

# Setting Moving FDEM systems in EMIGMA

## The coordinate system

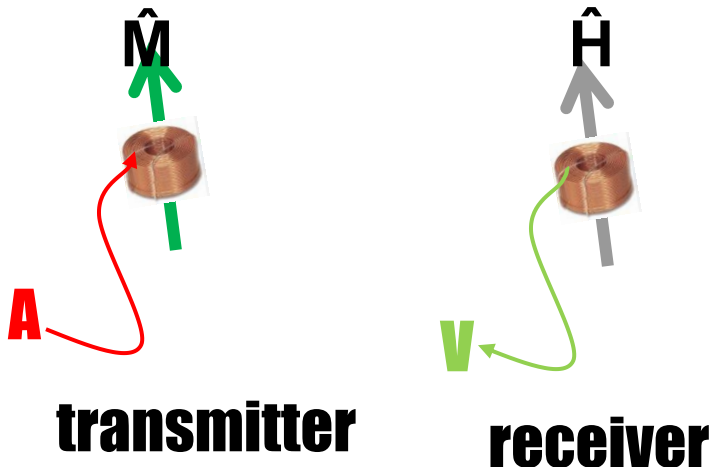
Normally, the Horizontal coordinate system is used for such systems in EMIGMA.



### 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

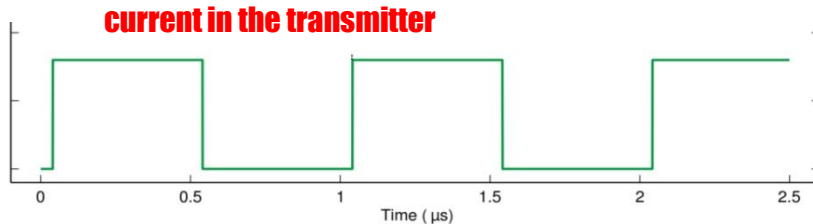


### System Components

- *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*

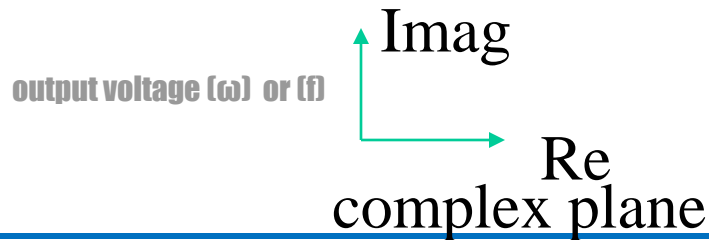
# Setting Moving FDEM systems in EMIGMA

## Data Processing



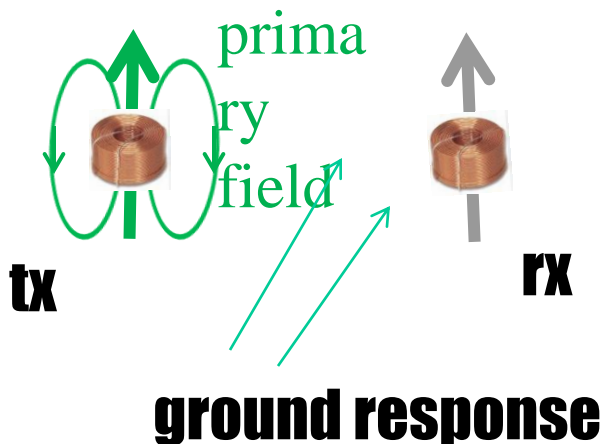
## Instrument Aspects

- 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



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

## Normalization



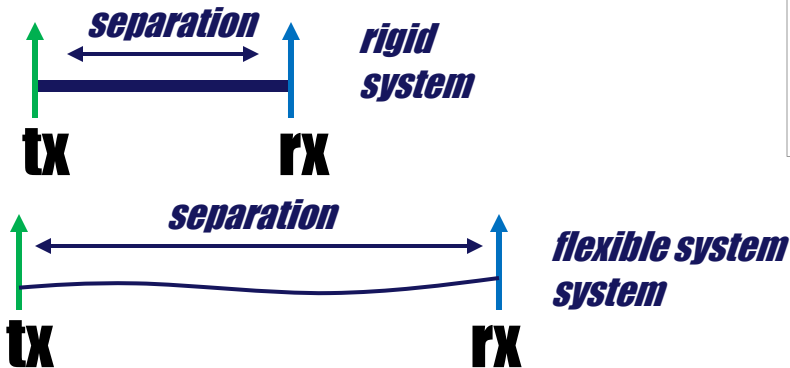
## Normalization

- 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

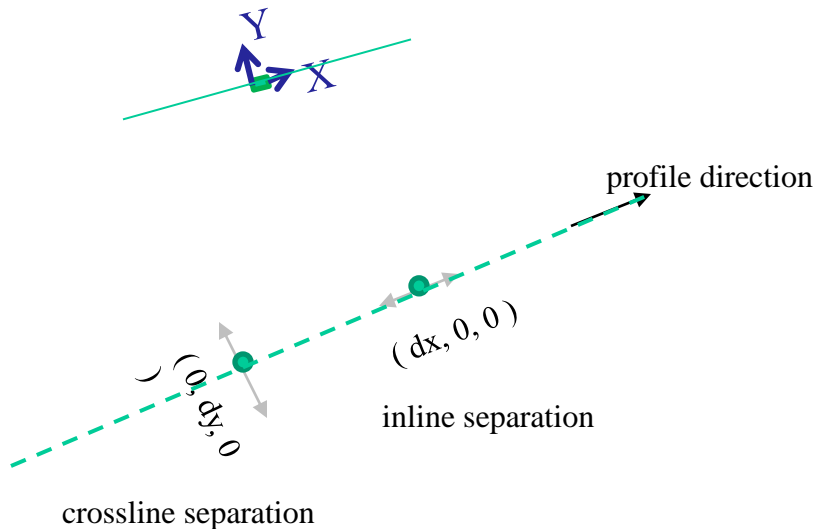
### Data Units Apparent Conductivity

- *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,  $[\sigma \omega \nu_0 s^2]$  is small*

$$\sigma_{\text{app}} = \frac{4}{\omega \nu_0 s^2} \frac{(\underline{H})_{\text{quadrature}}}{H_{\text{primary}}}$$

# 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):*  
 $Tx - Mz ; Rx - Hz ; \text{separation} ( dx, 0, 0 )$   
[ EM38 – (1,0,0), EM31 – (3.66,0,0)
- *standard horizontal coplanar crossline system configuration (HCP):*  
 $Tx - Mz ; Rx - Hz ; \text{separation} ( 0, dy, 0 )$
- *standard vertical coplanar in line system configuration (VCP):*  
 $Tx - My ; Rx - Hy ; \text{separation} ( dx, 0, 0 )$
- *standard vertical coplanar crossline system configuration (broadside VCP):*  
 $Tx - Mx ; Rx - Hx ; \text{separation} ( 0, dy, 0 )$

# Setting Moving FDEM systems in EMIGMA

## Configuration Page Example in EMIGMA – EM38

System Name:  System Type: Moving Tx, Moving Rx

1. System Mode: EM/IP/Resistivity

Transmitter: Horizontal: X horizontal along profile, Z vertical

Separation(s) (moving system) input -->

2. Transmitter Type:  Fixed  Moving

Coil  Current Dipole

Loop  Pole

Dipole Moment (Amp\*m<sup>2</sup>):

Transmitter Input -->

3. Receiver Type:  Coil  Voltage Dipole

Loop  Pole

Receiver Input -->

Ip/Res System Wizard

Transmitter List:

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

Receiver List:

- 1. RX-DIPOLE Hx
- 2. RX-DIPOLE Hy
- 3. RX-DIPOLE Hz

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: Horizontal: X horizontal along profile, Z vertical

Component: 4

Select All Create Comp

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

< Back Next > Cancel Help

1. Mz, Hz, (1,0,0)

2. My, Hy, (1,0,0)

3. Mz, Hz, (0,1,0)

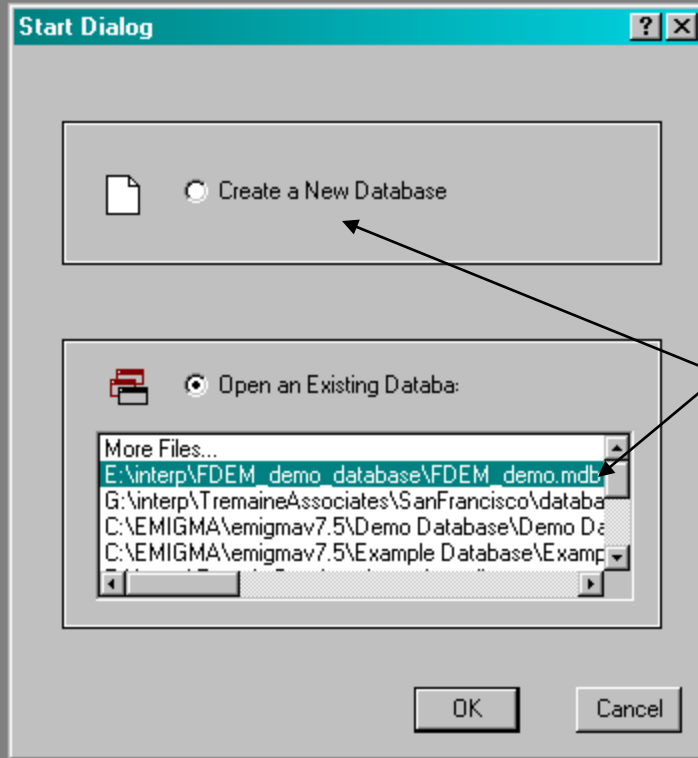
4. Mx, Hx, (0,1,0)

### System Configurations

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



# Opening a database



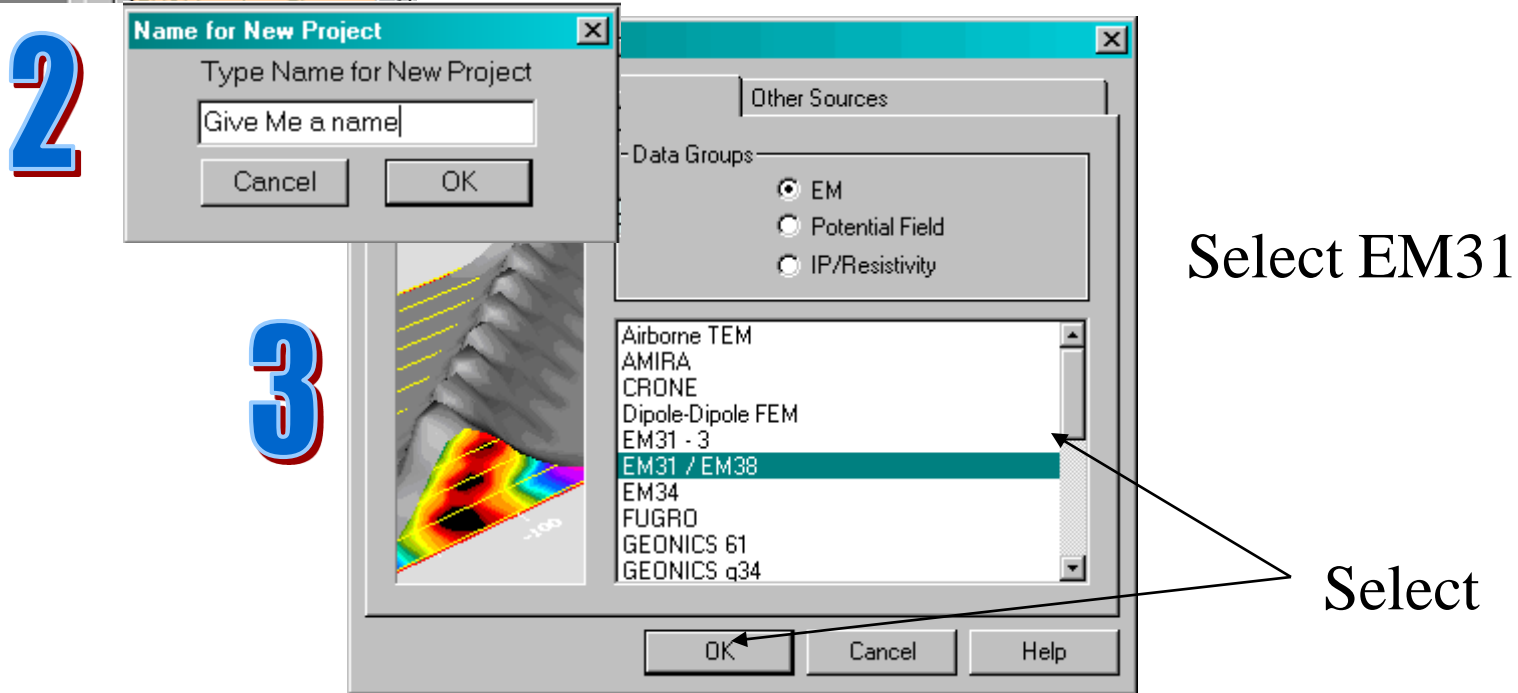
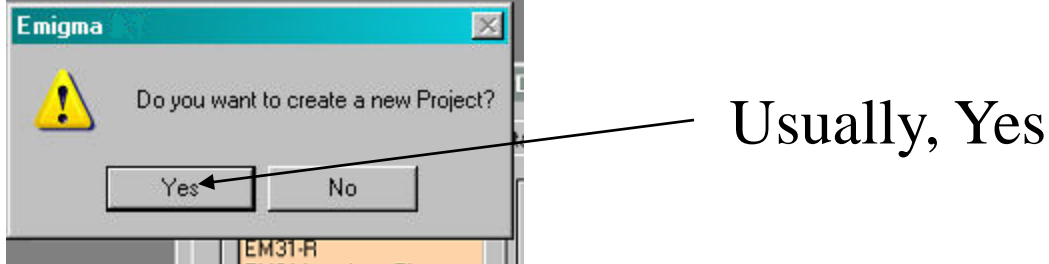
Select a Database

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

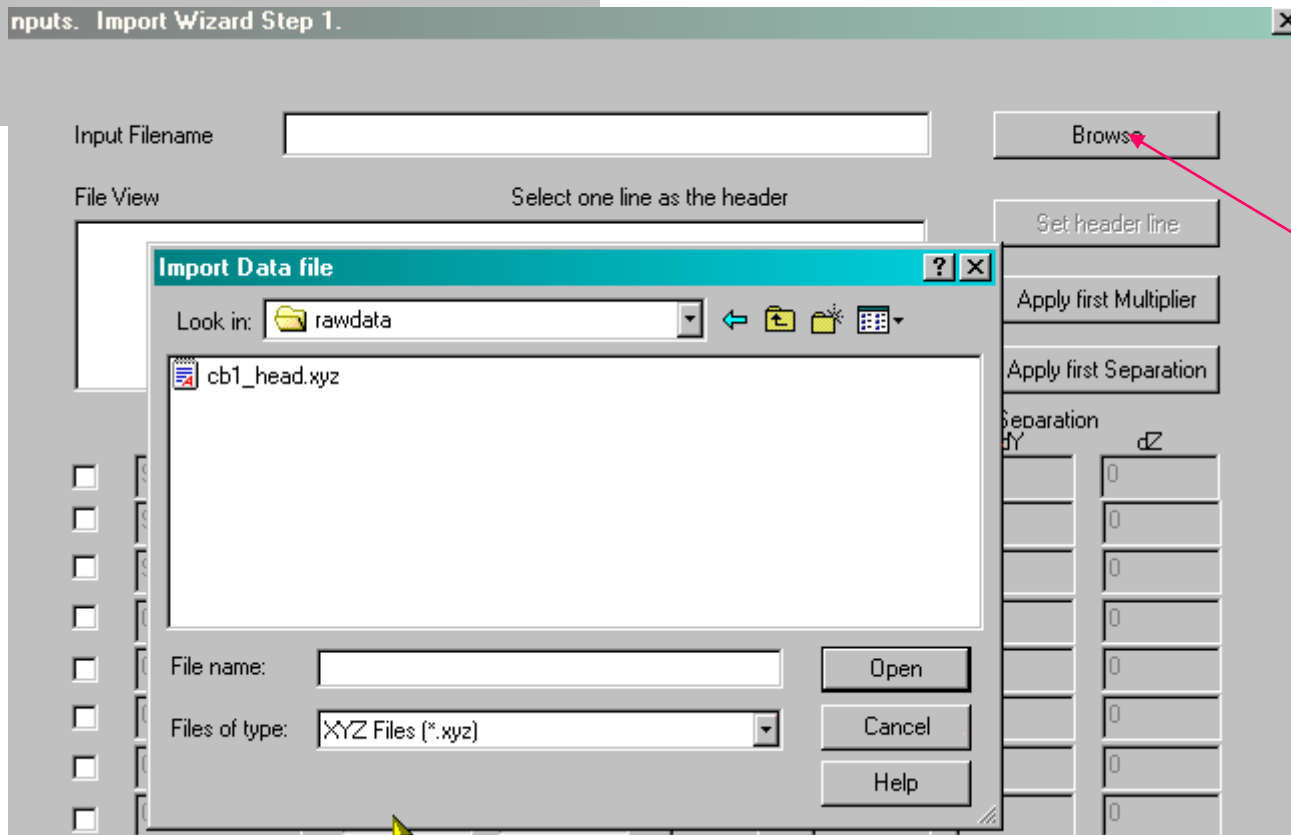
1

- Following systems and go to the next step.
- Em34
  - Em31/Em38
  - EM31-R
  - Max-Min
  - Fugro
  - AeroQuest
  - Unknown
- System Name

Select System

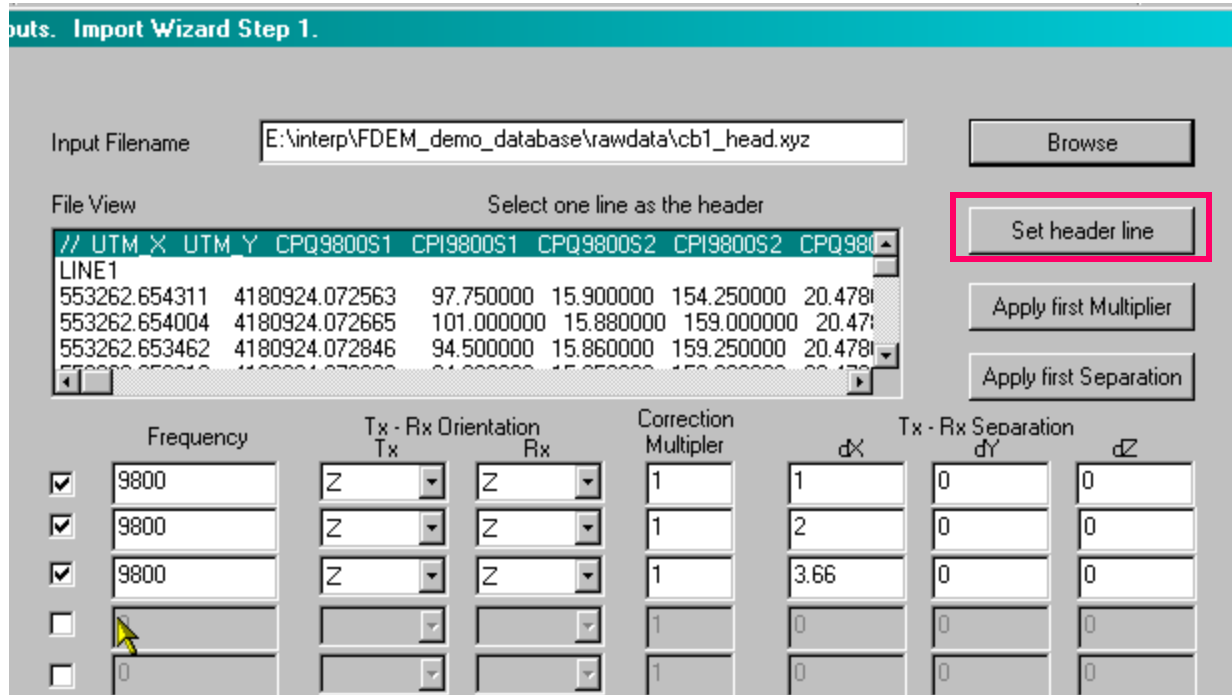
For other systems select Unknown and give it a name

2



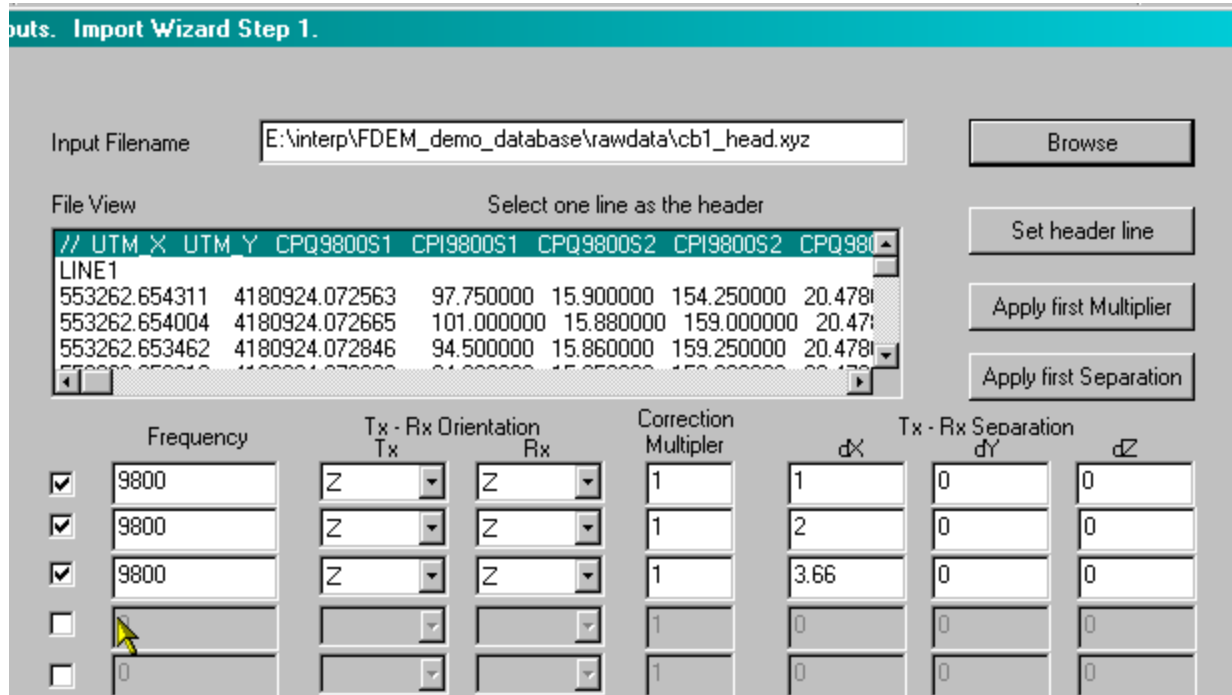
Browse for XYZ columnar datafile

# Importing Data - 3



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



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 coplanar ‘broadside’.

# Importing Data - 4

Format. Import Wizard Step 2.

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

LINE1	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	20.47800		
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

F11 9 FIDS3

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

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.

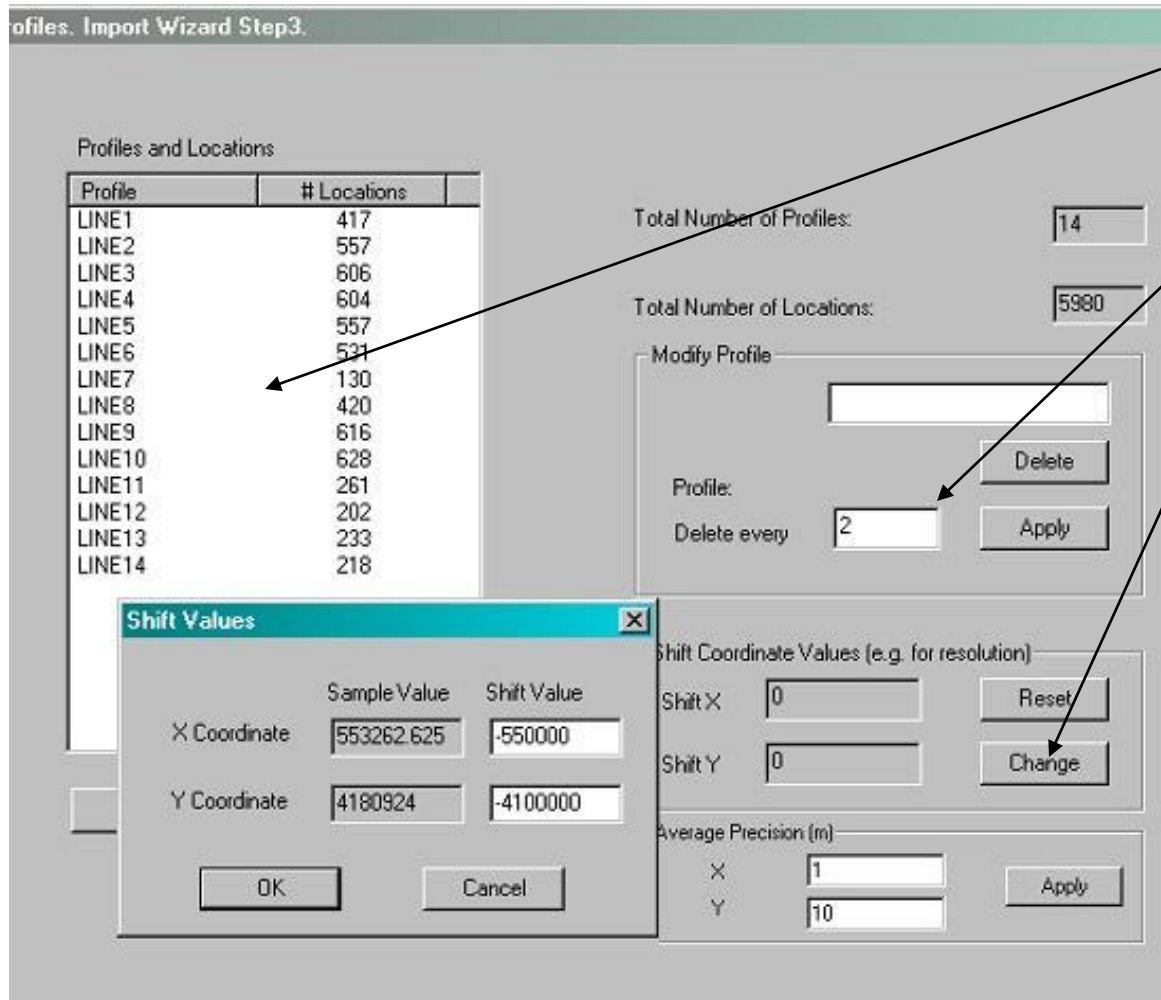
Set the height of the instrument.

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



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

Messages:

Run Import

...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

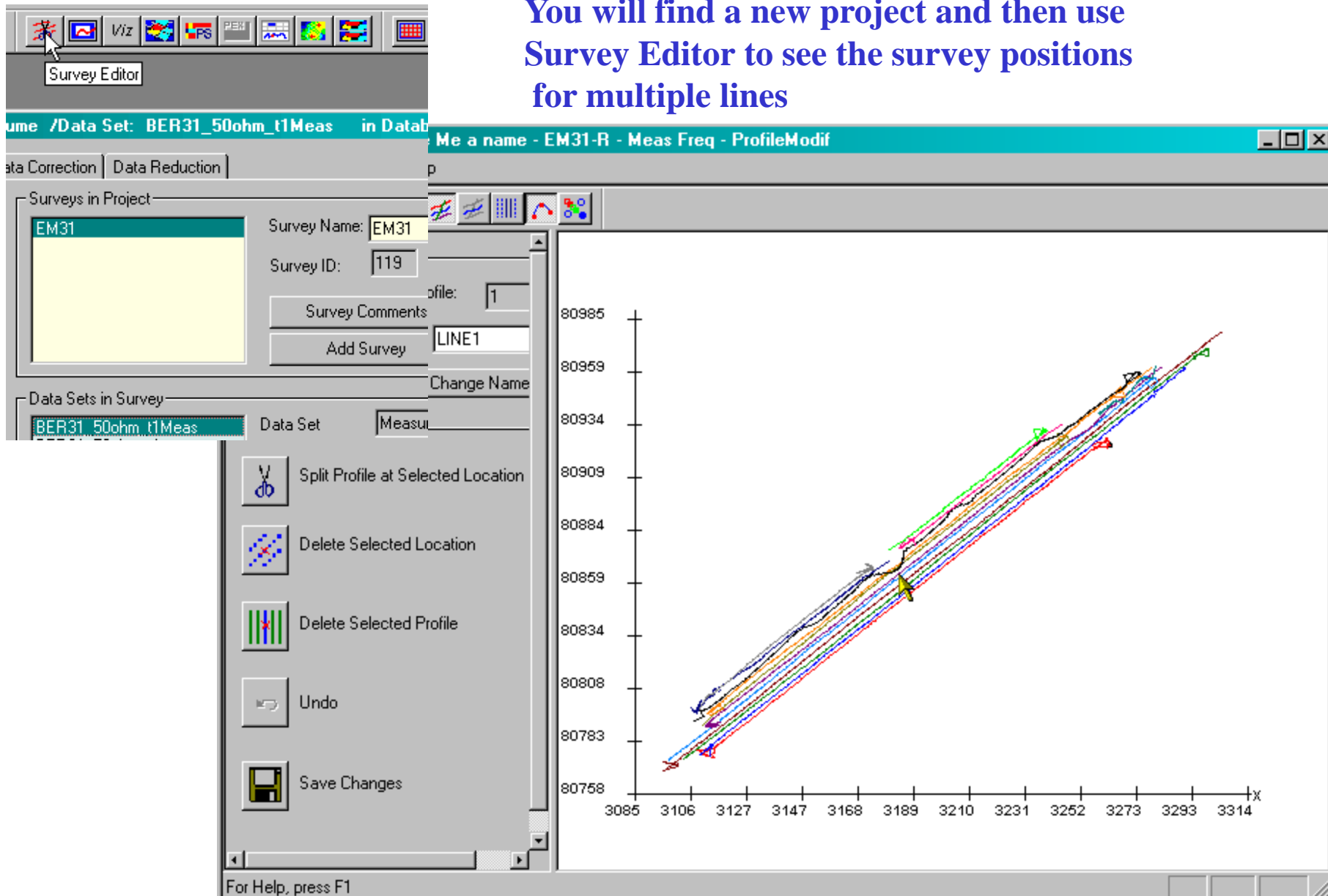
**Note:** The centre point of the 3 Rx-Tx data are not the same.

**Run Import:**

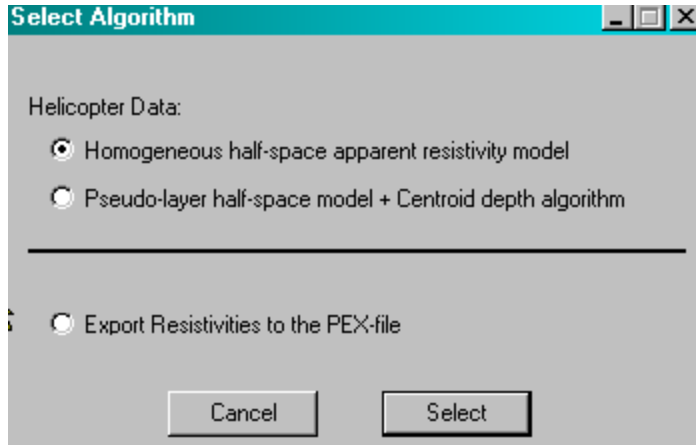


# Importing Data - Final

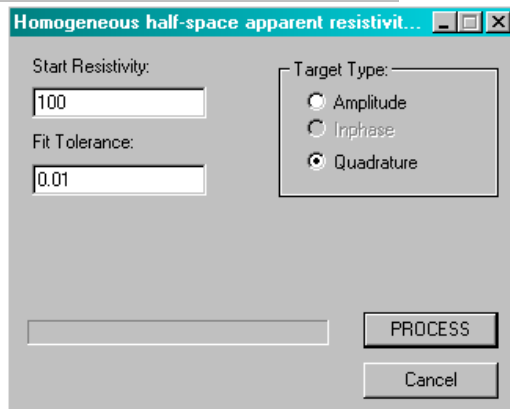
You will find a new project and then use Survey Editor to see the survey positions for multiple lines



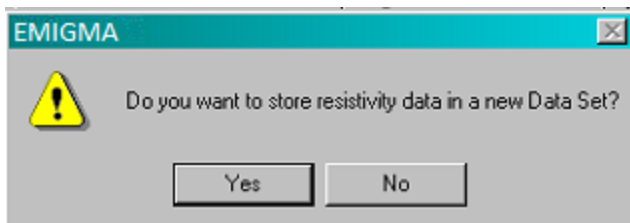
# Calculating Apparent Resistivity



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

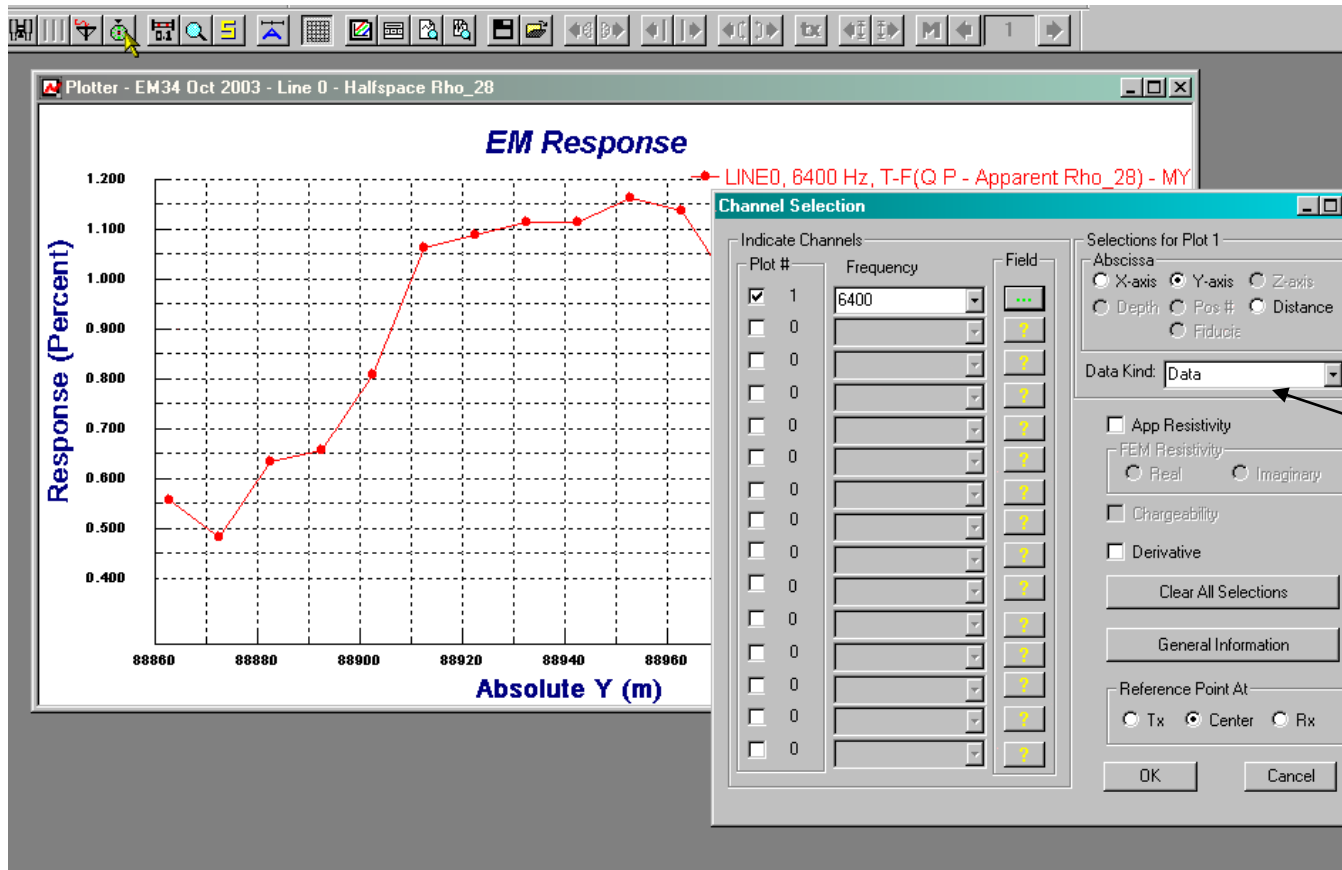


**Calculate the best fitting half-space app rho choose which data elements to use e.g. for EM34 then Quadrature is default**



**Store to new dataset or attach to original data**

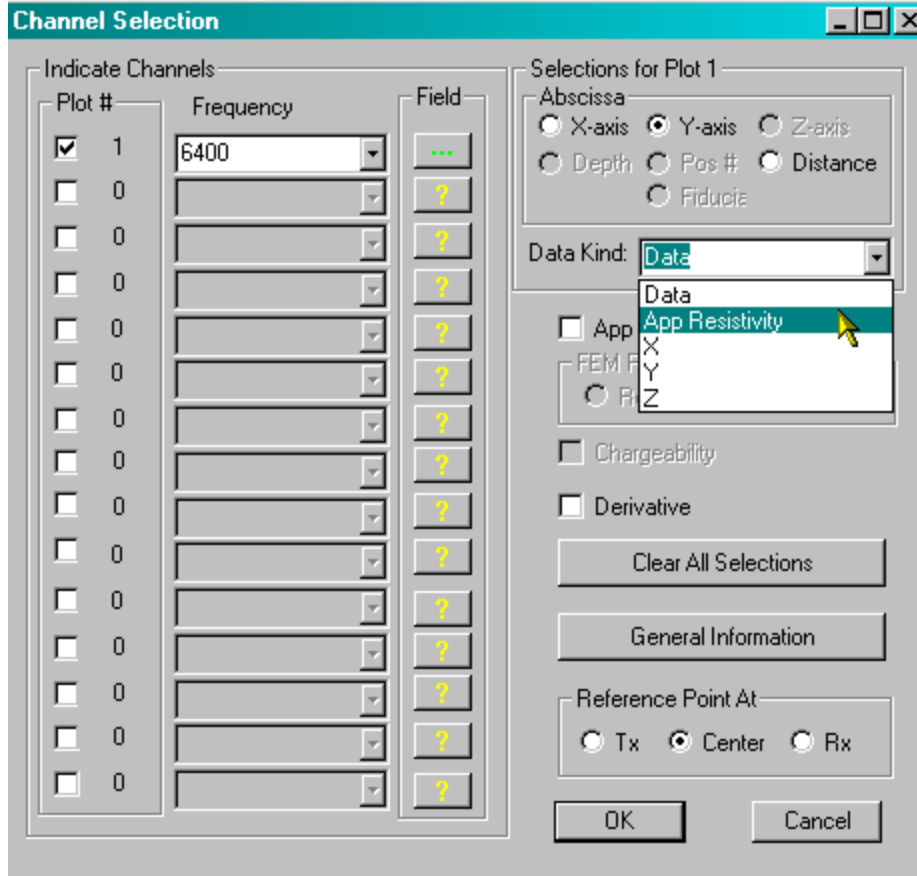
# Plotting Data - 1 ( V90\_tutorial .pdf for more details)



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

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

# Plotting Data - 2



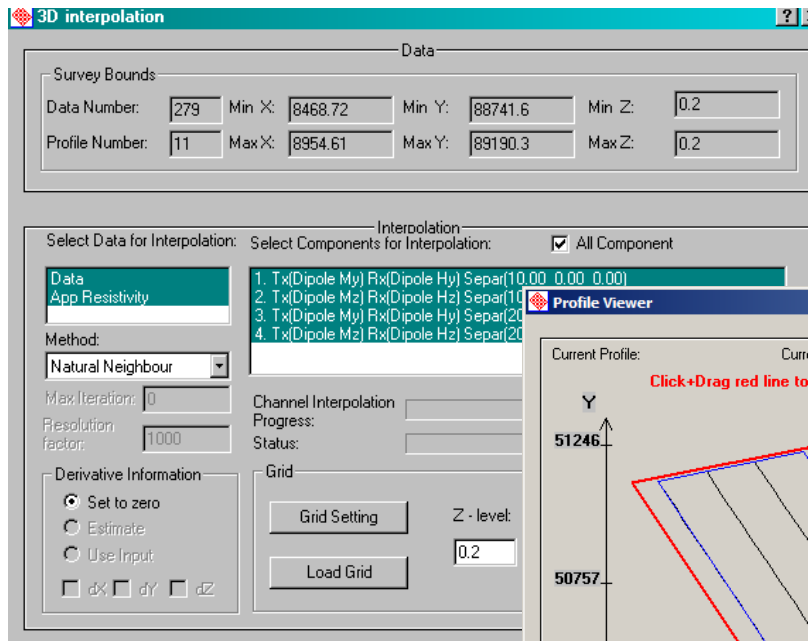
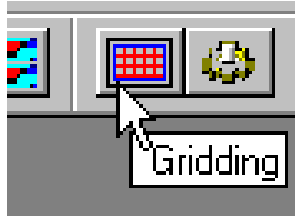
**app rho display**  
use calculated best fit  
apparent resistivity

for apparent conductivity  
Settings -> Custom -> App Cond

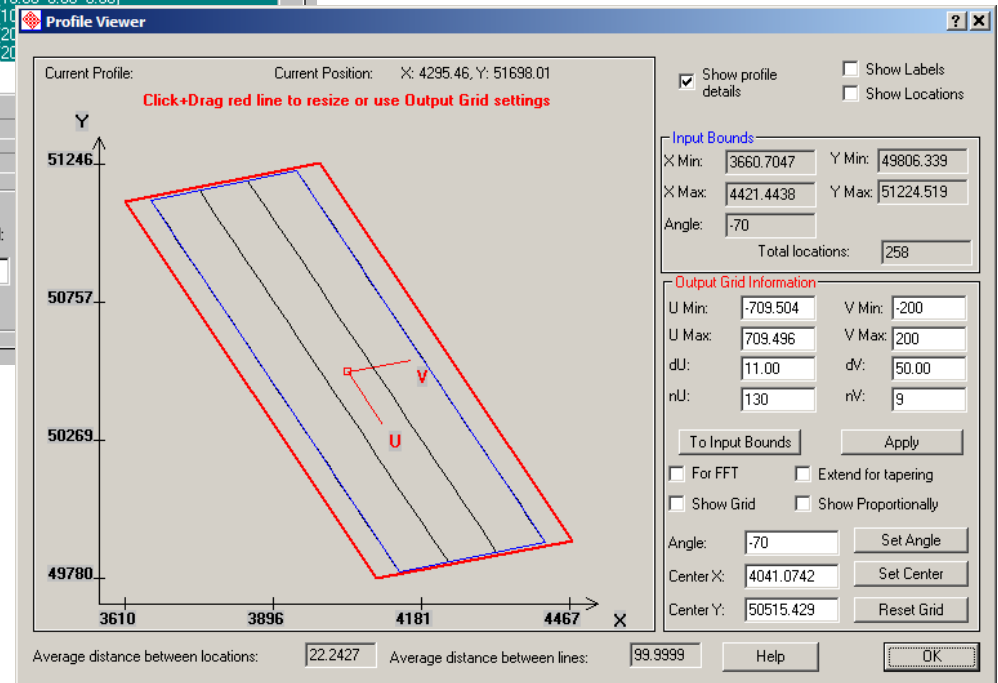
# Gridding data - 1

## Interpolate to Grid

interpolate to regular grid



## Select Components

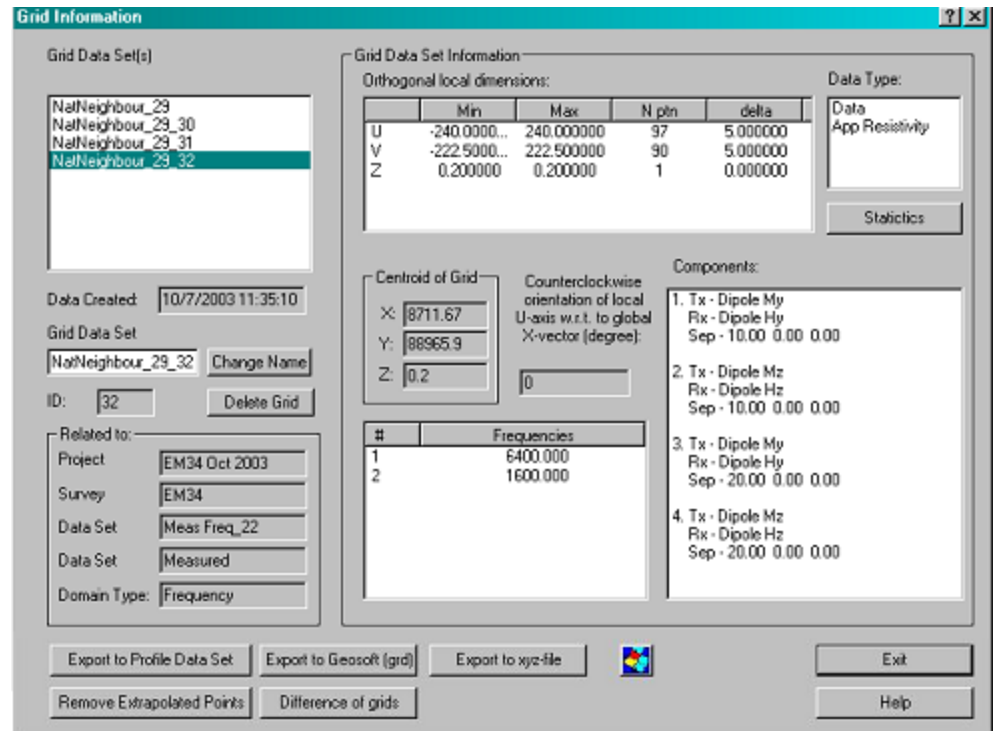
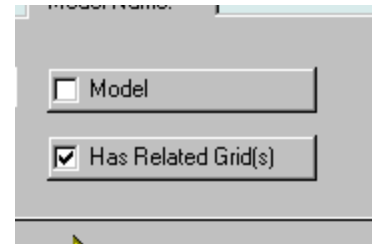
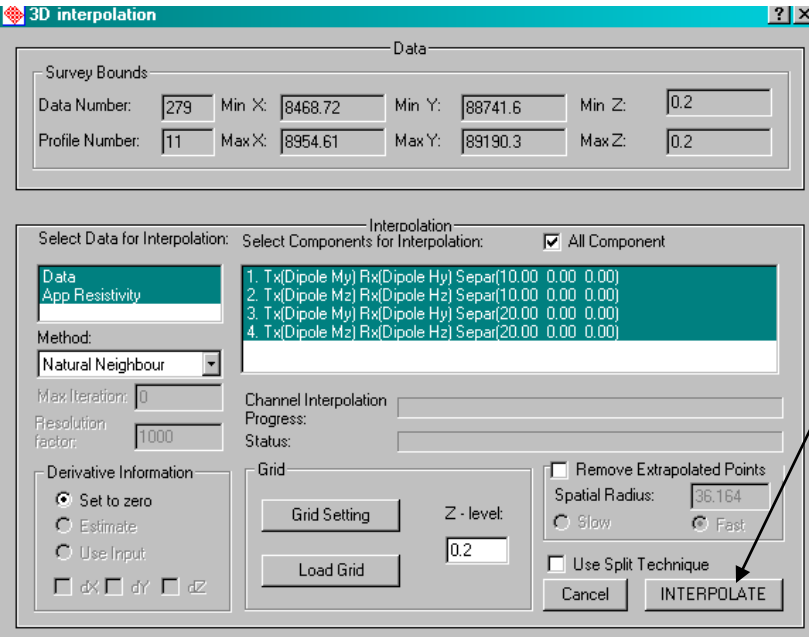


## Set Grid Settings

# Gridding data - 2

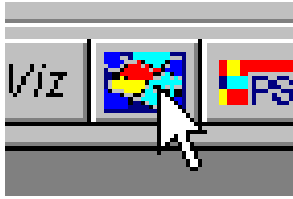
## Interpolate to Grid

## View Grids

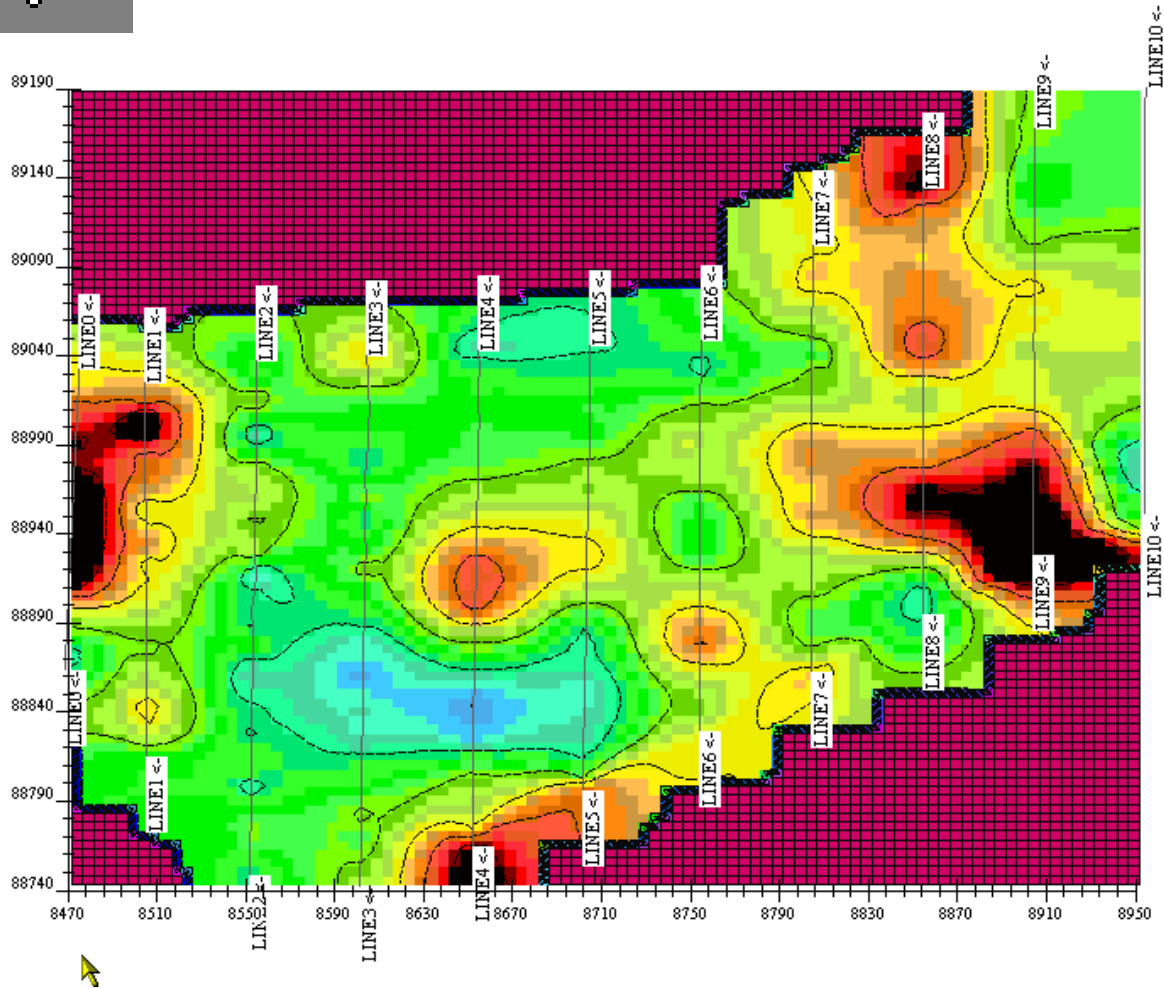


## View Grid Characteristics

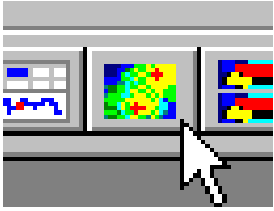
# Viewing Gridded Data - 1



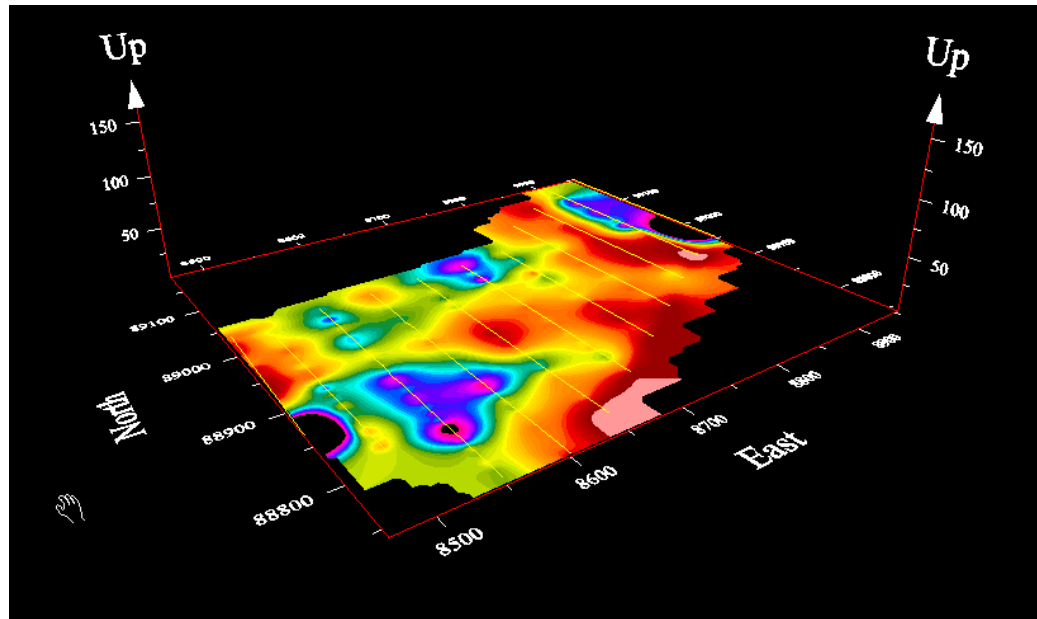
## Grid Presentation



# Viewing Gridded Data - 2

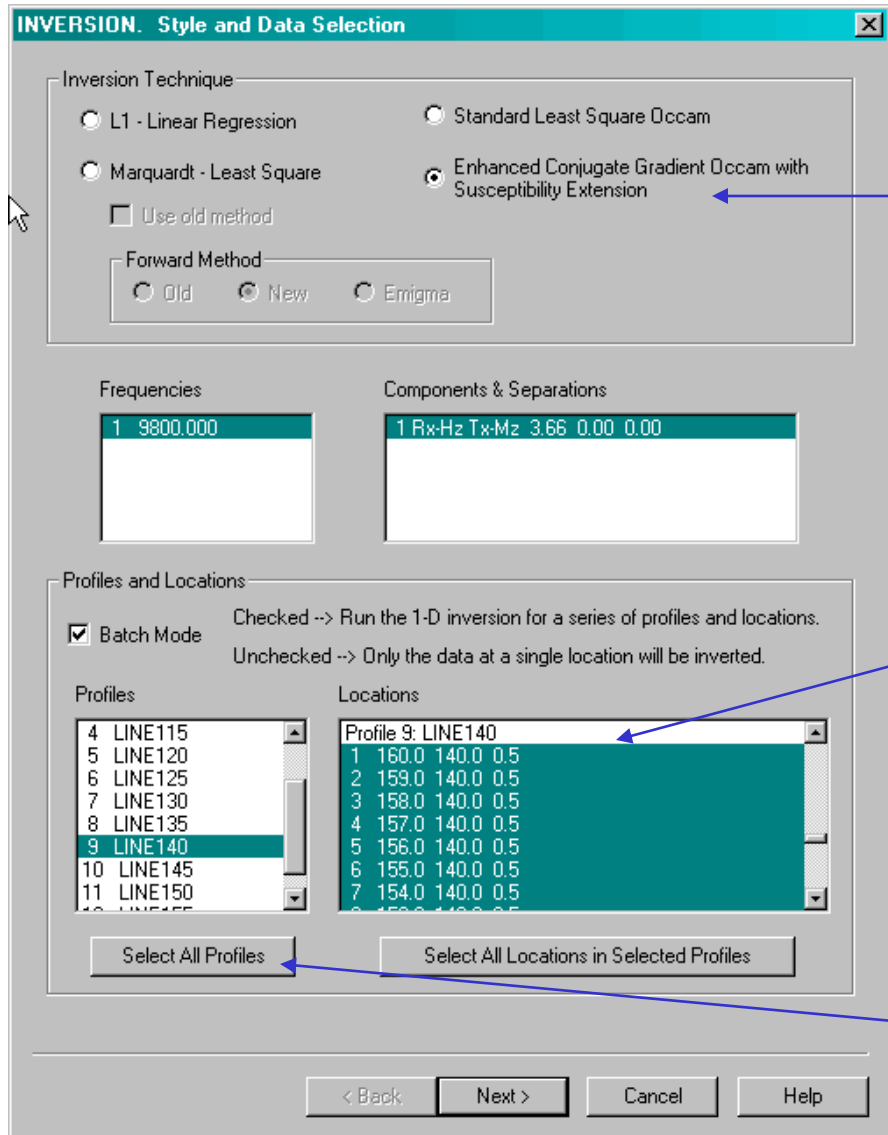


## Contour





# 1D FEM Inversion - 1

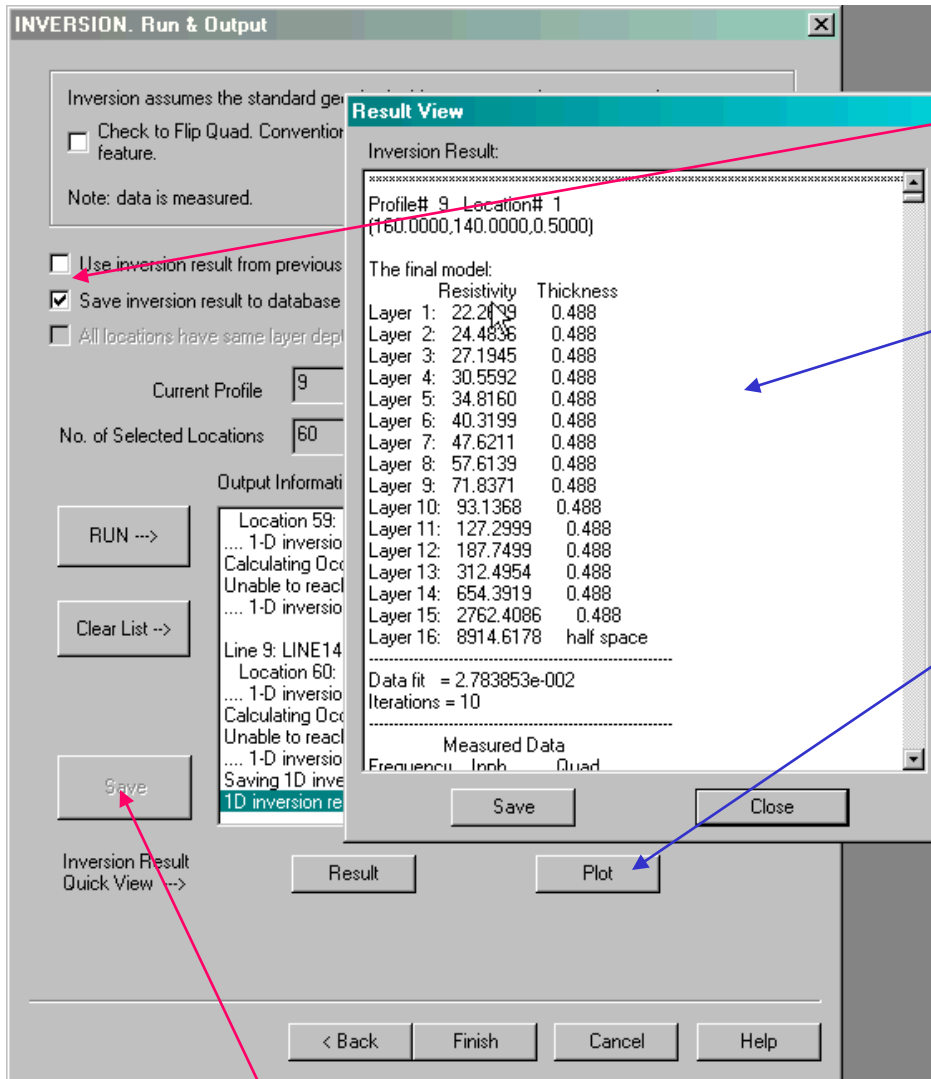


Optimized conjugate-gradient or Occam, Linear Regression and Marquardt

data points for selected profile

Invert single profile or All profiles

# 1D FEM Inversion - 2



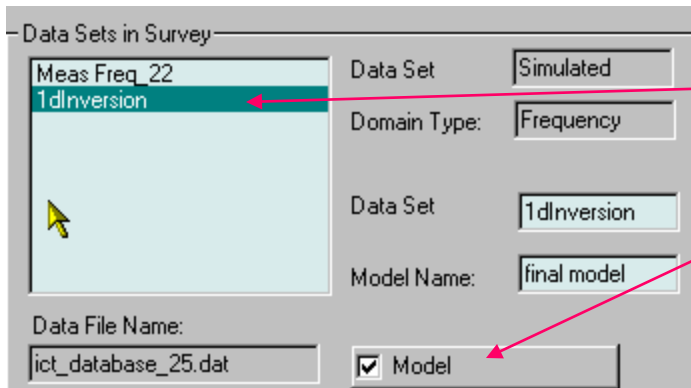
automatic save to database

contents of \*.mod file  
point by point information

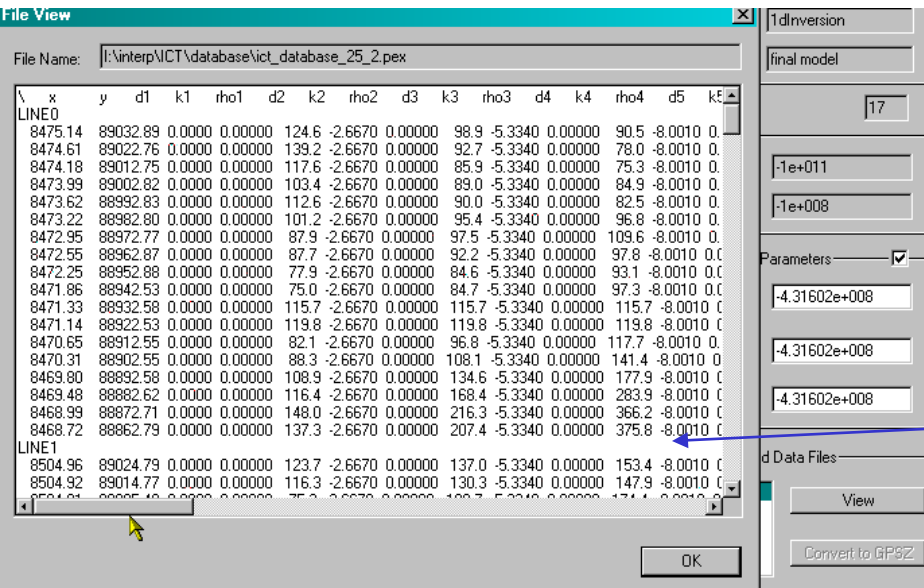
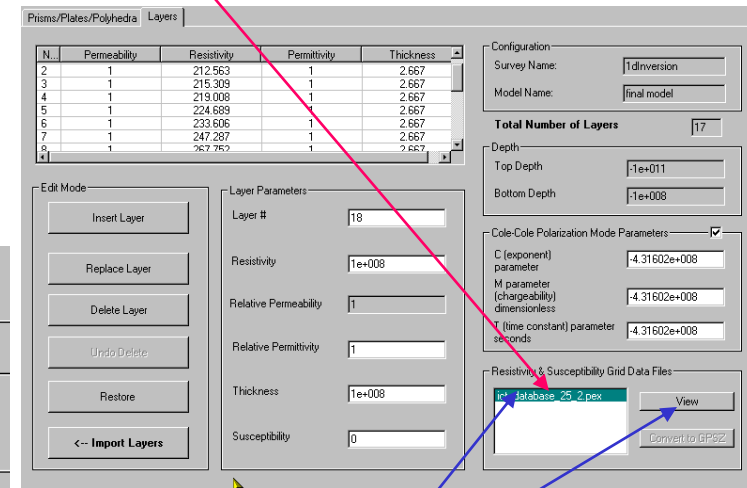
Single line depth contour  
available only for single line  
inversions

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)**



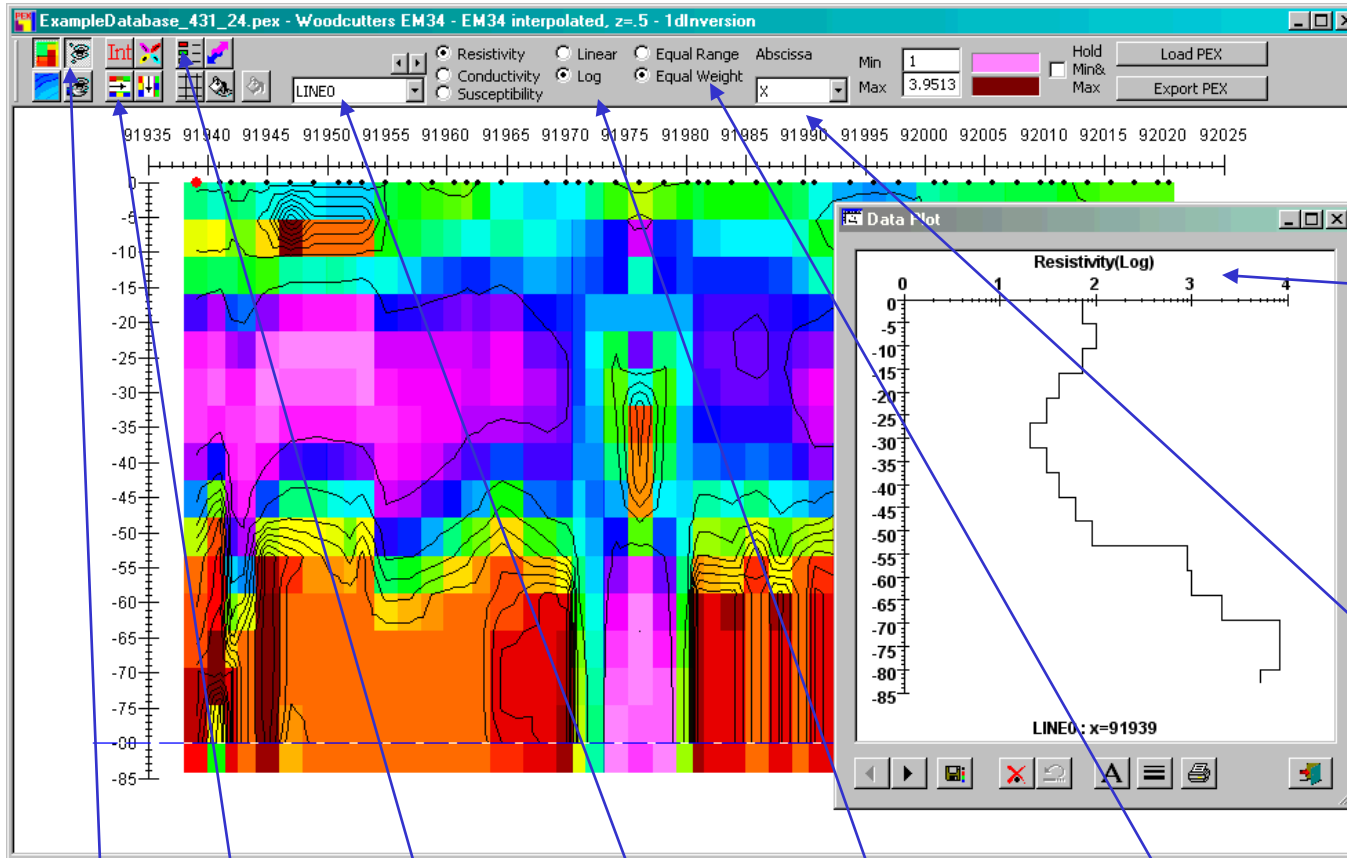
**The \*.pex file is a columnar ASCII file  
inside your database directory**

**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

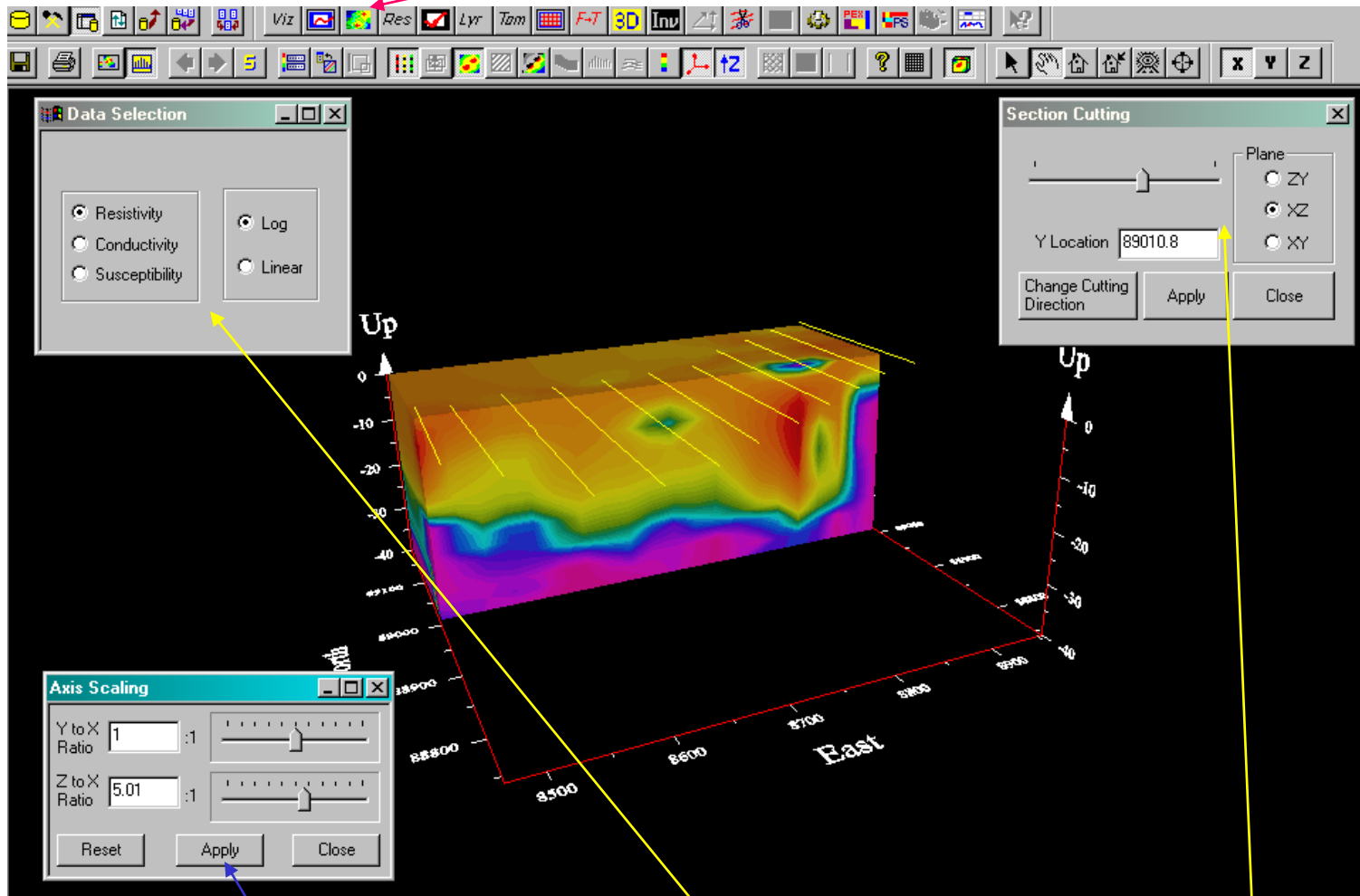
Model Units

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