



# EM4Soil Quick Start

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

**Version-1.01**

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**February 2012**



### **DISCLAIMER**

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



## 1. Introduction

**EM4SOIL** is a software package that has been developed in order to enable the inversion of electromagnetic (EM) induction data acquired at low induction numbers (LIN). The input data for **EM4SOIL** is the measured apparent soil electrical conductivity ( $\sigma_a$ ) as measured by EM instruments. The output data includes but is not limited to estimates of the true electrical conductivity ( $\sigma$ ).

The following **Quick Start** guide is intended to provide the first time user with an overview of the basic  $\sigma_a$  data input requirements,  $\sigma_a$  plotting and filtering options, inversion modelling,  $\sigma$  plotting and saving of the inversion output files.

In order to assist the user we have provided a set of DUALEM-421 data (i.e. D421Line0.txt). We use this data to demonstrate  $\sigma_a$  data input,  $\sigma_a$  plotting and filtering, inversion modelling,  $\sigma$  plotting and saving of the inversion output files. We do not go into all the functionalities of EM4soil.

Nevertheless, we have provided the this **Quick Start** guide bearing in mind the simplest instructions that would be required to provide results which could be shown in a written report or in a scientific research manuscript. The first time user should use this **Quick Start** guide as a template of how to achieve these results.



## STEP 1. Preparing the $\sigma_a$ data

All the input files required by **EM4soil** are **ASCII** files. For our Quick Start Guide set of **DUALEM-421**  $\sigma_a$  data the file is set up as follows:

Name of line

N h

X Y Z HCP1m PRP1m HCP2m PRP2m HCP4m PRP4m Lat Lon Time

Name of line	N	h	X	Y	Z	HCP1m	PRP1m	HCP2m	PRP2m	HCP4m	PRP4m	Lat	Lon	Time
D421Line0	41	0.3												
766551	6758792	231.5	93.5	37.3	134.1	80.2	147.1	133.4	0	0	0			
766549	6758782	231.6	91.8	33.7	135.5	78.7	147.2	134.8	0	0	0			
766546	6758772	231.7	94.9	33.3	138.8	81.5	147.9	137.1	0	0	0			
766543	6758761	231.8	83.5	29.7	122.1	72.4	132.3	125.5	0	0	0			
766542	6758752	231.6	84.2	26.9	130.3	74.9	126.7	126.8	0	0	0			
766540	6758743	231.6	97.7	41.2	131.8	86.2	136.6	129.5	0	0	0			
766538	6758733	231.4	93.9	39.1	128.2	80.9	138.1	125.4	0	0	0			
766536	6758722	231.4	94.8	39.1	130.4	81	139.5	129.6	0	0	0			
766534	6758711	231.4	93.8	37.7	129.8	79.9	140.3	127.8	0	0	0			
766532	6758703	231.4	93.4	39.8	127.6	80.1	137.1	125.3	0	0	0			
766530	6758692	231.4	92.6	38.4	126	79.6	133.6	123.2	0	0	0			
766528	6758682	231.4	95.3	37.6	129.1	84.5	133.1	129.4	0	0	0			
766526	6758672	231.5	97.4	42	131.7	84.8	138.1	131	0	0	0			
766524	6758661	231.6	98.1	42.1	132.8	85.9	140	131.7	0	0	0			
766522	6758652	231.6	104.8	48.3	139.4	91.4	148	140.1	0	0	0			
766520	6758643	231.5	108	52.1	141.1	98.6	137.6	143.5	0	0	0			
766518	6758632	231.5	72.6	36.7	94.6	63.3	104.6	89.3	0	0	0			
766516	6758621	231.5	75.8	36.4	98.6	67.3	103.3	95.9	0	0	0			
766514	6758611	231.4	93.8	45.5	121.1	84	120.2	118.7	0	0	0			
766512	6758601	231.4	101.7	49.3	129	90.6	129.6	124.8	0	0	0			
766510	6758592	231.4	109.3	52.5	140.3	97.7	140.3	139.7	0	0	0			
766508	6758581	231.4	115.1	56.1	148.7	103.1	149.3	152.1	0	0	0			
766506	6758572	231.3	106.5	48.6	143.8	95.4	147.2	145.7	0	0	0			
766504	6758561	231.2	111.7	50.7	148.1	99.1	148.9	148.6	0	0	0			
766502	6758552	231.1	111	53.3	143.9	99.9	144	145.1	0	0	0			
766500	6758543	231	109.5	51.6	144.3	97.4	149	146.1	0	0	0			
766498	6758532	231	111.4	53.2	144.3	99.6	147.3	145.2	0	0	0			
766496	6758521	231	113.1	52.4	147.1	101.2	147.7	148.4	0	0	0			
766494	6758512	231	110.3	49.9	147	97.1	151.6	147.8	0	0	0			
766491	6758500	230.9	117.4	56.3	151.3	105.8	147.4	152.7	0	0	0			
766489	6758491	230.9	114	53.3	149.7	102.2	148.5	152	0	0	0			
766488	6758483	230.9	111.5	53.9	141.3	99.7	142	137	0	0	0			
766485	6758470	231	103.6	48.5	136.2	91.5	142.1	134.1	0	0	0			
766484	6758461	230.9	109.4	53.6	139	99	137.4	137.7	0	0	0			
766482	6758452	230.9	105.1	49.1	137.7	94.5	136.3	138.9	0	0	0			
766480	6758442	230.9	97	44.7	128.9	85.2	136.1	126.6	0	0	0			
766478	6758433	230.7	94.4	43.1	126.1	82.6	134.8	126.1	0	0	0			
766476	6758422	230.6	101.2	42.7	140.5	87.6	149.3	140.2	0	0	0			
766473	6758412	230.6	113.5	48.4	155.4	101.8	154.2	156	0	0	0			
766472	6758407	230.6	108.1	44.4	150.9	93.5	159.5	149.4	0	0	0			
766471	6758396	230.7	115.8	50.3	154.2	101.2	154.5	153.1	0	0	0			

N is the number of  $\sigma_a$  sites (i.e. 41);

h is the height of the sensor in m (i.e. 0.3);

X, Y and Z are the coordinates in Easting and Northing and elevation (m), respectively;

HCP and PRP are the measured  $\sigma_a$  at site; and,

Lat and Lon are the Latitude and the Longitude in decimal degrees and Time is the time in any format not exceeding 14 characters. If this data does not exist columns still need to be added with 0 values assigned and as indicated.

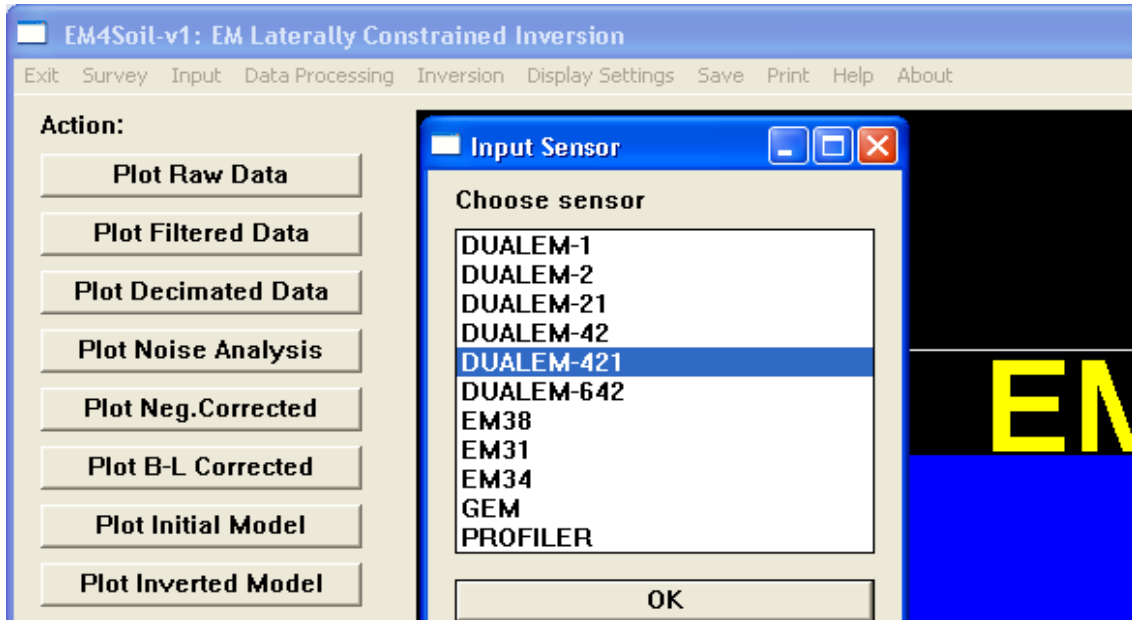
**NOTE** In our example **DUALEM-421**  $\sigma_a$  data file the data is tab delimited but comma delimited files can also be used.



## STEP 2. Inputting the $\sigma_a$ data into EM4soil

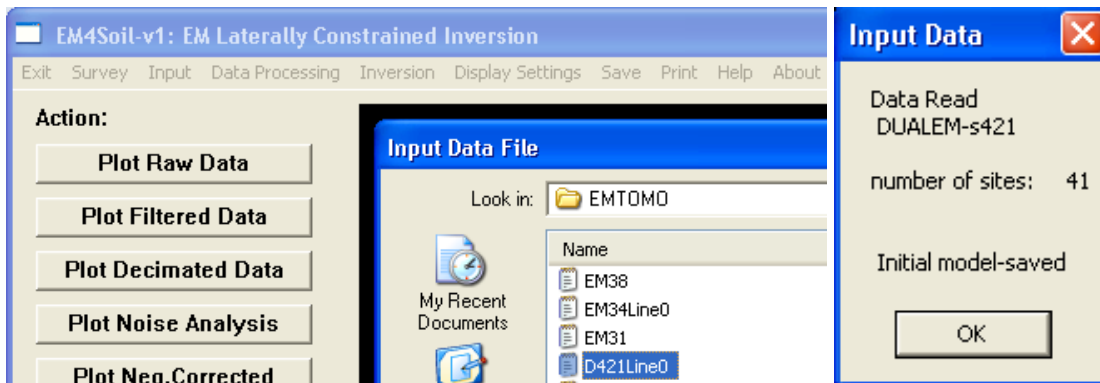
To enter the data into **EM4soil** start the software.

Go to the **Input** menu option and select the **Input Sensors** option.



The **Input Sensor** pop-up box will appear and the DUALEM-421 sensor is selected by default. Press the **OK** button.

Select the **Input** menu option again and this time select the **Input Data** option.



The **Input Data File** pop-up box will appear. Select the D421Line0 data file. Press the **Open** button. **NOTE:** Ensure that the data file is denoted with a .txt.

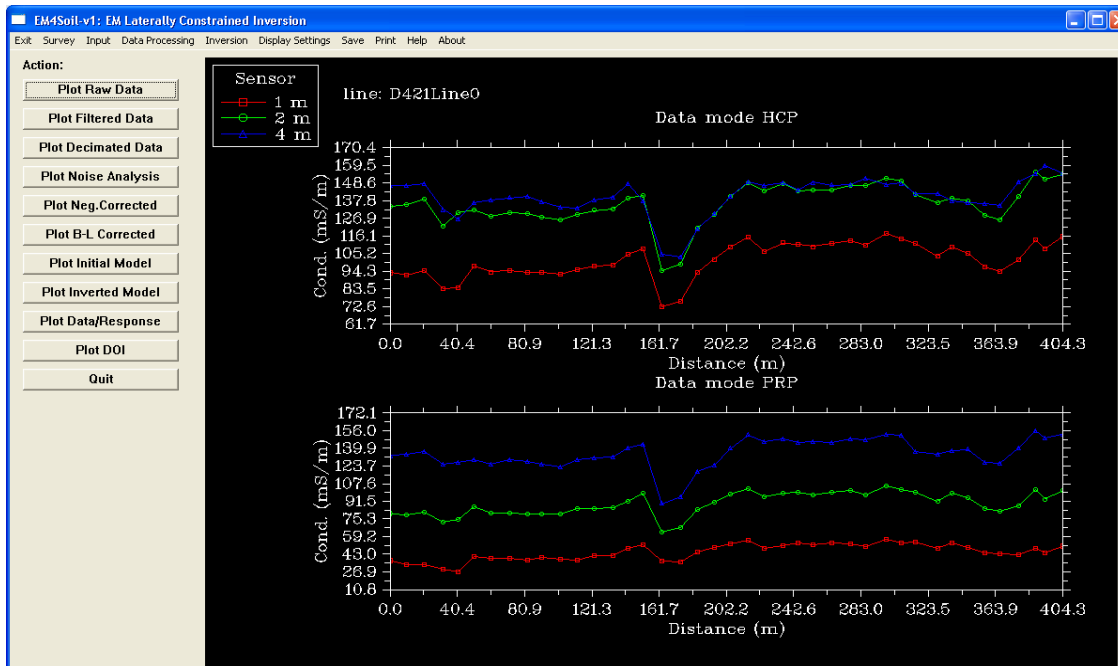
The **Input Data** pop-up box will appear indicating that the DUALEM-421  $\sigma_a$  data containing 41  $\sigma_a$  sites has been read successfully.

An initial model has also been saved automatically. Press **OK**.



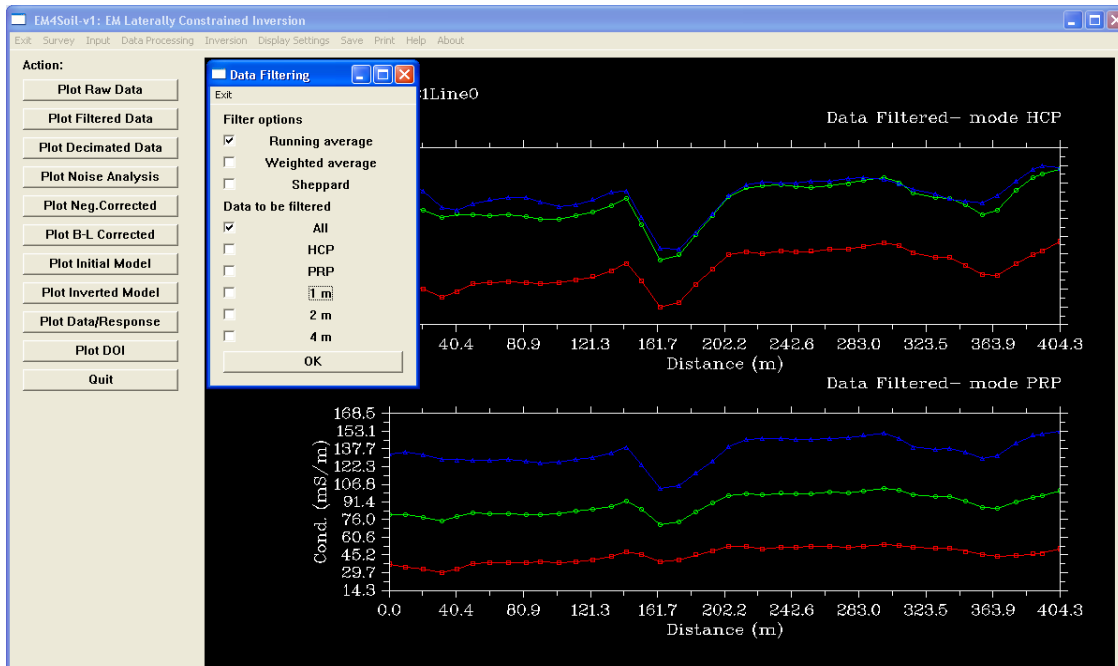
### STEP 3. Plotting the $\sigma_a$ data

To plot data in EM4soil select the **Plot Raw Data** action button on the left hand side.



### STEP 4. Filtering the $\sigma_a$ data

To filter data in EM4soil use the **Data Processing** menu and select the **Data Filtering** option.

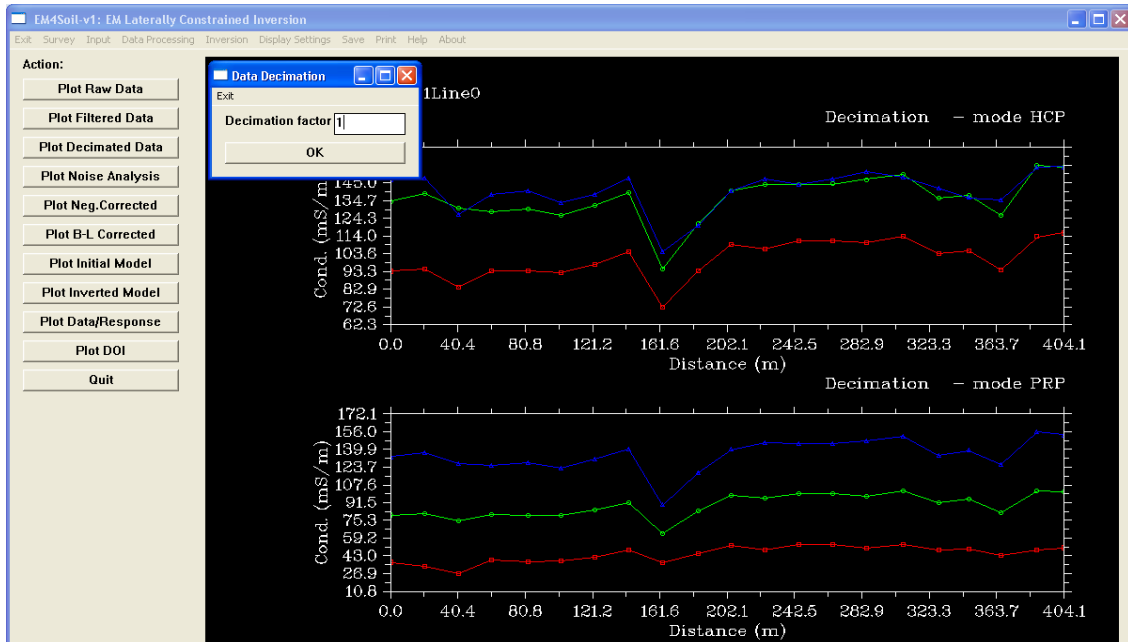


The **Data Filtering** pop-up box will appear indicating that the DUALEM-421  $\sigma_a$  data has been filtered. Press **OK**. To plot filtered data in EM4soil select the **Plot Filtered Data** action button on the left hand side.



### STEP 5. Decimating the $\sigma_a$ data

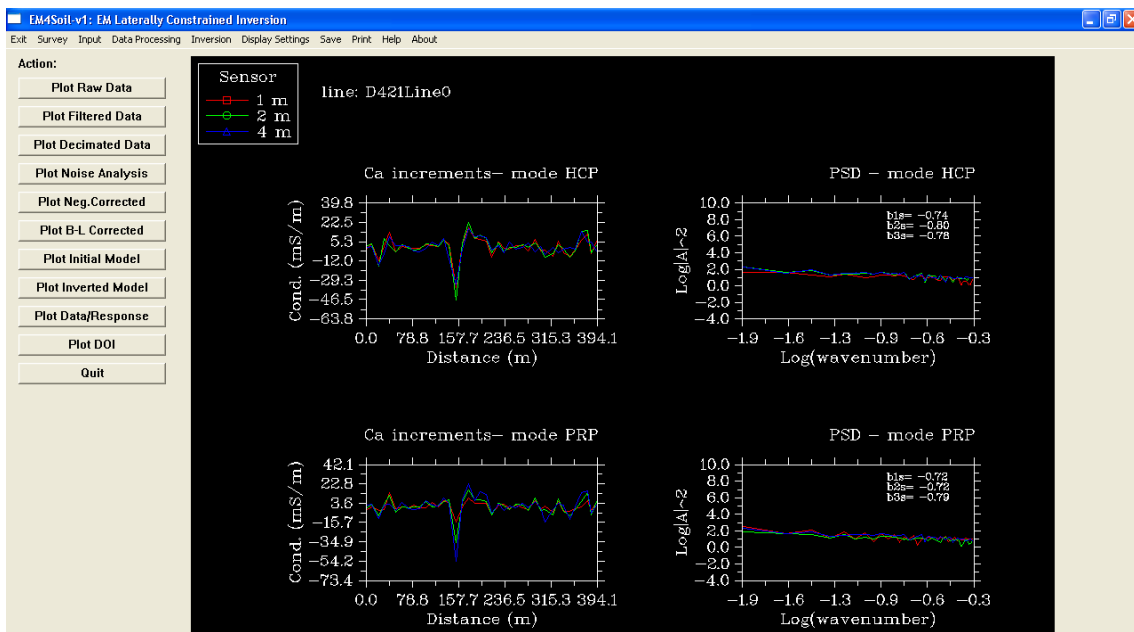
To decimate the data in **EM4soil** use the **Data Processing** menu and select the **Data Decimation** option.



The **Data Decimation** pop-up box will appear. Enter a value of 1 (to halve the raw data), 2, etc. Press **OK**. To plot decimated data in **EM4soil** select the **Plot Decimated Data** action button on the left hand side.

### STEP 6. Noise Analysis of the $\sigma_a$ data

To conduct a noise analysis use the **Data Processing** menu and select **Noise Analysis** option. To plot analysis results select **Plot Noise Analysis** action button on left hand side. This analysis may be used to determine if data requires editing or other correcting.

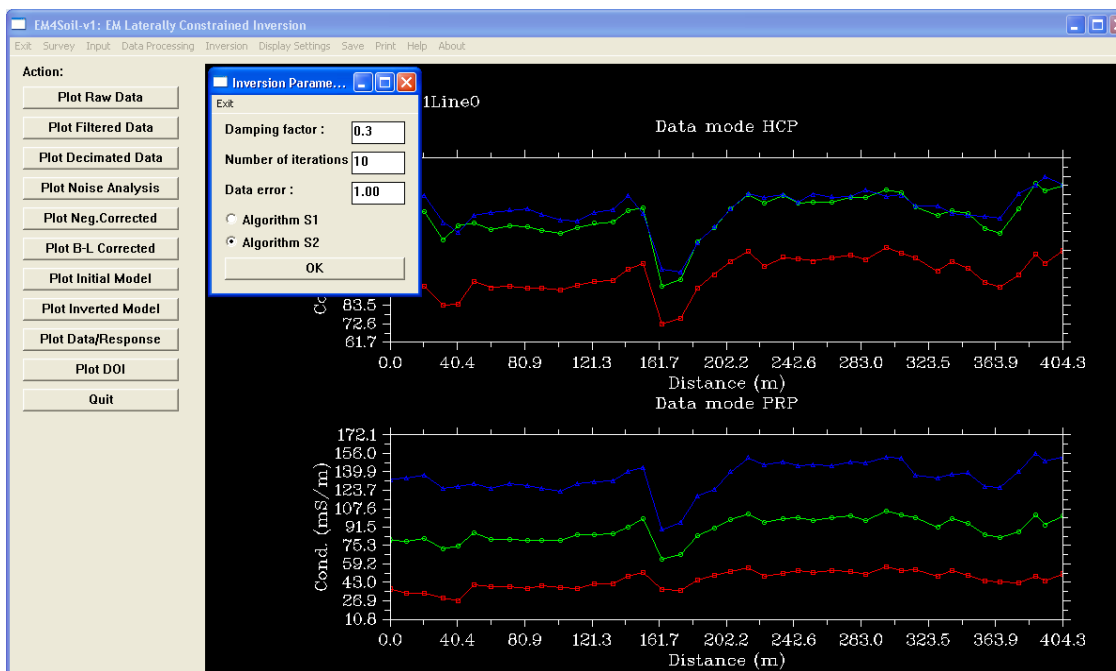




## STEP 7. Inverting the $\sigma_a$ data

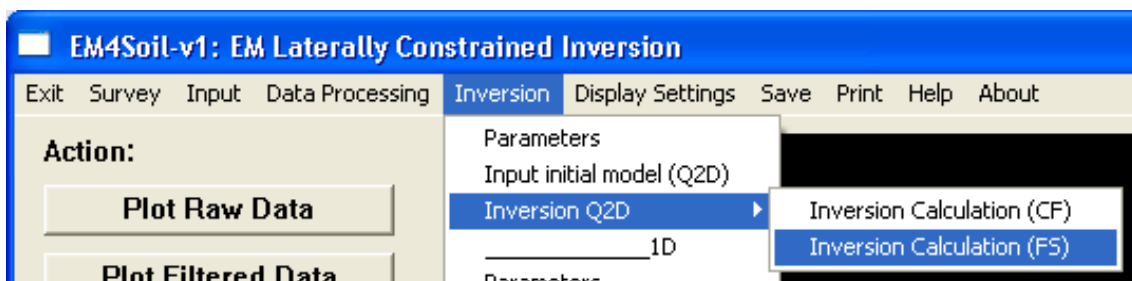
To prepare the data for inversion use the **Inversion** menu and first select the **Inversion Parameters** option.

The **Inversion Parameters** pop-up box will appear. Enter a value of 0.3 to 30. The number of iterations is set to 10 by default but this along with the choice of algorithm and damping factor should be determined empirically. Press **OK**.



The **Inversion Parameters** pop-up box will appear. Enter a value of 0.3 to 30. The number of iterations is set to 10 by default but this along with the choice of algorithm and damping factor should be determined empirically. Press **OK**.

To actually invert the data re-use the **Inversion** menu and now select the **Inversion Q2D** option. There are two options. **Inversion Calculation (CF)** uses a linear algorithm and is suitable for  $\sigma_a$  data that is generally below 100 mS/m. **Inversion Calculation (FS)** uses the so-called full-solution algorithm and is suitable for  $\sigma_a$  data that is over more conductive terrain and can exceed 100 mS/m.

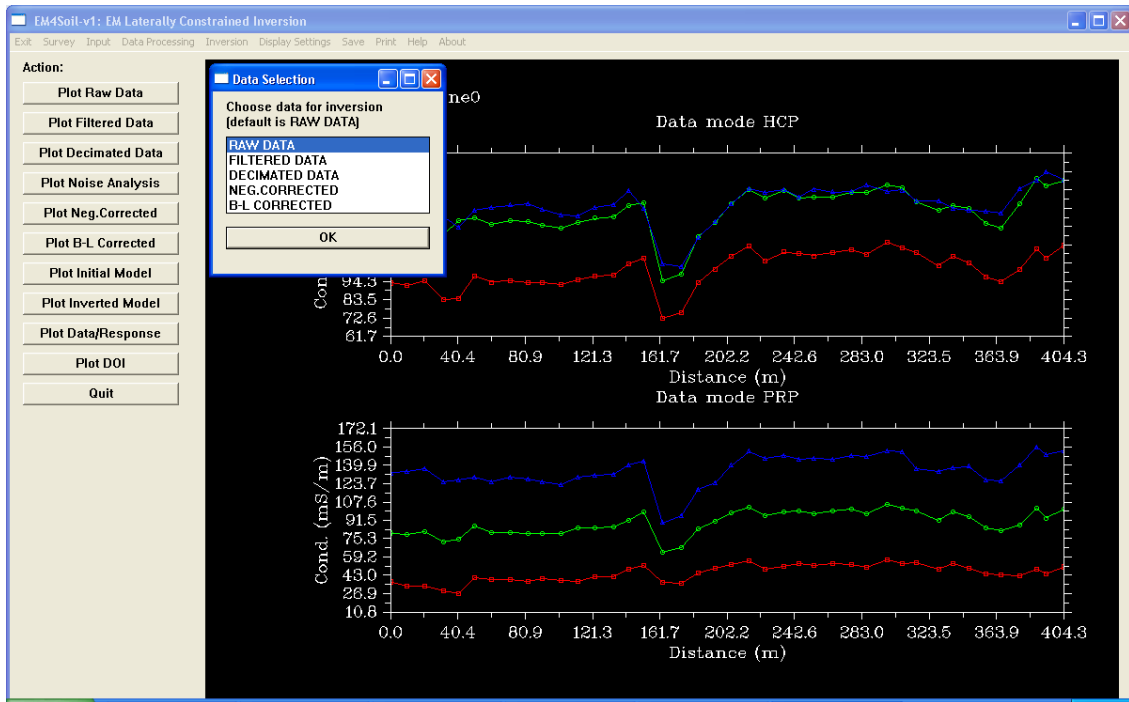


Given the latter is the case for the  $\sigma_a$  data contained within the D421Line0 file choose **Inversion Calculation (FS)**.



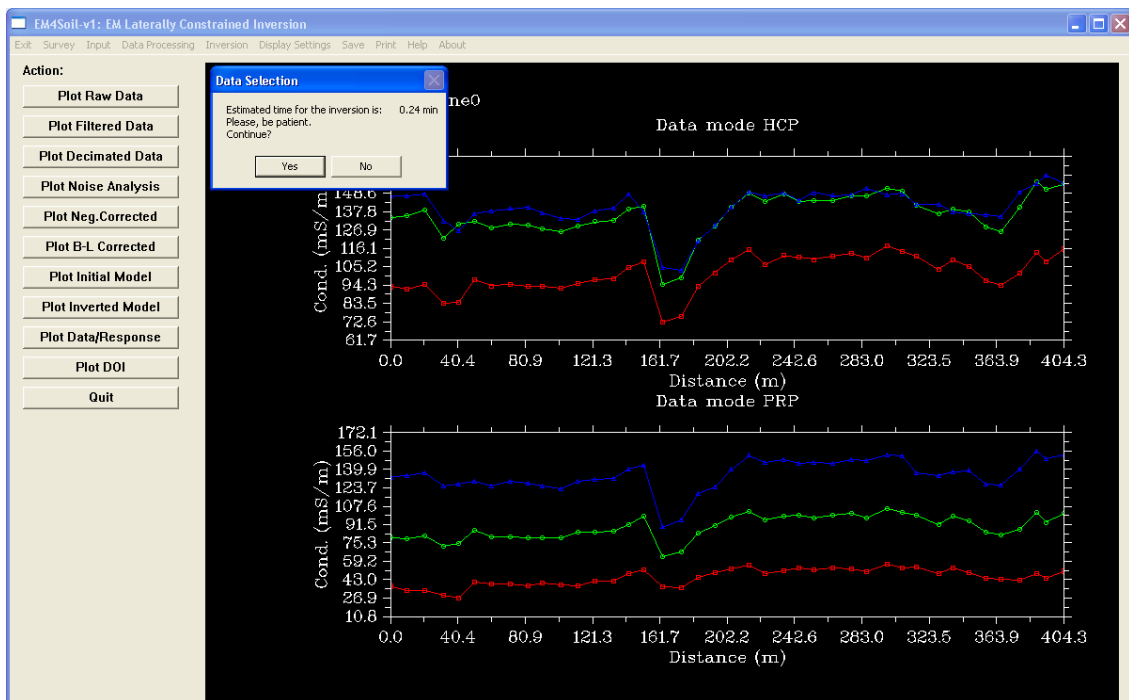


The **Data Selection** pop-up box will appear. Choose either the RAW DATA. Press **OK**.

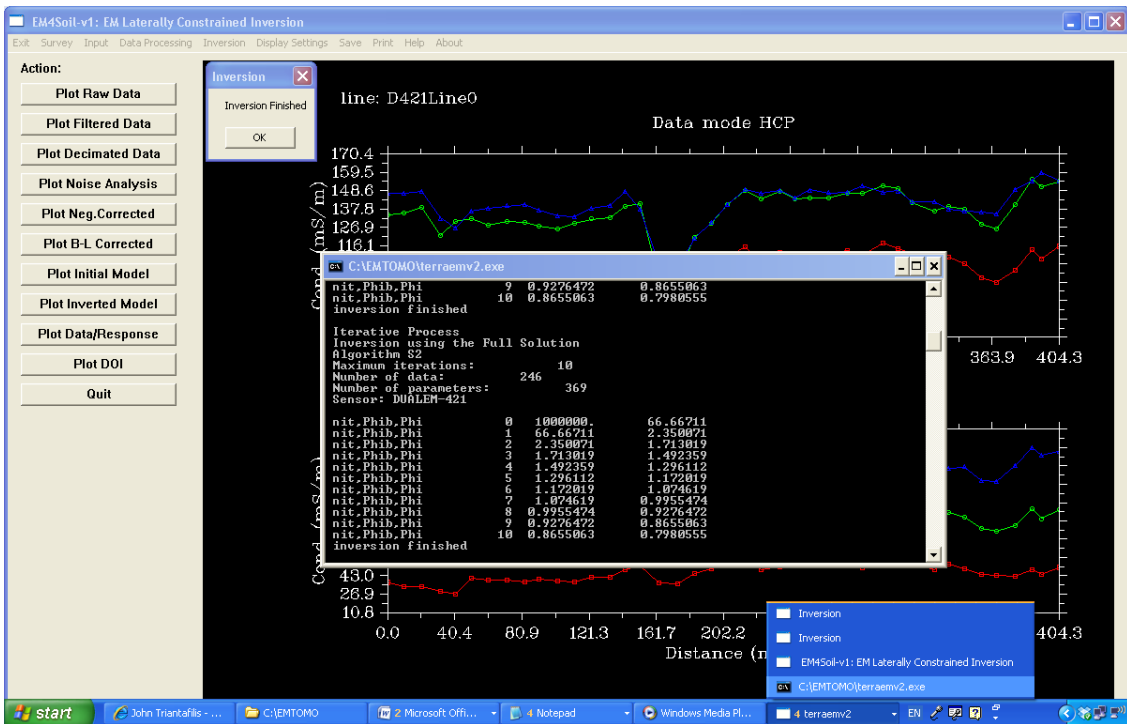


The **Data Selection** pop-up box will appear. Choose either the RAW DATA. Press **OK**.

Another **Data Selection** pop-up box will appear. It indicates an approximate time for the completion of the inversion process. Press **Yes**.



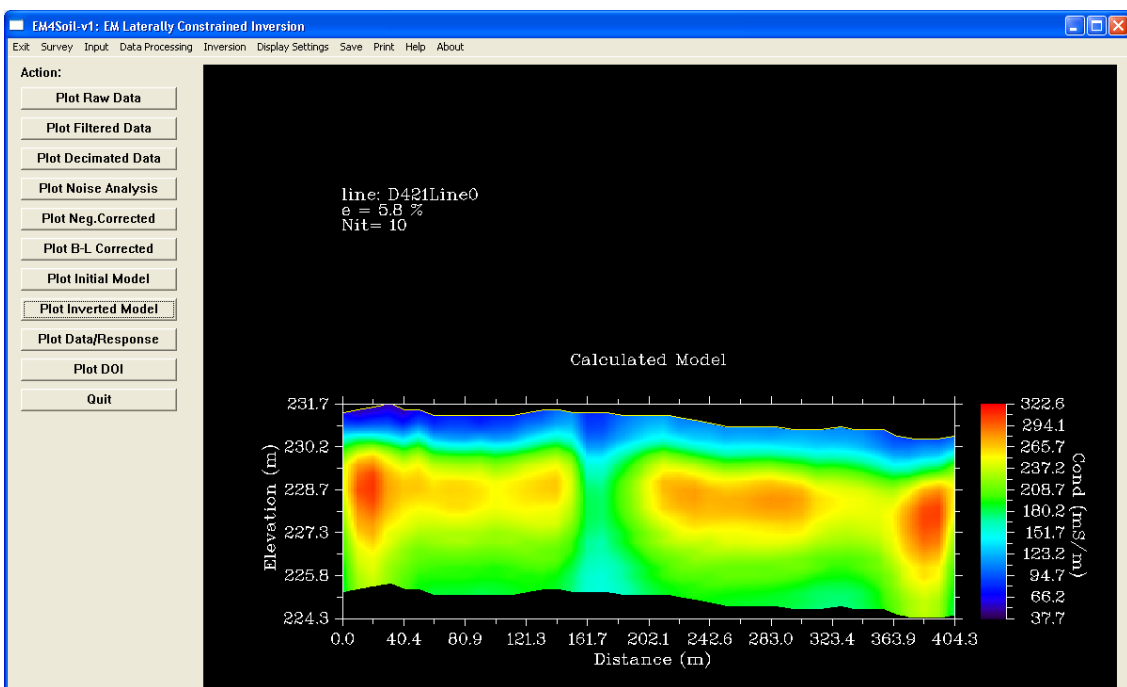
At this point the screen may go blank. However, EM4soil is in operation. Evidence for progress of the inversion iterations can be seen by clicking on the software, which is running in the menu bar.



When the number of iterations designated have been completed, the **Inversion** pop-up box appears. Press **OK**.

### STEP 8. Plotting the inverted $\sigma_a$ data (i.e. true electrical conductivity $\sigma$ )

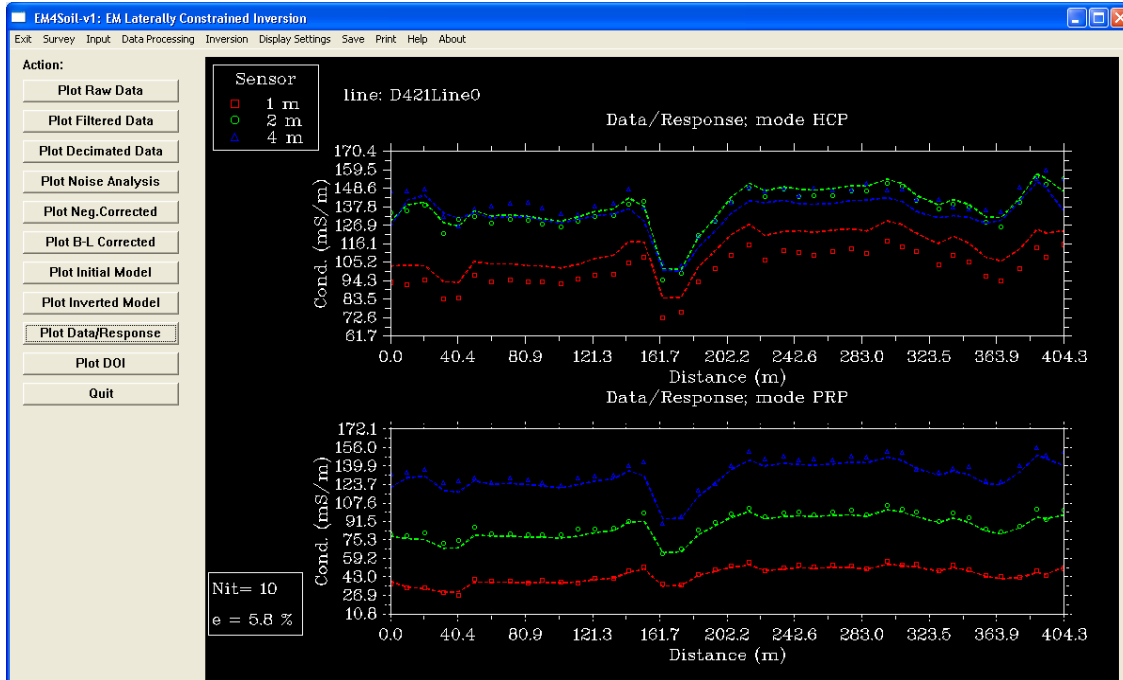
To plot the inverted data use the **Plot Inverted Model** from the action menu on the left hand side.





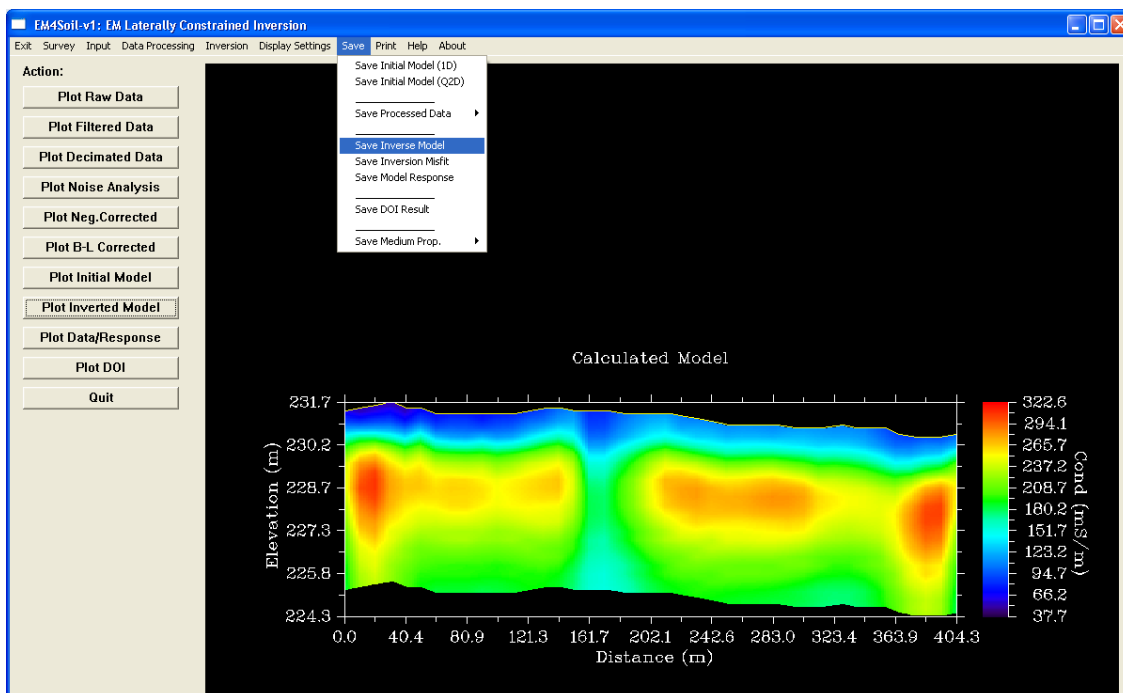
### STEP 9. Plotting $\sigma_a$ against the modelled $\sigma_a$ data response

To plot the observed  $\sigma_a$  data against the modelled  $\sigma_a$  use the **Plot Data/Response** from the action menu on the left hand side.



### STEP 10. Saving inversion modelled data

To save the inverted  $\sigma_a$  data (i.e. modelled true electrical conductivity  $\sigma$ ) select the Save menu and select the **Save Inverse Model** option.





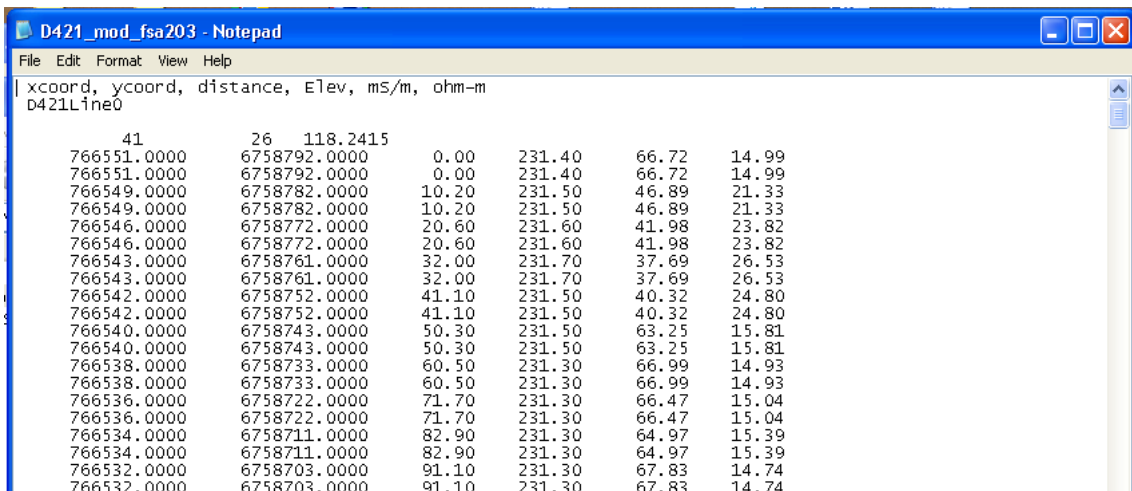
The **Save Model File** pop-up box appears. Save the file using an appropriate file name. The authors to denote the inversion model commonly use notation as follows:

D421\_mod\_fsa203.txt

which denotes;

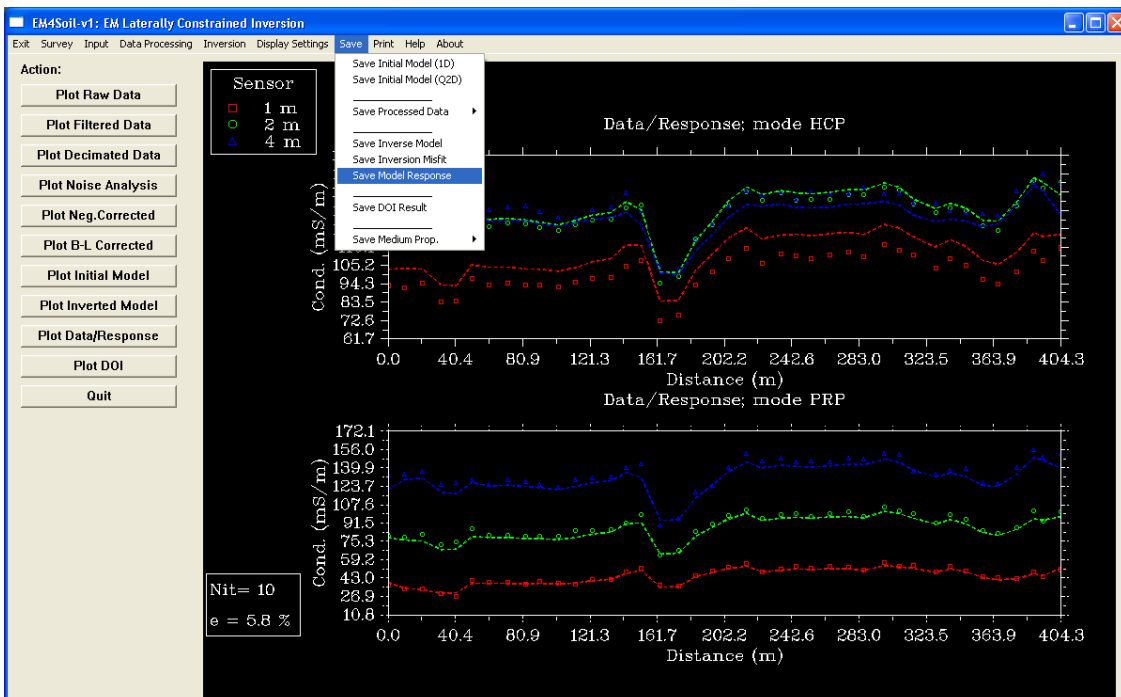
- D421 - original sensor data,
- mod - modelled results
- fs - achieved using the full solution,
- a2 - implementing algorithm 2 and
- 03 - considering 0.3 as the damping factor.

The data can be opened in **Notepad** or any other software package.



### STEP 11. Saving response data

To save the  $\sigma_a$  response data (i.e. observed  $\sigma_a$  and modelled  $\sigma_a$ ) select the Save menu and select the **Save Model Response** option.





The **Save Model Response File** pop-up box appears. Save the file using an appropriate file name. Again the above notation can be followed with a slight modification to distinguish it from above as follows:

D421\_res\_fsa203.txt

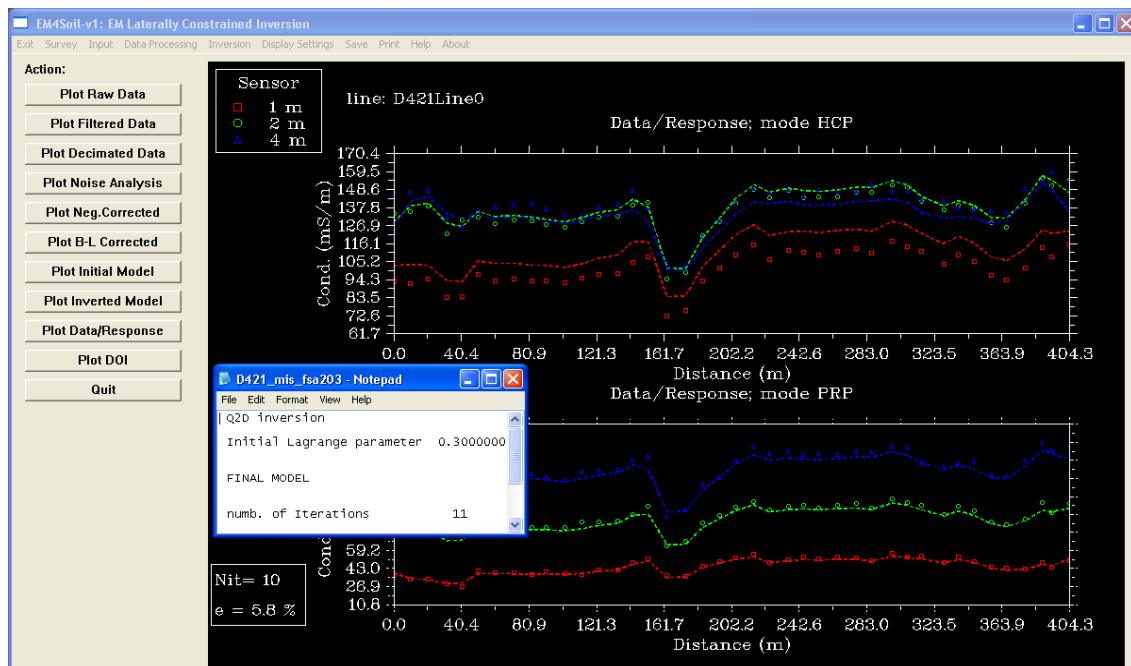
which denotes;

- D421 - original sensor data,
- res – response modelled results
- fs - achieved using the full solution,
- a2 - implementing algorithm 2 and
- 03 - considering 0.3 as the damping factor.

d1st	rh1o	rh1c	rp1o	rp1c	rh2o	rh2c	rp2o	rp2c	rh4o	rh4c	rp4o	rp4c
0.00	93.50	102.92	37.30	38.84	134.10	129.22	80.20	78.50	147.10	126.10	133.40	121.14
10.20	92.80	103.52	33.70	34.19	125.50	138.95	78.70	76.51	147.20	141.64	134.80	129.68
20.64	94.90	103.05	33.30	32.87	138.80	140.50	81.50	75.58	147.90	144.58	137.10	138.98
32.04	83.50	95.60	29.70	29.59	122.10	128.22	72.40	68.08	132.30	133.88	125.50	128.57
41.10	84.20	93.49	26.90	30.32	130.30	126.95	74.90	68.49	126.70	130.87	126.80	117.10
50.32	97.70	105.53	41.20	38.33	131.80	135.42	86.20	79.73	136.60	134.05	129.50	126.96
60.51	93.90	104.12	39.10	38.63	128.20	132.41	80.90	78.82	138.10	131.08	125.40	124.12
71.69	94.80	104.27	39.40	38.48	130.40	133.04	81.00	78.80	139.50	132.04	129.60	124.70
82.87	93.80	103.15	37.70	37.85	129.80	132.02	79.90	77.78	140.30	131.51	127.80	123.62
91.12	93.40	102.94	36.90	38.39	127.60	130.73	80.10	77.87	137.10	129.77	125.30	122.48
102.30	92.60	101.68	38.40	37.86	126.00	129.16	79.60	76.88	133.60	128.30	123.20	120.88
112.50	95.30	103.85	37.60	38.64	129.10	131.83	84.50	78.66	133.10	130.39	129.40	123.56
122.70	97.40	107.27	42.00	40.71	121.70	134.87	84.80	81.66	128.10	132.44	132.00	126.81
133.88	98.10	109.29	42.10	42.00	132.80	136.55	85.90	83.44	140.00	133.54	131.70	128.63
143.10	104.80	117.41	48.30	47.24	139.40	142.96	91.40	90.87	148.00	136.56	140.10	135.68
152.32	108.00	117.02	52.10	49.97	141.10	137.78	98.60	91.68	137.60	129.26	143.50	131.23
163.50	72.60	84.03	36.70	35.04	94.60	101.07	63.30	64.19	104.60	100.62	89.30	93.89
174.68	75.80	84.69	36.40	35.67	98.60	101.17	67.30	64.95	103.30	99.98	95.90	94.13
184.87	93.80	102.53	43.50	44.32	121.10	123.02	84.00	80.03	120.20	114.09	118.70	113.41
195.07	101.70	112.09	49.30	48.15	129.00	131.44	90.60	87.78	129.60	123.65	124.80	124.85
204.29	109.30	121.23	52.30	51.44	140.30	143.01	97.70	95.07	140.30	133.64	139.70	136.43
215.47	115.10	127.58	56.10	53.43	148.70	151.57	103.10	100.02	149.30	141.30	152.10	144.98
224.69	106.50	120.88	48.60	48.59	143.80	147.15	95.40	93.67	147.20	140.09	145.70	139.91
235.87	111.70	123.29	50.70	49.95	148.10	149.41	99.10	95.79	148.90	141.56	148.60	142.31
245.09	111.00	123.64	53.30	51.16	143.90	148.13	99.90	96.44	144.00	139.57	145.10	141.28
254.31	109.50	122.77	51.60	50.55	144.30	147.50	97.40	95.66	149.00	139.25	146.10	140.58
263.49	111.40	124.01	53.20	51.32	144.30	148.32	99.60	96.78	147.30	139.73	145.20	141.69
276.67	113.10	124.78	52.40	51.08	147.10	150.26	101.20	97.27	147.70	141.44	148.40	143.33
285.89	110.30	123.48	49.90	49.83	147.60	149.83	97.10	95.98	151.60	141.62	147.80	143.70
298.26	117.40	129.49	56.30	53.98	151.30	154.10	105.80	101.60	147.40	145.11	152.70	147.50
307.48	114.00	127.14	53.30	53.01	149.70	151.25	102.20	99.70	148.50	140.69	152.00	144.60

### STEP 12. Saving response data misfit value

To save the  $\sigma_a$  response data misfit select the Save menu and select the **Save Inversion Misfit** option.



The **Save Misfit** pop-up box appears. Save the file using an appropriate file name. Again the above notation can be followed with a slight modification to distinguish it as follows: D421\_miss\_fsa203.txt