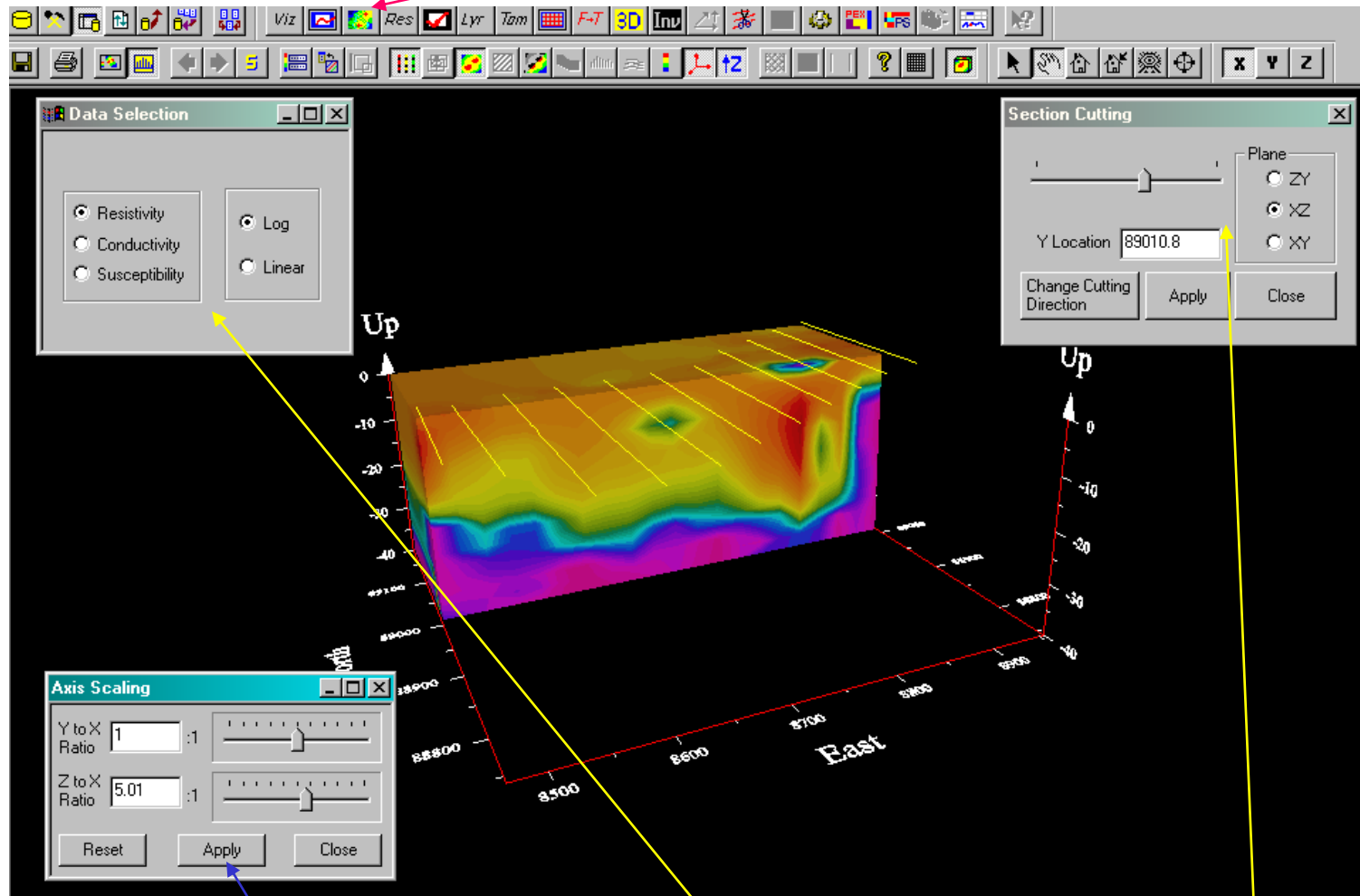
Model
Units

Colour Distribution
Equal Range – intervals equal
Equal Weight – distribution equal

2D Interpolation

1D FEM Inversion - 5

3D Volume Contour
(with Inversion model
dataset selected)



Axis Scaling

Model Units

Section Cutting