Tutorial E (Airborne EM Forward Modelling and Inversion)

***Parent topic:* User Manual and Tutorials**

This case study includes:

- A demonstration of 3D GeoModeller's 1D and 2.5D forward and inverse AEM capability using parts of the Bryah Basin SPECTREM time domain survey (DeGrussa region) and a frequency domain example using a RESOLVE survey subset from the Riverlands area near Renmark, SA.

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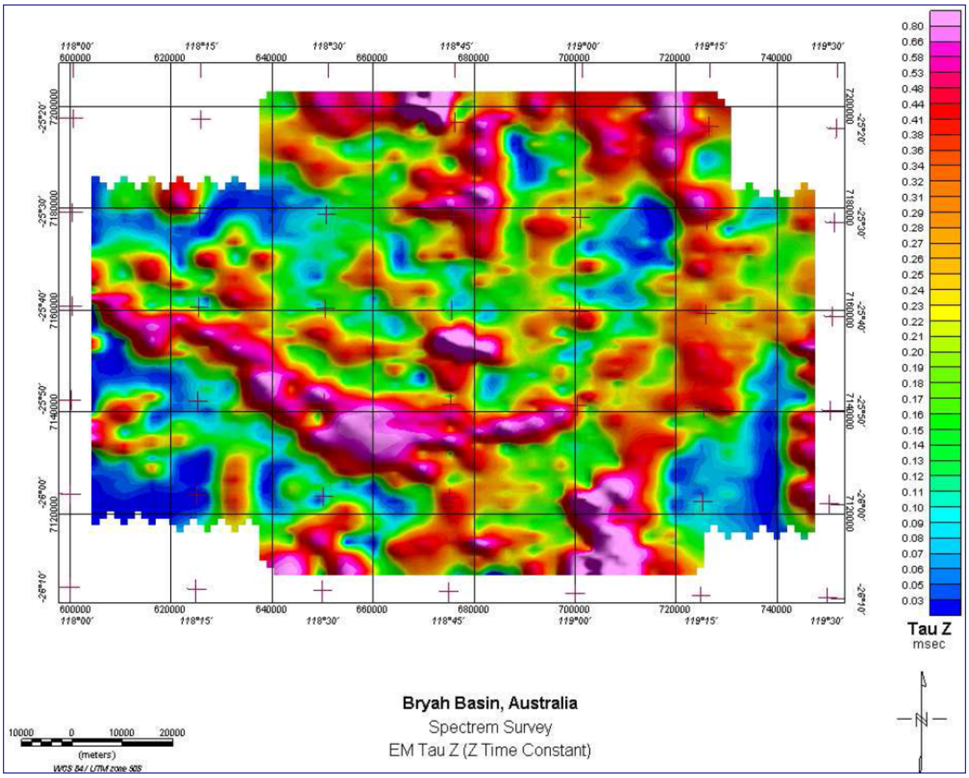


Disclaimer

Intrepid Geophysics provides this tutorial document and associated data for the purpose of training in the use and application of 3D GeoModeller. The material and data cannot be used or relied upon for any other purpose. Intrepid Geophysics is not liable for any inaccuracies (including any incompleteness) in this material and data.

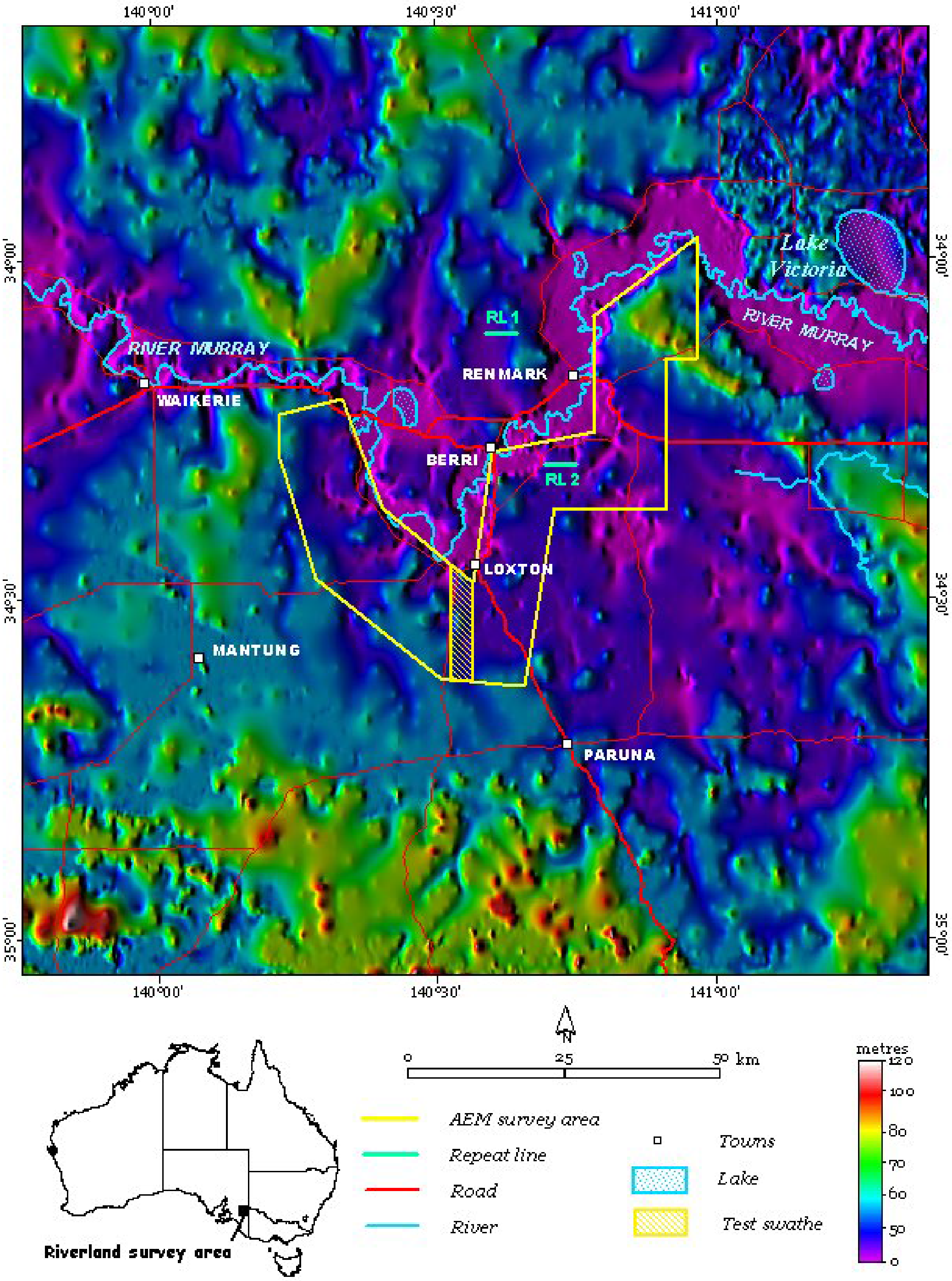
Acknowledgements

The case studies have been sourced from the Geological Survey of Western Australia and Department of Primary Industries and Resources, South Australia.

The SPECTREM survey was flown for CSIRO Earth Science and Resource Engineering and is known as the Bryah Basin survey, 2012. A formal GSWA license statement is included with the data sourced for this project.

The RESOLVE survey was first acquired in 2002 for the Bureau of Rural Sciences, and is known as the Riverland and Tintinara, SA survey. This data was reprocessed and inverted in 2004 for the CRC LEME as part of the South Australia salinity mapping and management support project. Permission to use this data is provided under CC-BY https://creativecommons.org/licenses/by/3.0/au/. The only requirement is Attribution (see references). No changes have been made to this data.

The following image contains a DEM of the Riverland study area in South Australia. The RESOLVE Airborne Electromagnetic Survey area lies within the yellow polygon.



This case study is organised as follows:

Case Study EM Introduction

Parent topic: **Tutorial E (Airborne EM Forward Modelling and Inversion)**

In this case study we demonstrate the main methods available in 3D GeoModeller to rapidly create near surface 3D geology derived from an interpretation of EM survey data.

The electromagnetic methods implemented in GeoModeller include:

1. Apparent resistivity and conductivity estimated for each measurement channel.
2. 1D EM Inversion (MPI by survey line)
3. 2D EM Forward Modelling (MPI/Pardiso)
4. 2.5D EM Inversion (MPI/Pardiso)

The methods are implemented for the airborne case with support for both time domain and frequency domain systems. Support for ground survey systems with similar transmitter/receiver geometry will be a simple adjustment.

The starting point for the 2.5D algorithmic work is the original CSIRO/AMIRA codes developed over 25 years, mostly at Macquarie University with Art Raiche. In the last year of this work, the 2.5D forward modelling code was extended in order to open up the possibility of tractable 2D inversions.

A major rewrite has been completed such that only the input/output and some of the general mathematical routines (i.e. Hankel transforms etc) remain in their original form. The forward and inversion solvers have been replaced and the code has been parallelised for MPI.

Other functional improvements included in the GeoModeller AEM modelling module are:

- a fast approximate apparent resistivity/conductivity calculation.
- a reduction of the time taken to solve large systems by using an MPI strategy (multiple processors are deployed in parallel).
- reduction in memory usage in order to handle larger models on a typical workstation or high end laptop.
- an increase in the speed of the forward solver using INTEL's Pardiso libraries.

- dramatic improvements to the inversion solution by use of a new inversion solver which uses a generalised single value decomposition method where far field cell conductivities are ignored during early stage calculations and by imposing smoothing constraints on the model.
- allow the use of a starting or reference geology model to influence the inversion.

During this work Intrepid identified 4 or 5 algorithmic bugs that were not picked up in the original CSIRO testing. These mainly effected 2D geometry responses for more complex geology (non-layered earth) and problems with calculation of topographic effects.

Importance of EM for aiding Geology Interpretation

In the absence of drilling, near surface geology can be difficult to define, especially when trying to model the regolith (weathering profile), alluvial cover or shallow aquifers. Typically, EM methods are useful in these situations where there can be large variations in conductivity with depth. The added complication of recognising and incorporating structure into your model can be assisted by the use of good quality 2.5D EM inversion.

Undercover exploration for metallogenic bodies using EM survey methods can show conductors at depths of up to 500m. One of the tutorial examples contains just such a case. Uranium is sometimes associated with graphite conductors so EM surveys can be useful in this geological environment also.

Intrepid developments

Two wizards have been added to GeoModeller as optional tools to support EM.

- The first specifies the EM survey system and allows specification of the necessary units, channels, signal type and response curves, loads the survey data and creates sections for each flight line.
- The second provides for selection of the spatial fields. x, y, clearance and ground elevation and an optional interpretation field (i.e. mag, powerline monitor) for profile display (interp or QC).

Bryah Basin project scenario

The following are quoted verbatim from the processing report, which is also *distributed with the training materials.*

“SPECTREM AIR LIMITED surveys were flown for the CSIRO over the Bryah Basin area. The main purpose of the surveys was mainly to stimulate mineral exploration by mapping the very conductive carbonaceous/graphitic/BIFS/iron rich sediments which are present under the regolith or at depth in this area. Another purpose was to better understand regional water resources.

Because of the very conductive and relatively thick sediments that were present in parts of the survey area, the SPECTREM data had to be re-processed by fitting a sum of exponentials to the full waveform data. The surveys indicated that the CSIRO would be able to gain a better understanding of the subsurface structure of the very conductive sediments by a 1D or 2D inversion of the exponentially re-processed data.

The Bryah Basin area is probably a favourable area to explore for iron ore deposits. We do not know enough about the geology in this area to understand what the association could be between the very good sedimentary conductors and possible iron ore deposits. For this reason we graded the good conductors on the AEM anomaly map mainly in terms of the interpreted conductance values.”

The following is quoted from a KEGS 2013 paper by Tim Munday:

The Bryah Basin, part of the Capricorn Orogen, in northern Western Australia contains a succession of mafic and ultramafics overlain by clastic and chemical sedimentary rocks. The Basin is host to significant mineralisation, including the DeGrussa and Horseshoe Cu-Au VMS deposits. Among the challenges in the study of, and exploration for, these mineral systems is the paucity of outcrop and the extent and variability of a complex regolith cover. To better understand this regolith, a reconnaissance, regional-scale, SPECTREM AEM survey over the Bryah Basin in 2012. For the Bryah Basin the inverted SPECTREM data show the most dominant regolith features are associated with sediment filled palaeovalleys. Their orientation indicates a strong lithostructural control.

And then from the discussions about the De Grussa discovery from the web:

Also, in this same area are located the DeGrussa copper deposits, part of the 2.0 to 1.8 Ga Capricon Orogen that separates the Yilgarn and Pilbara Cratons, approximately 900 km NNE of Perth and 150 km north of Meekatharra in Western Australia.

The VMS mineralising environment at DeGrussa has been confirmed over a +30km long, 2km wide corridor, which has seen minimal exploration below 100m depth. The existing DeGrussa deposits have a strike length of just 1.2km within this broader 30km corridor.

Structural interpretation from mapping within the underground mine and open pit has proved to be invaluable in improving Sandfire's understanding of the lithological sequence, structural setting and, consequently, the positioning of potential accumulations of VMS mineralisation, giving the geological team a unique level of insight into the most likely areas where ore zones could occur.

The structural complexity of the VMS environment at DeGrussa represents both a significant challenge and an opportunity given the impact of vertical and lateral displacement and faulting combined with the obscuring effect of transported cover.

Mineralisation is hosted by the Palaeoproterozoic (2.0 Ga) Narracoota Volcanics, occurring as the DeGrussa, Conductor 1, 4 and 5 deposits. The 2 km-thick sequence of volcano-sedimentary rocks that comprise the Narracoota Volcanics are spread over a strike length of 22 km.

The Narracoota Volcanics comprise basalts, basaltic hyaloclastites, sediments, dolerite and gabbro and minor local mineralised quartz carbonate breccias, jasper beds and banded iron formation. This sequence is overlain by the Karalundi Formation, which comprises metamorphosed and locally ferruginous shale and sandstone with metaconglomerate bands and lenses, and chert and siliciclastic metasediments. Together, the Narracoota Volcanics and Karalundi Formation constitute the Bryah Group.

The ores at DeGrussa are classified as volcanic hosted massive sulphide (VHMS)-style deposits, occurring as massive lenses of primary pyrite, chalcopyrite and pyrrhotite with minor magnetite, sphalerite, galena and arsenopyrite in a gangue of siderite, ankerite, stilpnomelane, minnesotaite, quartz and calcite.

The primary mineralisation has been subjected to oxidation and supergene enrichment near surface to produce a surface zone with native copper and siliceous cap with gold, overlying a layer of oxide/carbonate copper and a blanket of supergene chalcocite with tenorite, cuprite and complex tellurides.

All are distributed along the steep, northeast-trending Shiraz Fault zone which offsets the ore bodies and is a significant local structure with varying widths of highly broken material. The Merlot and Pinot faults also have a local, but less pronounced interaction with the massive sulphide lenses.

Exploring Under Cover Comments (these from Intrepid Geophysics, after P.Gunn)

Looking more regionally, this prospective area lies on the Northern margin of the Yilgarn craton. One could expect this to be a rifted margin, with significant crustal scale East-West faulting along the craton margin. The Murchison River could well track along part of this fault system. The regional gravity coverage can be used to define the course of this primary faulting and perhaps also pick up the dip/strike of this feature along its course. The regional gravity should define the deeper location but perhaps, miss the finer near surface secondary and tertiary faulting.

From what has been reported, the VHMS near surface conductors, appear to be associated with this deep crustal fault feature. The presence of volcanic sills also is consistent with a rifting scenario. Often these volcanic sills are easily identified in the corresponding aeromagnetic survey data. As we are in WA, the compilation of magnetics is very good, with resolution of 40m cell size.

Given the above comments from various active exploration programs, the combination of EM and structural geology, is a vital tool to understanding where to explore for success.

For the EM dataset used in this tutorial we investigate an ENE striking series of conductors approximately 2 kms to the South East of the mining lease. These conductors occur on 3 consecutive lines of the Bryah basin SPECTREM survey (5km line spacing) and are associated with a narrow sequence of sediments shown on the government 1:100K geological map. This is an example of a possible buried compact ore-body conductor.

Course Structure

Parent topic: **Tutorial E (Airborne EM Forward Modelling and Inversion)**

The time domain case study has three main sections:

1. Set up the GeoModeller project for AEM survey
2. Select and setup the AEM system specifications and load the survey database
3. Perform Geophysical Modelling

Set up the GeoModeller project for AEM survey

Parent topic: **Course Structure**

Tutorial T1: Open the Bryah Basin GeoModeller Project

We open an existing project with a defined 3D project box and examine the DTM (digital terrain model) properties and visualise it in 2D and 3D.

We also set a token geological formation to allow us to proceed.

Tutorial T2: Specify SPECTREM configuration then Import EM data

We examine the EM system specification for the SPECTREM time domain case. This involves reviewing the pre-defined system configuration file for this worked project, and making any necessary adjustments in the setup wizard. Each commercially available EM system has some unique characteristics. These include waveforms, number of channels, geometry of the transmitter and receiver coils, conventions for storing the observed data in fields, and the units of measure. This section allows you to become familiar with the various formats and system characteristics which are managed in a common framework in the **EM Survey System Setup** dialog.

The EM database is loaded and new sections in your project are generated for each EM line.

We select the AEM channels required for the modelling and the associated channels describing spatial location of the transmitter and receiver in 3D (X, Y, DTM, Transmitter Clearance). An optional channel can be chosen to aid data interpretation or other analysis (ie TMI, Tau, RadAlt) by comparison with observed EM profiles.

Optionally add images of other datasets or contractor supplied inversions as backdrops to sections ie TMI, TMI 1VD, Gravity, Radiometrics, Google snapshots, CDI's etc

Perform Geophysical Modelling

Parent topic: **Course Structure**

Tutorial T3: EM Modelling Wizard - Noise

We want to visualise AEM data from any of the lines, as well as the observed magnetic or other profile data. We also need to estimate the noise characteristics of the measured signal to ensure the solver can manage to converge to a stable and reliable result.

To make the noise estimate we try to identify an area of very low signal within the survey area. The easiest way to do this is to import a selection of late time channels as a Mesh grid and then visualise them on the surface topo section and examine the statistics. We then draw a polygon around an area of low signal and use this to calculate the noise statistics using the **Noise Settings** dialog in the **EM Modelling Wizard**. An alternative method of identifying an area of low signal is to load a contractor supplied grid of apparent conductivity or similar.

Tutorial T4: Calculate Apparent Resistivity

We start with the calculation of Apparent conductivity and resistivity. This is a fast approximation of conductivity based on each data channel from the topo surface down. We save the results to a Mesh grid and visualise them on the Surface Topography using a suitable colour look table stretch and point size. We examine the spatial conductivity distributions and statistics at early and late times to obtain a quick look at the anomalous patterns in our data and their relationship to surface geology. These results also provide an indication of the suitability of our noise estimates.

Tutorial T5: Setting up MPI

Instructions on how to set up the environment for MPI and parallel processing.

Tutorial T6: 1D EM Inversion - Time Domain

We run a 1D inversion on 3 survey lines to test a set of 1D inversion parameters. This is an actual inversion of the data rather than a data transform method such as the one commonly used to compute CDI's. We examine the resulting conductivity sections and compare the predicted profiles with the observed survey data.

Tutorial T7: 2.5D EM Inversion - Time Domain

We run a 2D inversion on a single survey line and demonstrate the significant improvement in geometry which 2D inversion provides when 1D assumptions break down. We examine the resulting section and the predicted profile misfits with the observed survey data as for 1D.

Tutorial T8: Riverland Frequency Domain 1D & 2.5D Case Study

Tutorial T1: Open the Bryah Basin GeoModeller Project

Parent topic: **Tutorial E (Airborne EM Forward Modelling and Inversion)**

In this tutorial we load a *GeoModeller* project and examine the components of the *GeoModeller* workshops.

In the tutorial:

- T1 Steps
- T1 Discussion
- T1 More information

T1 Steps

Parent topic: Tutorial T1: Open the Bryah Basin GeoModeller Project

1 Copy the zip file from from the shipped tutorial directory or workshop USB

OR

Download the zipped tutorial data using the following link

http://..... TBD

2 Unpack the zipfile into a suitable working directory, for example: `d:\tutorial_e`

Note: There must be no spaces in the directory path

3 Launch *GeoModeller* from the desktop icon

The *GeoModeller* welcome screen appears with a main menu and toolbars arranged across the top, left and right sides.

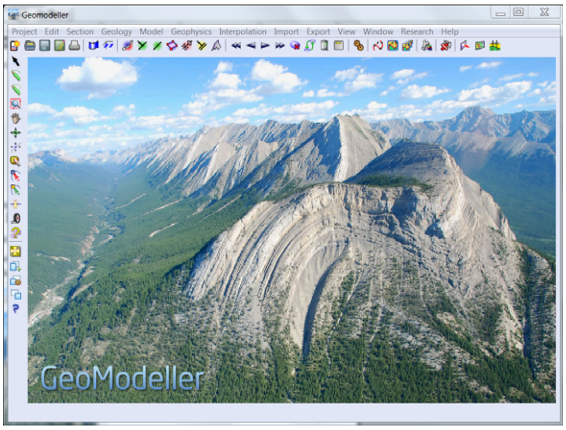


Figure 1. GeoModeller welcome screen.

4 Open the supplied starting *GeoModeller* project.

From the main menu choose **Project > Open** or
from the **Project** toolbar choose **Open** or
press CTRL+O

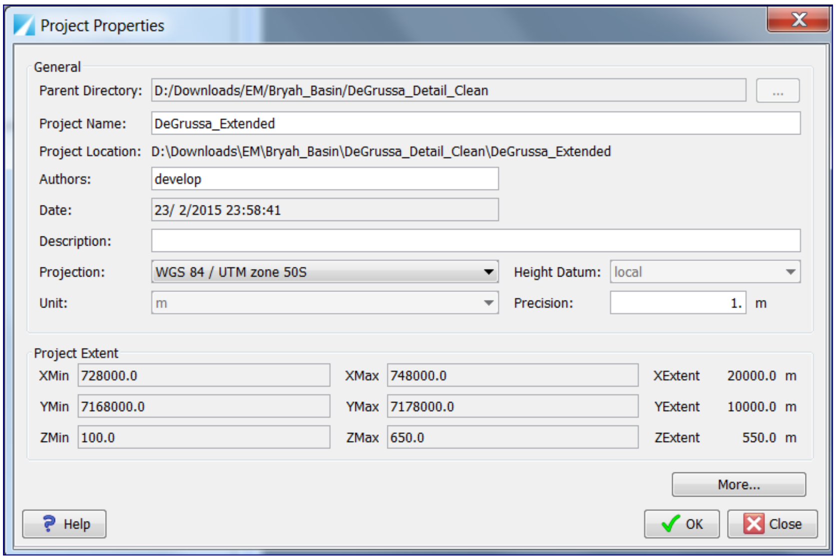
In the **Open** dialog box navigate to the 3D GeoModeller Project `.xml` file (using our example project folder `d:\tutorial_e`):

`d:\tutorial_e\SPECTREM\DeGrussa_Detail_Clean\DeGrussa_Detail_Clean.xml`

For this project the project dimensions and coordinate system (Datum and Projection) are:

- **Projection**—WGS84/UTM zone 50S
- **Height Datum**—Local
- Extents

	Minimum	Maximum	Range
East	728,000	748,000	20,000 m
North	7,168,000	7,178,000	10,000 m
Z-axis	100	650	550 m

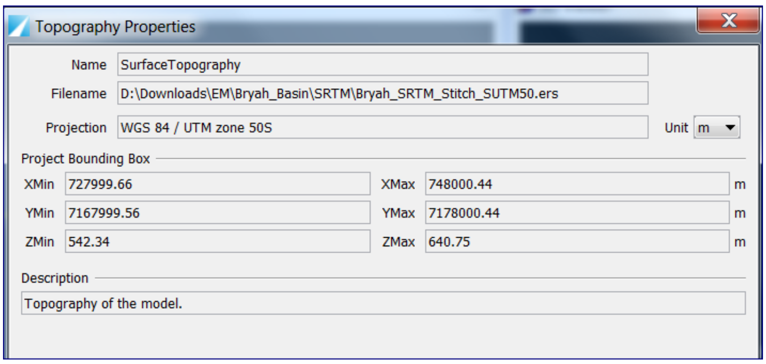


5 Review the DTM for this project. The grid to be used is in the **`\SPECTREM\Bryah_DTM`** directory

The name of the SRTM file is **`Bryah_SRTM_Stitch_SUTM50.ers`**.

We have already loaded the DTM into this project to save time.

6 Check the DTM properties by selecting: **Section > Topography > Properties** from the Main menu

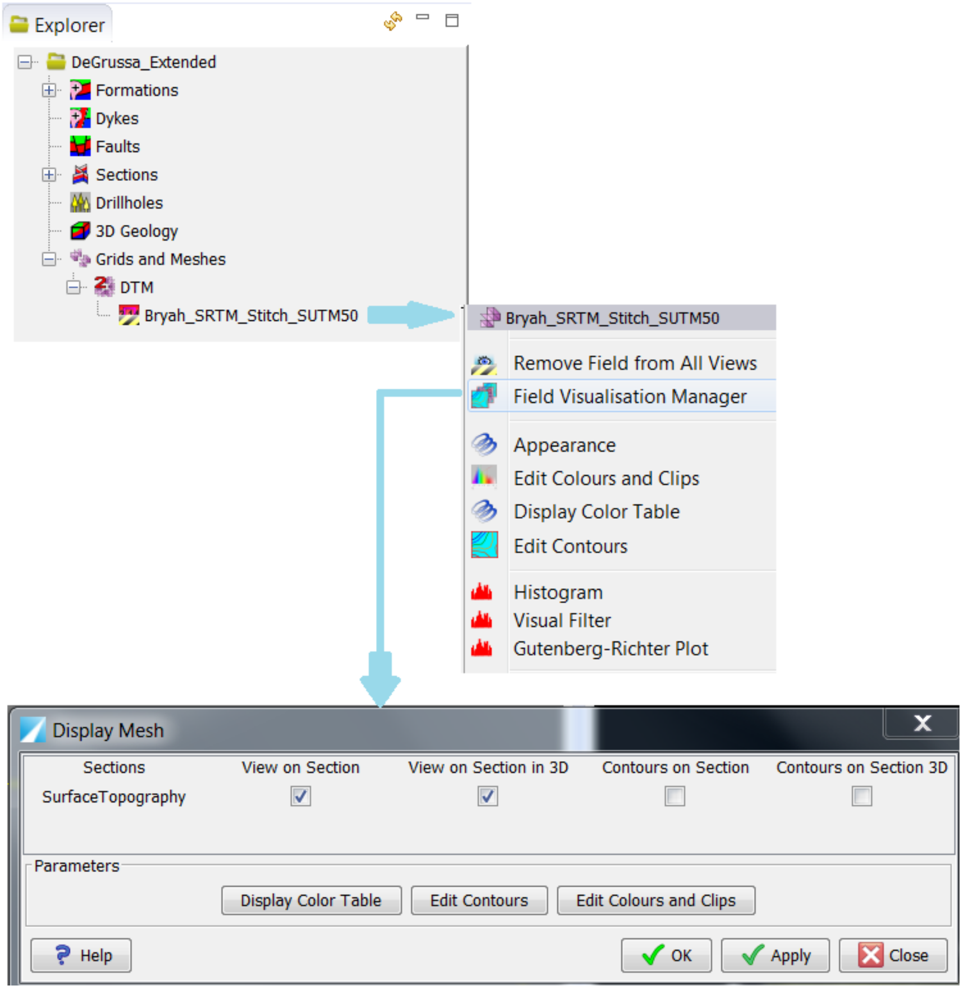


Note: Directory paths in the above dialogs will change depending on where the user installs the zipped tutorial data.

Show the DTM using the Field Visualization manager from the Explorer tree as illustrated below.

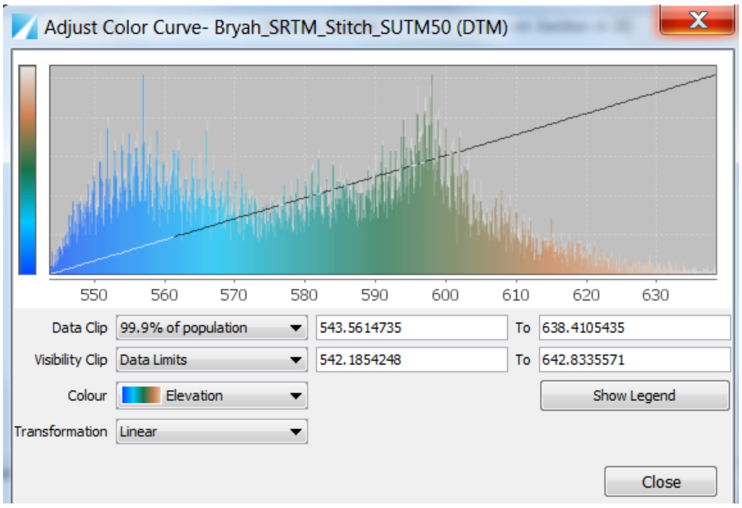
1 Click on **Grids and Meshes** and click **+** to open up the **DTM** 2D Grid branch

2 Right Click on the **Bryah_SRTM_Stitch_SUTM50** field and choose **Field Visualization manager**:



3 Select the 2D and 3D display options **View on Section** and **View on Section in 3D**.

4 Click Edit Colours and Clips and choose the Colour table and stretch for display.



5 Choose **Colour: Elevation** from the selection list

6 Choose **Data Clip 99.9% of population** from selection list

7 Click **Close**

8 Click **Apply** to preview the new displays or **OK** to close and display the results.

The following figure shows the 2D and 3D Viewers with the DTM displayed.

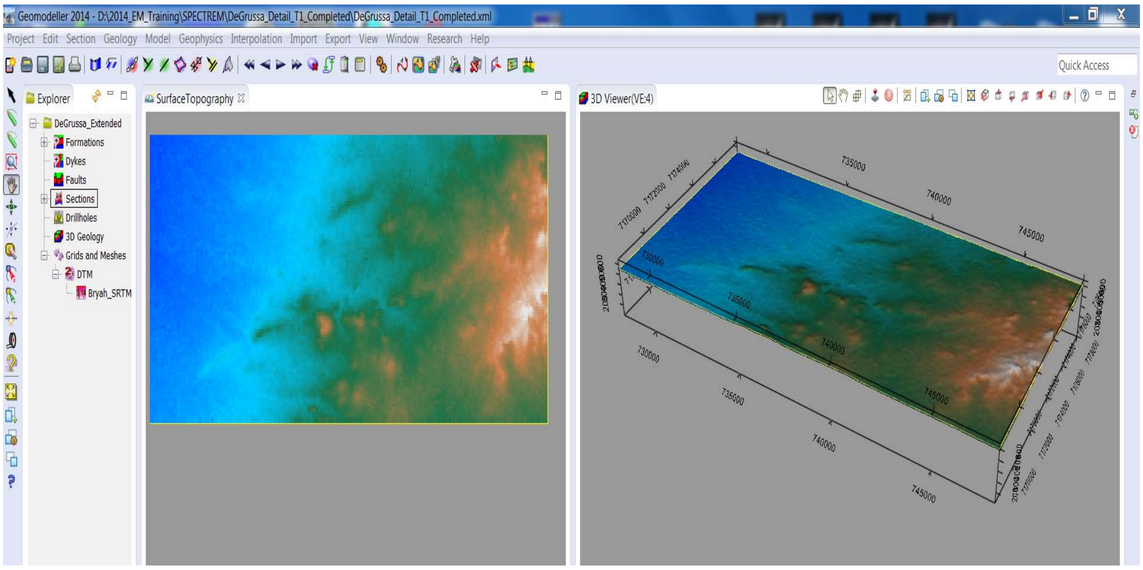
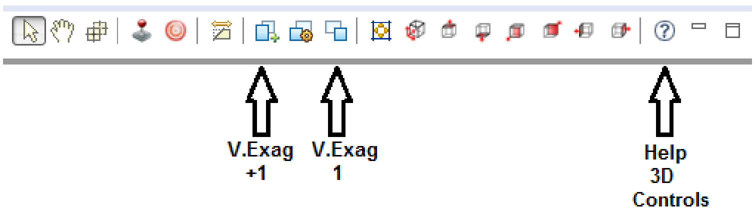


Figure 2. GeoModeller 2D and 3D viewers showing Digital Terrain Model

9 Click the left most **Vertical exaggeration** glyph on the **3D Toolbar** to increase vertical exaggeration by 1 (i.e. 1 to 2)

10 Click the right most **Vertical exaggeration** glyph to reset vertical exagg. to 1.

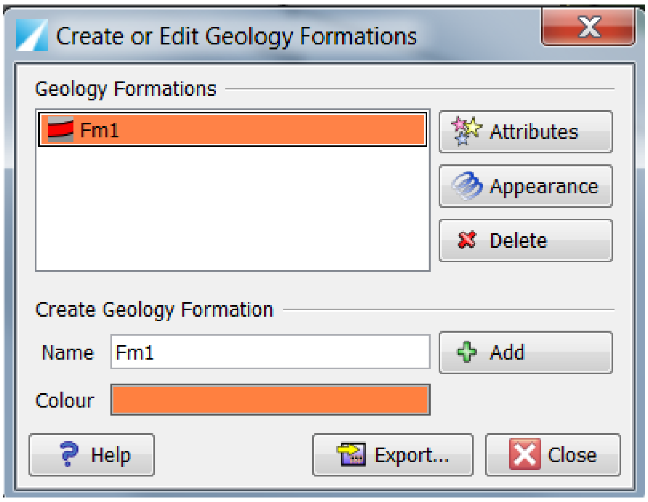


11 Click on right most glyph on the 3D toolbar to get **Help** on the 3D viewer controls

Create a Geological Formation

You must now create one geological formation in order to proceed with the import of any EM geophysical data. This is a notional restriction for geophysics operations.

1 From the main menu, choose **Geology > Formations: Manage.** The following dialog appears.

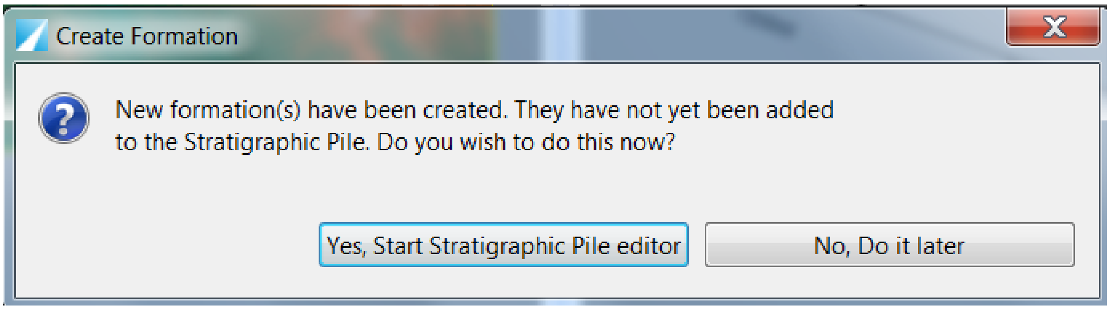


2 Type in **Fm1**, choose an Orange colour then

3 Click **+Add**

4 Click **Close**

5 Choose **No, Do it Later** when the **Create Formation** dialog asks if you want to add the formation to the stratigraphic pile



6 **Save your project**

From the main menu choose **Project > Save As**.

We save your project so that you can continue to the next stage without having to repeat any of the above steps again. We suggest (using our example project folder **`d:\tutorial_e`**):

`d:\tutorial_e\SPECTREM\DeGrussa_Detail_MyT1`

T1 Discussion

Parent topic:
Parent topic:
Tutorial T1: Open the Bryah Basin GeoModeller Project

Examine the main elements of the 3D GeoModeller workspace from Figure 2 above.

Note in particular:

- **Project Explorer**—this has a tree structure containing the many objects that make up our 3D geology project: Formations, Faults, Models, Sections, Drillholes, 3D Geology and Grids and Meshes.
- **2D Viewer**—contains 2D sections. This Tutorial contains several sections—a special one—the 'geological map view' (labelled as Surface Topography in this project), and three vertical cross-sections. We use the sections for data input, and for examining 2D plots of our 3D model.
- **3D Viewer**—contains the 3D view of our project. At this stage it shows only the bounding extents of the project. The yellow lines are the outlines of the TopoMap section (the topography of the project area) in the 3D Viewer, and the four vertical sections.
- **MeshGrids** —contains the DTM grid as a separate item to be queried, manipulated, visualized. Both the 2D and 3D view have the DTM displayed using a default colour look up table. the shortcut (right click) menu shows all the query options

T1 More information

Parent topic:
Parent topic:
Tutorial T1: Open the Bryah Basin GeoModeller Project

Some comments about the 3D GeoModeller project space:

- X (East), Y (North) and Z (Elevation, positive upwards) are a standard coordinate framework according to a right-hand rule
- X, Y and Z are all in the same units (metres or feet - cannot be degrees of latitude or longitude)
- X and Y would typically be real world projected coordinates, but could be a local mine grid, etc.
- Z is Elevation, and is positive upwards. It would typically use a real world vertical datum such as mean sea level
- You should define the Projection (a Coordinate System, consisting of a Datum and Projection pair) for your project.
- All data must be within the project limits; data outside those limits cannot be imported or created
- Likewise all modelled results—geology lines, polygons and surfaces—are within those limits

So, when you create your own project, make the project dimensions large enough to include all geology data used in the project.

Remember to allow for the full topographic height of the project area:

- We recommend that you leave, say, 5–10% extra space at the top of the project, above the highest point of the topography
- Allow sufficient project space at the bottom for the entire range of modelled geology that you are interested in. Don't, however, make it too large or you will take extra time to compute model shapes that are of no interest

The topography map view (TopoMap) in a 3D GeoModeller project is a special (pseudo-non-planar) section, and it is an essential part of the project. You cannot do any practical work in a 3D GeoModeller project until the map view section has been created. Since topography defines the natural upper limit of a typical 3D geology model, we use a digital terrain model (DTM) file to correctly define the shape of this special TopoMap section. Using the correct topographic shape has geology mapping advantages, and we recommend it.

Once the DTM (topography) has been loaded, and the map view section created (called TopoMap in this project), the 3D GeoModeller project dimensions cannot be changed.

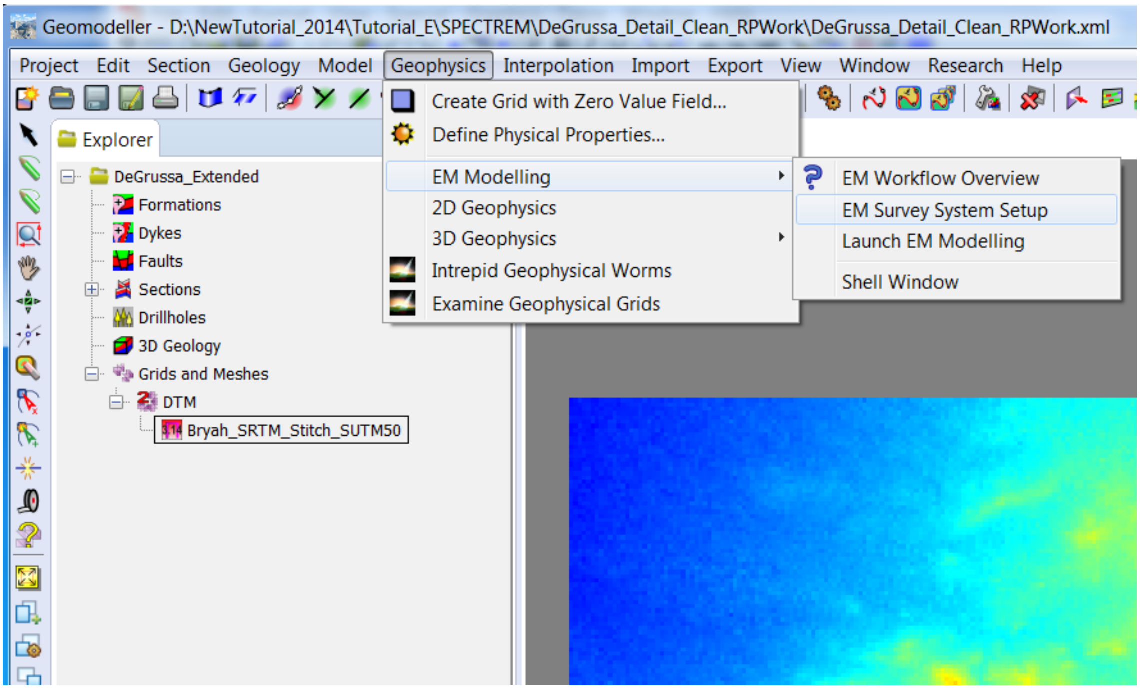
Tutorial T2: Specify SPECTREM configuration then Import EM data

Parent topic: **Tutorial E (Airborne EM Forward Modelling and Inversion)**

The Tutorial T1 3D GeoModeller Project that we have just loaded has been prepared to import a subset of the Bryah Basin AEM SPECTREM survey. AEM survey located data is normally delivered as a geophysical database in the Geosoft gdb format. The GeoModeller AEM software supports either Intrepid style or Geosoft GDB style databases.

The two wizards that provide access to the EM capabilities are accessed from the main menu.

1 Choose **Geophysics > EM Modelling**



T2 Overview

Parent topic: **Tutorial T2: Specify SPECTREM configuration then Import EM data**

In this tutorial we:

1 Examine the **EM Survey System Setup** configuration window.

2 Import the EM database.

3 Set the system specific geometry, power and waveforms

4 Create the sections for each survey line

5 Choose the measured EM signal fields from the database

T2 The EM Survey System Setup Wizard

Parent topic: **Tutorial T2: Specify SPECTREM configuration then Import EM data**

This section follows directly from the previous task of adding a formation to your project.

If not still open then open your project using the saved version from the end of the previous section. It can be selected from the Recent Projects list in the main Project menu.

1 From the main menu choose **Project > Recent Projects**

(using our example project folder `d:\tutorial_e`)

`d:\tutorial_e\SPECTREM\DeGrussa_Detail_MyT1`

Alternatively you can choose to begin with the **T1_Completed_Project** provided

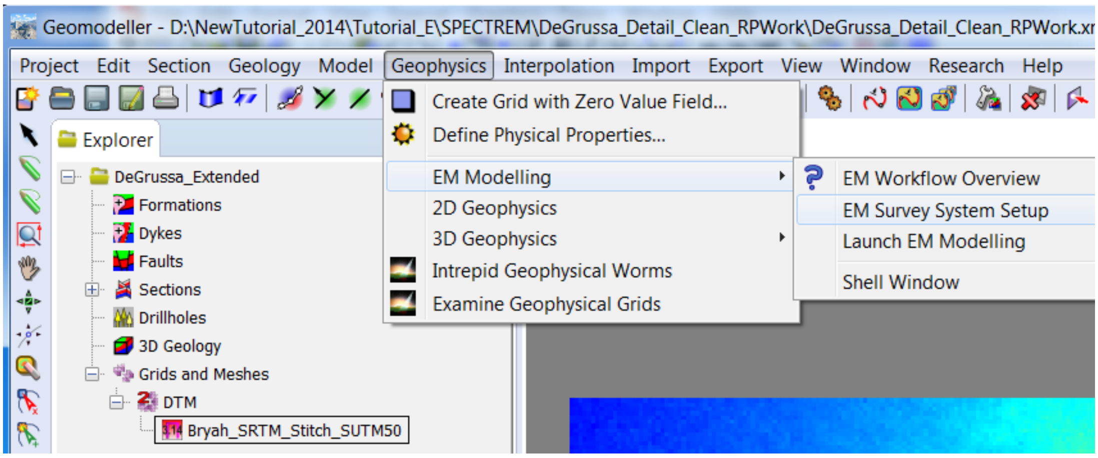
Choose **Project > Open**

In the **Open a project** dialog box navigate to (using our example project folder `d:\tutorial_e`):

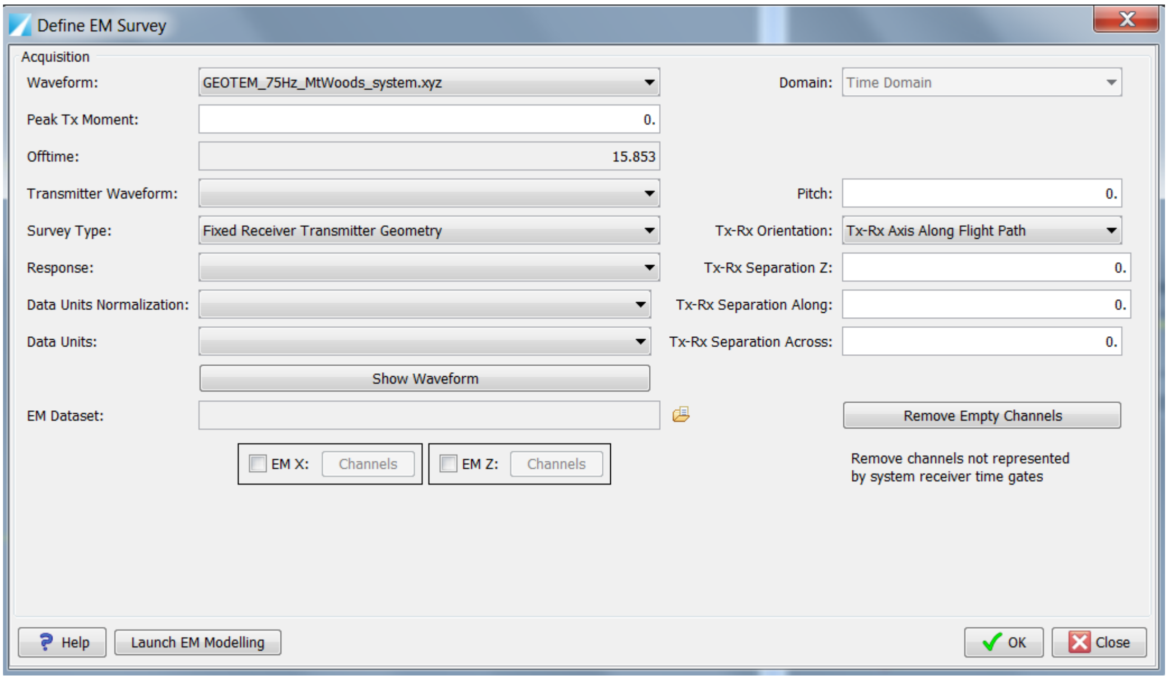
`d:\tutorial_e\SPECTREM\DeGrussa_Detail_T1_Completed\DeGrussa_Detail_T1_Completed.xml`

Select the first EM modelling menu item to begin the system setup procedure.

2 Choose **Geophysics > EM Modelling > EM Survey System Setup.**



- The following dialog appears:

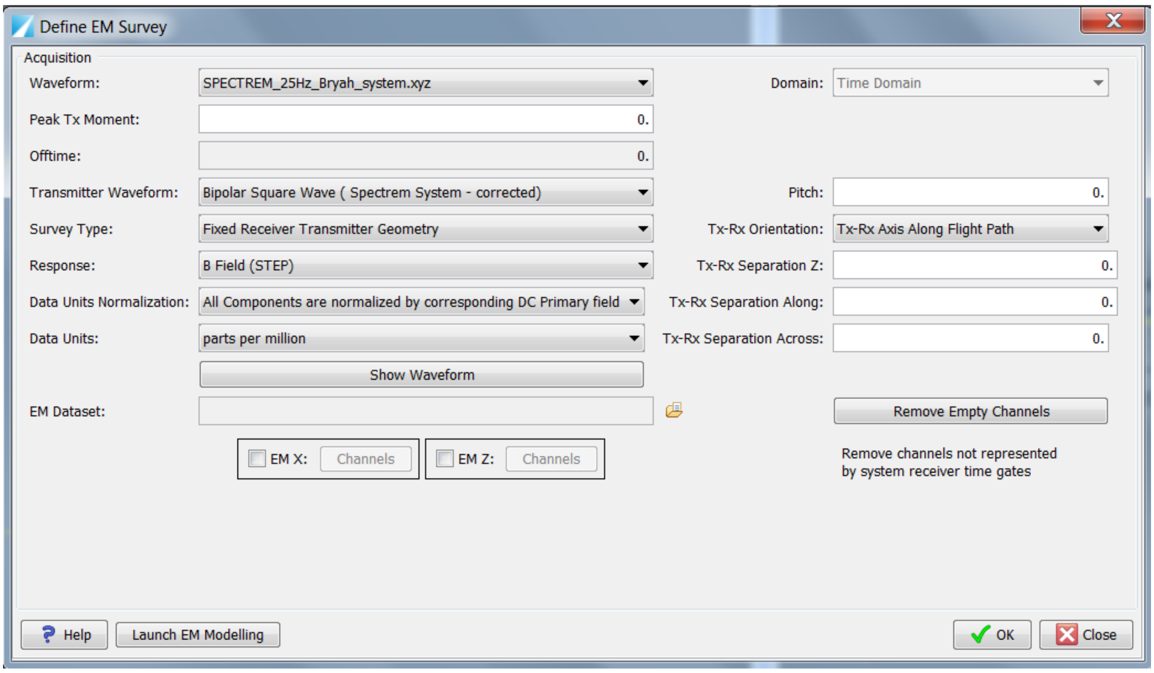


3 Click the down arrow on the **Waveform** selection list and pick the pre-configured file for this tutorial "**SPECTREM_25Hz_Bryah_system.xyz"** from the drop down list**.**

The choice of a system file beginning with the word SPECTREM or another standard system name results in a set of defaults being chosen for some of the system parameters. These are based on currently available experience with each system.

The defaults should not be taken for granted as these parameters may change from survey to survey due to modifications or improvements to the current system or as a result of Client requests.

In this case the dialog updates with the defaults for the $SPECTREM_{2000}$ system.



The Survey System File Description (this section is for reference only).

Proceed to item 1 on Page 19 for help on completing the definition of the remaining, required survey parameters.

The user can create/modify a survey specific configuration file that is a variant of the templates shipped with the software. The configuration files are ASCII and are found in the software installation directory in subdirectory **`config/em`**. The reference manual gives a full description of all the options in the configuration file. No changes are necessary for this introductory tutorial as this work is already done for you.

A copy of this file is reproduced below for your reference. See notes on the EM configuration file format following this example.

```
SPECTREM2000 25Hz Transmitter Waveform & Sample Times
1 10 1   ! NTRANS, NCHNL, NSX
10 1 0   ! NCHNL NSX, OFFTIME
25 1     ! FREQ(I) I=1,NFRQ
0.0260   ! 10 Gate Centre times in milliseconds (ms)
0.14325
0.29945
0.6120
1.23695
2.4870
4.98695
9.9870
16.6536
0.0001   ! 10 Gate widths in milliseconds (ms
0.0260
0.0781
0.1823
0.3906
0.8073
1.6406
3.3073
6.6406
6.6667
```

This format must contain standard fields that capture the essential features of an EM survey system. Required entries are :

Line 1 - A single line containing the EM system and user supplied survey ID

Line 2 - Three space delimited fields, No of Transmitters [NTRANS], No of measurement channels [NCHNL] and No of points defining the transmitter waveform [NSX].

Line 3 - Three space delimited fields, Number of Channels [NCHNL], No of points defining the transmitter waveform [NSX], Offtime in milliseconds [OFFTIME].

Line 4 to NSX+3 - A series of space delimited numeric values describing the transmitter waveform. Two fields per line - Time in milliseconds (ms) and Transmitter current in amps (normalised to 1 amp).

Line NSX+4 to NGates + NSX+3 - A single value with gate centre times in milliseconds.

Line NSX+4+NGates to 2* NGates+NSX+3 - A single colum with gate width in milliseconds.

A full description of how to build a survey system file is covered in the main GeoModeller manual under the heading and link **Preparing the EM System File**.

1 Click the **? Help** button on the bottom left of the **Define EM Survey** wizard to open the context sensitive Help for a detailed description of the wizard options.

2 Set or review the system specific parameters in the wizard window. The contractors survey acquisition report from the contractor will detail most of the required information.

3 Having chosen the SPECTREM option, the Domain is shown to be ***Time Domain***, and cannot be changed.

The following diagram illustrates the inflight geometry of the **SPECTREM**$_{\mathbf{2000}}$ system.

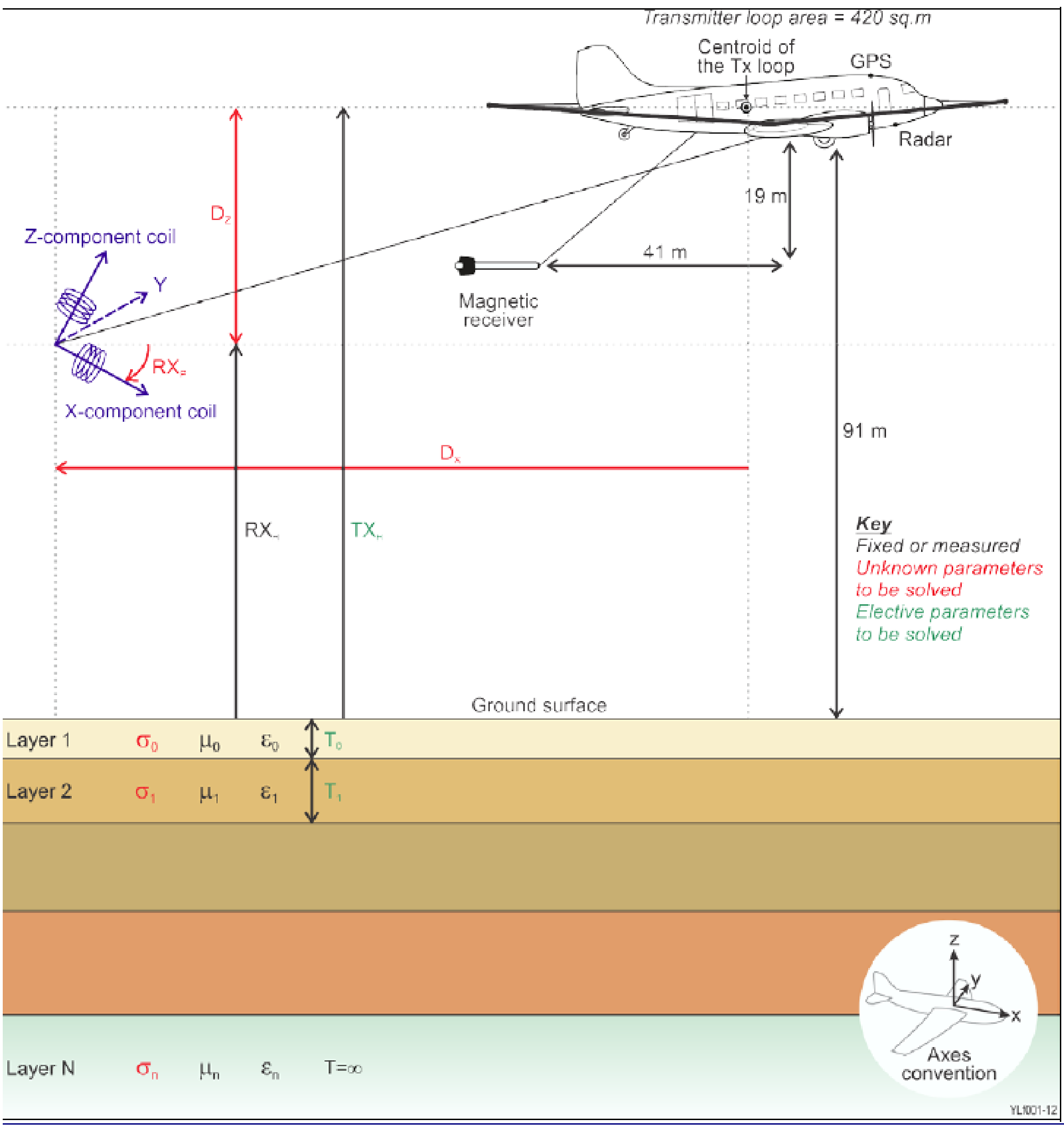


Figure 3. SPECTREM System In Flight Geometry, AY Ley_Cooper and TJ Munday (2013)

Set the remaining, required system parameters as follows:

1 **Peak Tx Moment = 400000 amps** - for SPECTREM2000 system

2 **Offtime** = ***0*** - for SPECTREM the transmitter is never off.

3 **Transmitter Waveform** - This is normally a constant for each system. In the case of SPECTREM, there are two options relating to the treatment of channel 10.

- **Bipolar Square wave (Spectrem System - corrected)**
- **Bipolar Square wave (Spectrem System - uncorrected)**

For the **Spectrem System - corrected** processing scheme, the last window of the measured decay is subtracted from all the earlier windows in an attempt to remove the transmitter primary signal present from the recorded response and channel 10 is set to zero.

For the **Spectrem System - uncorrected** processing scheme channel 10 is not subtracted and remains fully populated.

From the drop down menu, choose:

Bipolar Square wave (Spectrem System - corrected)

4 **Survey Type**: ***Fixed Receiver Trasmitter Geometry***

5 **Response**: ***B Field (STEP)***

6 **Data Units Normalization**: Choose ***All components are normalised by the corresponding DC Primary Field.***

7 **Data units**: ***parts per million***. The amount of energy returned vs transmitted.

8 **Pitch** = ***0***

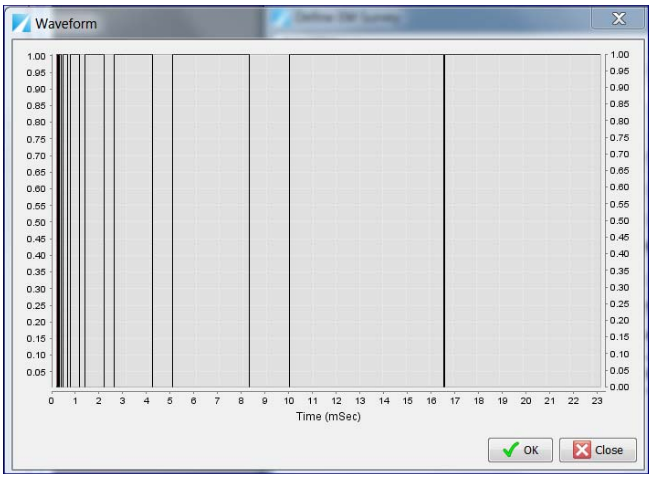
9 **Tx-Rx Orientation**: ***Tx-Rx Axis along Flight Path***

10 **Tx-Rx Separation Z** = ***41m*** - The receiver bird is 41 metres below the aircraft (*sign convention is positive below*)

11 **Tx-Rx Separation Along = *121m*** - The receiver bird trails the transmitter coil by 121 metres (*sign convention is positive behind.*)

12 **Tx-Rx separation Across = *0*** - The Tx->Rx offset in the Y direction is zero (*sign convention is positive to starboard - to the right side in the direction of travel*).

13 Choose **Show Waveform** to show a graphic of the waveform from the system file; for **SPECTREM & TEMPEST** the waveform is not displayed since the waveform is a simple square wave and always on. We display the receiver time gates only.



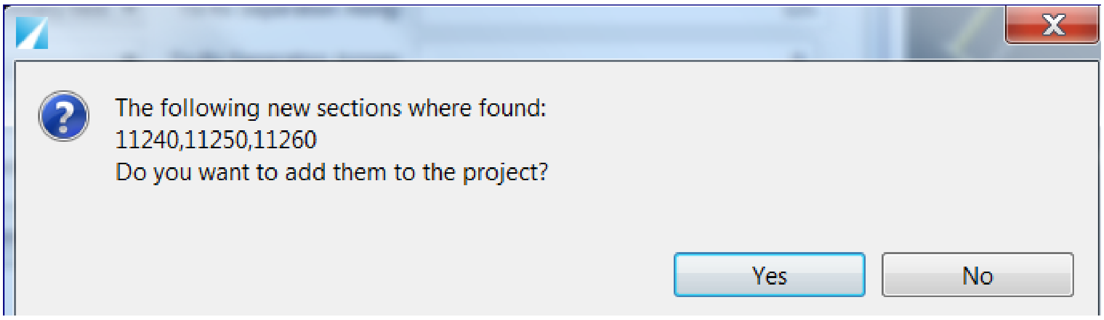
14 Click OK or Close

15 Now choose the EM dataset.

- Select the **EM Dataset: Browse** button

  Navigate up one level into the **`Bryah_Basin_Database`** directory and choose: **`Bryah_Basin_Exponential_Processed_DeGrussa_Detailed.gdb`**

  The next dialog asks if you want to add a new section for each flight line of EM data not found in the current project.



16 Click on **Yes.**

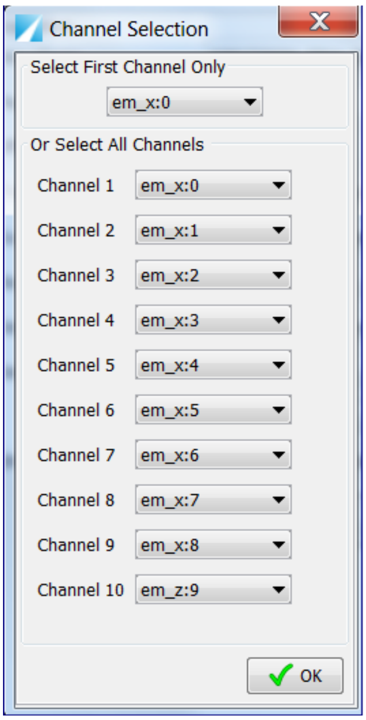
In this beginner tutorial, there are only 3 lines, so 3 sections are created. You can immediately see evidence of this in the 2D view of the **Surface Topography** section and also in the **Section** tree of **Explorer**.

17 Now you must choose the measured AEM signal fields. In this case both the X & Z directional components were recorded. The X component is positive in the direction of aircraft motion and the Z component is positive up, Figure 3. SPECTREM System In Flight Geometry, AY Ley_Cooper and TJ Munday (2013).

18 Toggle select both **EM X** and **EM Z.**

19 Click the Channel buttons and choose the starting channel number for each component as shown in the following dialogs. X and Z in these dialogs refer to the EM signal measurements and must not be confused with X, Y, Z spatial location.

- For X choose em_x:0, check that channel list is populated correctly



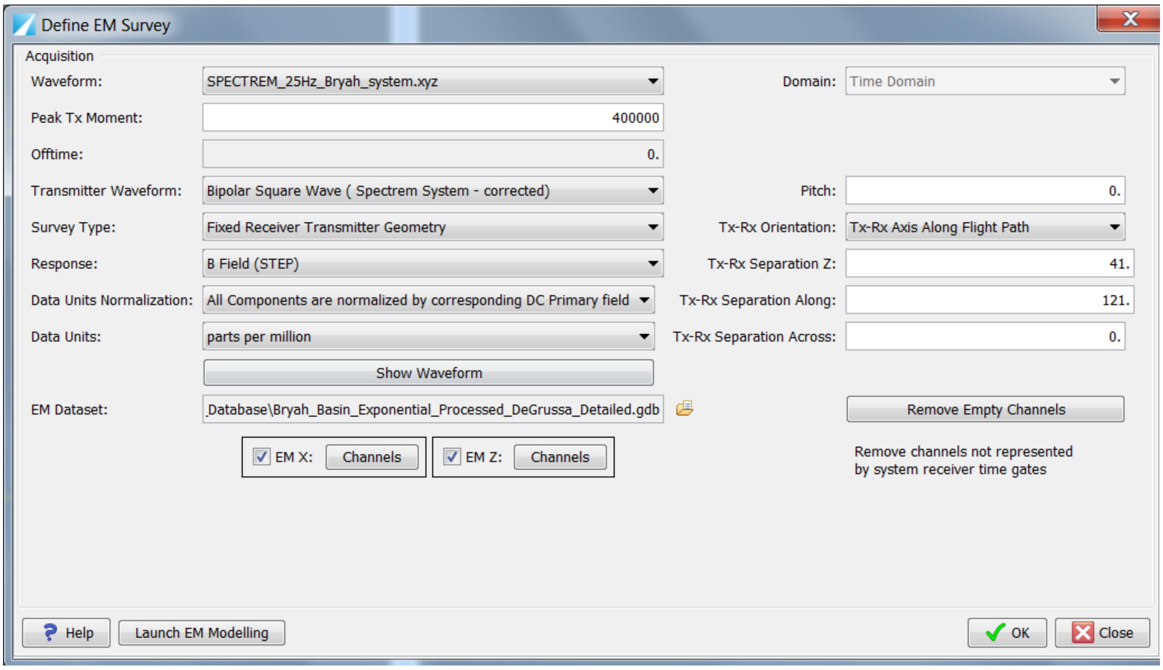
The channel lists are based on the number of receiver gates defined in the system file. The lists will autopopulate in increasing numeric order if the channels are stored in arrays (as in this case) or if they order correctly when numerically sorted. Otherwise each channel will need to be chosen individually.

Note: The selected channel numbers (i.e. **em_x:0)** are incremented by 1 so that they are 1 relative (**em_x:0 == Channel 1**). This 1 relative numeric system applies throughout the AEM module.

20 Repeat for the Z case, and choose **em_z:0**

As this is a **SPECTREM$_{2000}$** system, there are no Null fields in the recorded arrays for each field so there is no need to **Remove Empty Channels**. This option removes Null channels from the database but is not strictly necessary in most cases. In the case of VTEM systems it should ***NOT*** be used as Null channels occur in the X channel list for the first 7 or 8 populated Z channels. The channel gates must be kept aligned, time wise, for the software to work correctly.

This completes the EM system setup stage. The completed wizard should be set as illustrated below.



You can proceed to **Launch the EM Modelling** wizard directly, or choose **OK** and come back to this next step via the main Geophysics menu option.

21 Save your project

From the main menu choose **Project > Save As**.

This ensures that the new sections created are captured in your project so that you can continue to the next stage without having to repeat any of the above steps again.

We suggest (using our example project folder `d:\tutorial_e`):
`d:\tutorial_e\SPECTREM\DeGrussa_Detail_MyT2`

Tutorial T3: EM Modelling Wizard - Noise

Parent topic: Tutorial E (Airborne EM Forward Modelling and Inversion)

Before we can begin EM modelling we must choose the spatial fields that define the 3D position of the transmitter and receiver during flight.

We must also estimate system noise for each measured EM channel if it was not provided as part of the contract specifications. If previously estimated then we can import it for each channel from a CSV formatted file.

A procedure for estimating the noise from raw survey data is provided in this tutorial segment.

T3 Overview

Parent topic: Tutorial T3: EM Modelling Wizard - Noise

In this tutorial we:

1. Open the EM modelling wizard and select the required 3D spatial fields.
2. Examine profiles of all your observed EM and your chosen ancilliary field such as magnetics (TMI or TMI_1VD or PowerlineMonitor etc.).
3. Import or Estimate system noise
   - Importing System Noise
   - Calculating System Noise from survey data

T3 Field selection

Parent topic: Tutorial T3: EM Modelling Wizard - Noise

1. Open your project using the saved version from the previous section. It can be selected from the Recent Projects list in the main Project menu. From the main menu choose (using our example project folder **`d:\tutorial_e`**):

   Project > Recent Projects
   `d:\tutorial_e\SPECTREM\DeGrussa_Detail_MyT2`

   Alternatively you can choose to begin with the **`T2_Completed_Project`** provided.

   Choose **Project > Open**

   In the **Open a project** dialog box navigate to (using our example project folder **`d:\tutorial_e`**):

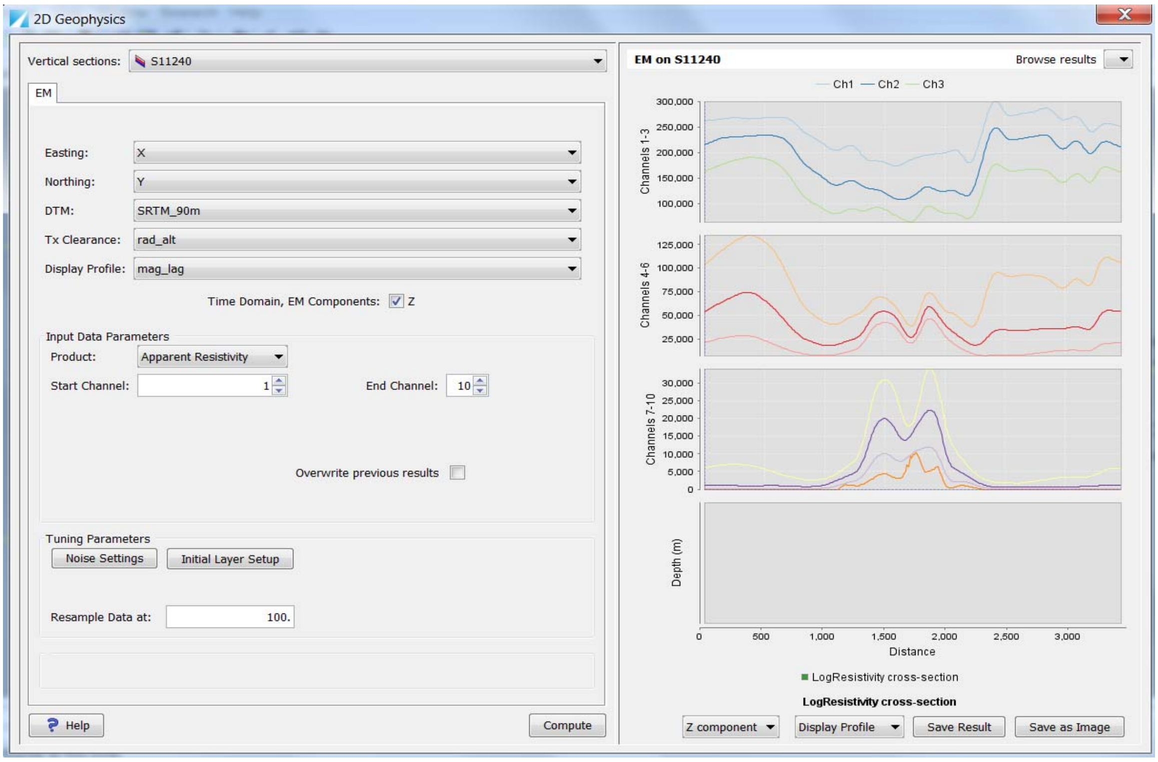
   `d:\tutorial_e\SPECTREM\DeGrussa_Detail_T2_Completed\DeGrussa_Detail_T2_Completed.xml`

2. Save a copy of this project in your own data area.

   From the main menu choose **Project > Save As**

   Save your project work as **`DeGrussa_Detail_MyT3`** in your current working folder.

3 From the main menu choose **Geophysics > EM Modelling > Launch EM Modelling**



- We show the already completed dialog.
- The first time you enter this dialog you must choose the database locational fields **X ,Y , DTM Elevation, Transmitter Clearance** and any optional field such as TMI that you would like to use to assist with interpretation of the EM profiles.
- The **Vertical Sections:** selection list at the left top of the EM Modelling wizard allows you to choose the section (flight line) to preview the measured EM field profiles. The first line in the EM dataset, S11240 is shown by default.
- Once the pulldown has the focus you can use the up/down cursor arrow keys to cycle through the sections to preview each line in turn.

4 For the supplied dataset

- **Easting** field is set to **X**
- **Northing** field is set to **Y**
- **DTM** field is set to **SRTM_90m**
- **Tx Clearance** field is set to **rad_alt**
- **Display Profile** field can be optionally set to **mag_lag**

5 **Channel selection == 1 to 10**. This includes all the measured fields that the SPECTREM system collects. The top three right side panels show the early to late time EM signal profiles with the scale auto adjusting in each panel as the signal strength declines at later times.

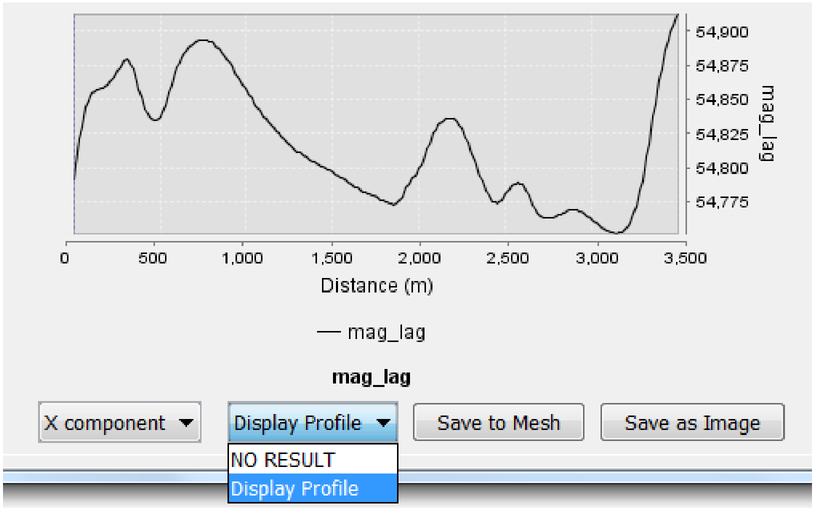
6 When the **Product:** selection is **Apparent Resistivity** (the default mode), the bottom right side panel is reserved for the optional field profile such as TMI (**mag_lag**).

7 When you have computed an inversion this bottom panel defaults to a vertical section of log conductivity for the inversion output.

8 When a forward or inversion **Product** is chosen and computed, the right side panel profile components and the right side bottom panel products are selected from dropdown lists below the bottom panel.

The available dropdown lists are dependent on the **Product** selection. Section displays include **Log Resistivity**, **Log Conductivity, Current Geology etc**.

When no **Product** has been computed the dropdown contains **Profile Display** and **No Result** only.



9 Save your project

From the toolbar choose **Save** or
press CTRL+S.

When parameters are set in the two EM wizard dialogs, a configuration file **`electrical.cfg`** is continually updated to preserve your settings for the current project. When the project is closed and reloaded the last settings will be restored

This file is saved in the project **Settings** sub-directory.

T3 Estimating System Noise

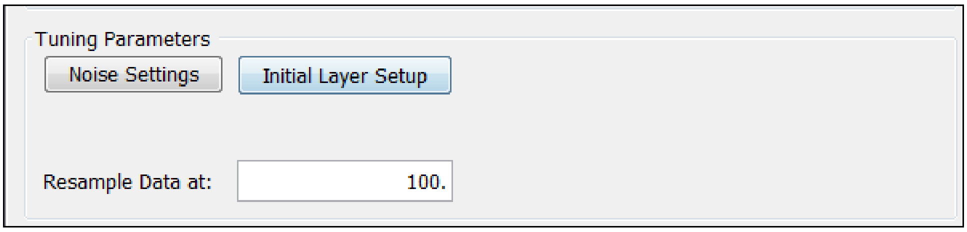
Noise Settings: Prior to computing any EM products the user must supply or estimate the survey system noise in order to produce products as free from this type of noise as possible.

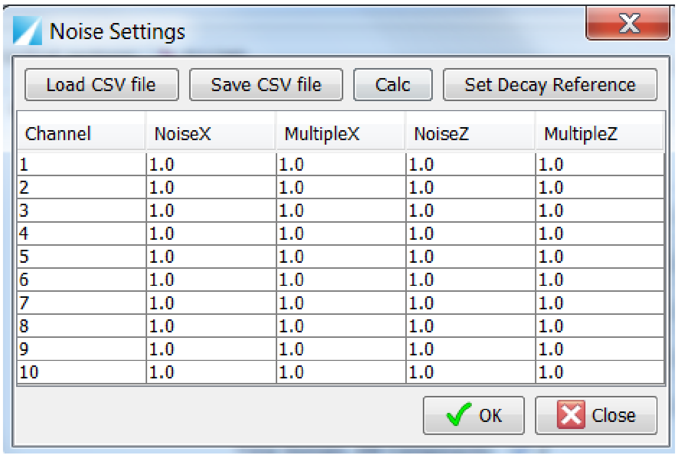
In this beginner tutorial we provide some pre-estimated noise values for each channel in a csv file.

Sometimes the contractor may estimate noise values which can be used directly or the Client contract may require noise to be estimated from duplicate lines or high level flights.

More commonly user’s must make their own noise estimates.

1 In the **Tuning Parameters** panel click on the **Noise Settings** button to open the noise dialog.





Setting accurate estimates of channel noise is a critical step in producing quality results from inversion. You have the following options:

- You can enter or import your own noise estimates or those supplied by the contractor and set the Multiplier to 1

  OR

- Calculate noise estimates from a low signal subset of your survey data.

Importing Noise Estimates

The **Load CSV file** button enables you to easily import noise estimates. We have estimated these values previously using the procedure described below. In this tutorial we use these estimates but we will also run through the noise calculation procedure.

Channel	StdDev	X Mult	StdDev	Z Mult
1	37.801	19.599	70.278	19.599
2	37.801	12.386	70.278	12.386
3	37.801	8.350	70.278	8.350
4	37.801	5.775	70.278	5.775
5	37.801	4.040	70.278	4.040
6	37.801	2.841	70.278	2.841
7	37.801	2.004	70.278	2.004
8	37.801	1.415	70.278	1.415
9	37.801	1.000	70.278	1.000
10	37.801	0.774	70.278	0.774

The contents of the noise file “**Noise_DeGrussa_Detail.csv**” are shown above.

1 Click the **Load CSV file** button, navigate up one level and enter the `Noise_Estimates` directory to import `Noise_DeGrussa_Detail.csv` into the **Noise Settings** table.

Calculating System Noise from Survey data

An alternative method of calculating a system noise estimate from the delivered late time data is described in the following section.

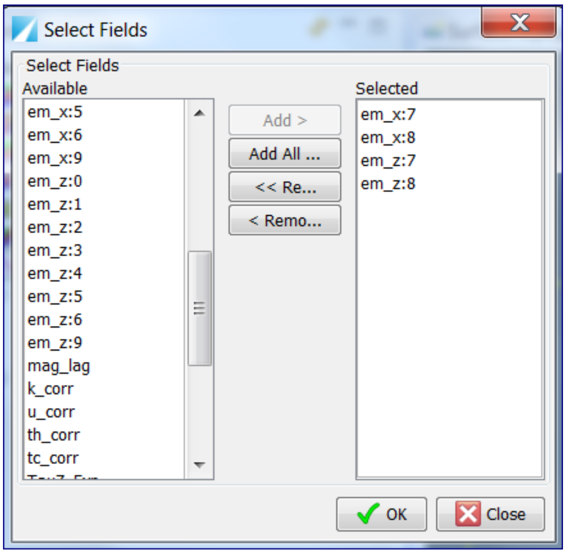
The procedure involves importing a few late time channels from the delivered database as a 2D vertex mesh, displaying the point cloud on the topography section using a suitable look up table and then digitising a polygon around a very low signal portion of the survey. The steps are:

1 Right click on Grids and Meshes in Explorer tree and choose:

Import > 2D/3D Observations

2 Navigate up one level to the delivered survey database:
`Bryah_Basin_Database\Bryah_Basin_Exponential_Processed_DeGrussa_Detailed.gdb`

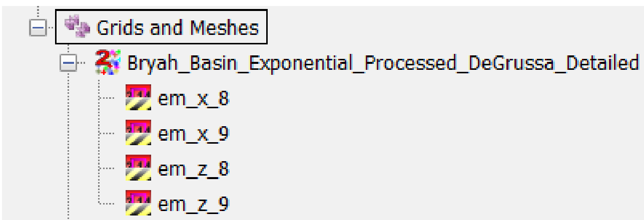
- The import chooser opens:



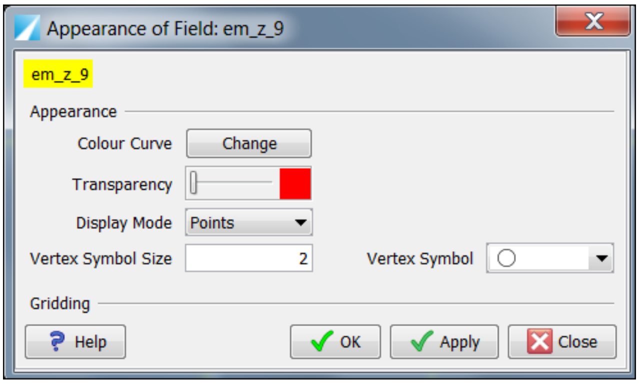
3 Multiselect **em_x:7, em_x:8, em_z:7, em_z:8** and click **Add >**

4 Click **OK:** A Mesh with the database name will be created in the **Grids and Meshes** tree.

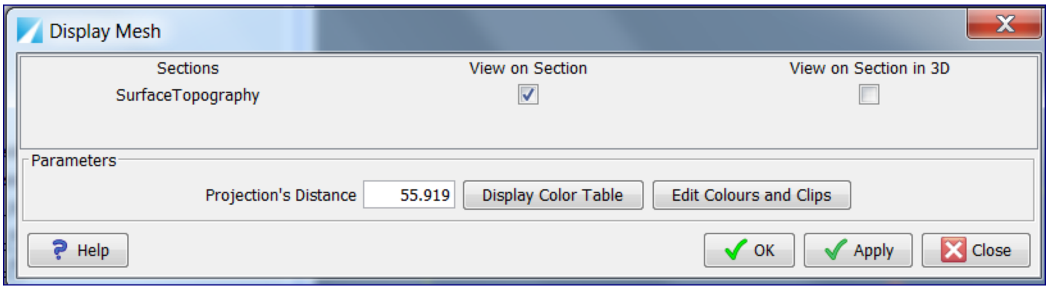
5 Click **+** to open the Mesh tree and display the mesh fields. The fields are named **em_x_8, em_x_9, em_z_8, em_z_9;** the numbers are incremented by 1 as we convert the channel numbers from 0 relative to 1 relative so that by convention the first channel is Channel 1.



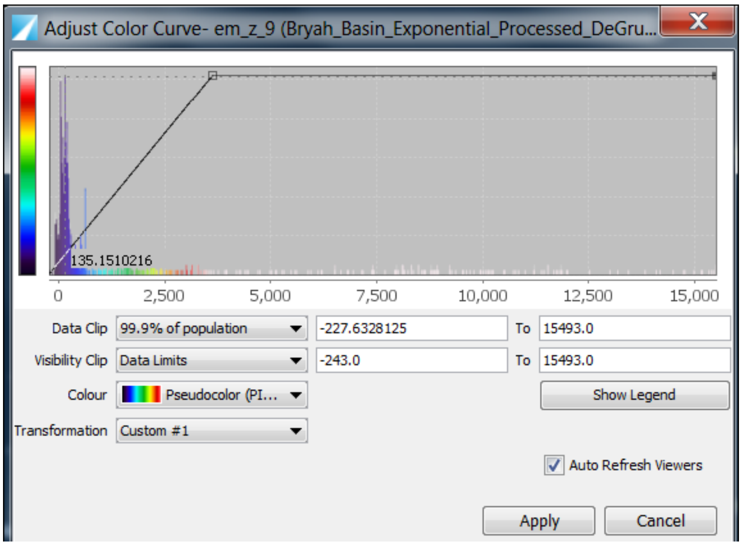
6 Right Click on **em_z_9,** select **Appearance** and set Vertex Symbol size to **2**.



7 Right Click on **em_z_9** and select **Field Visualisation Manager**



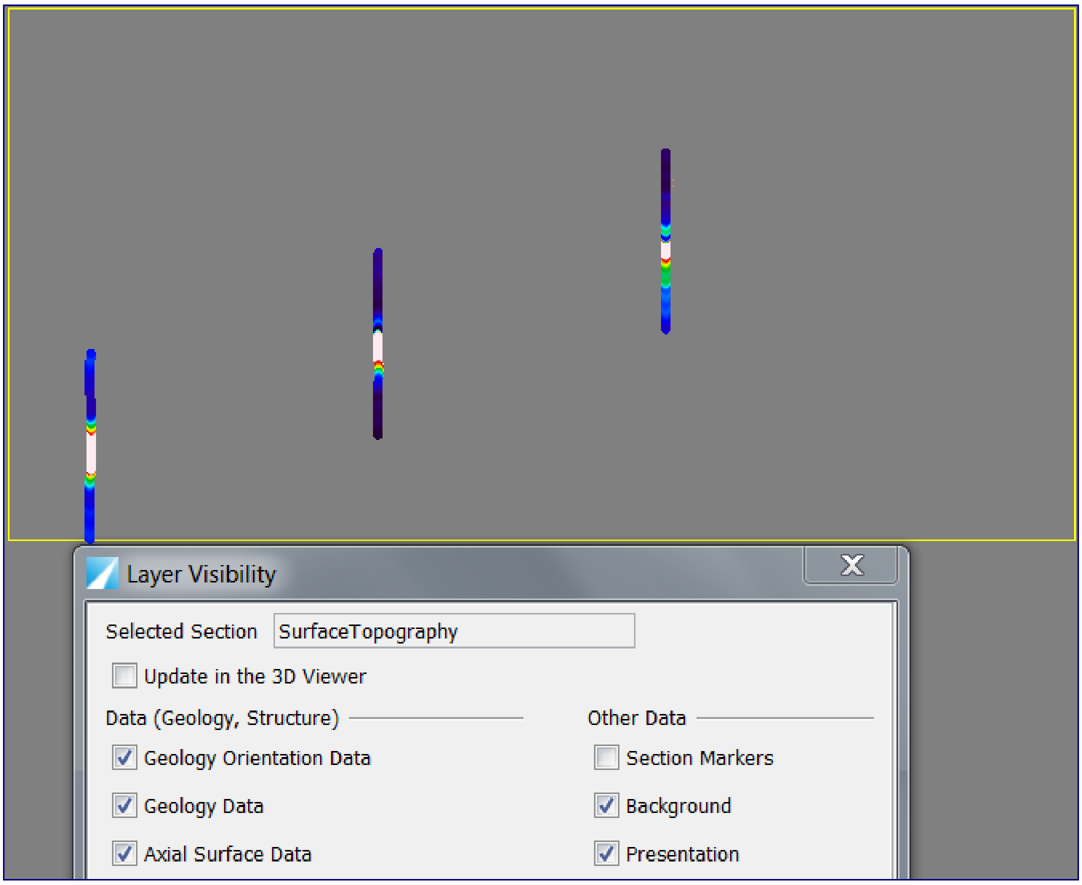
8 Click on **Edit Colours and Clips** and choose **Colour** LUT and manually alter the colour clip by clicking in the graph window and dragging the point on the transform line to the left to improve colour separation of the lowest values as shown below:



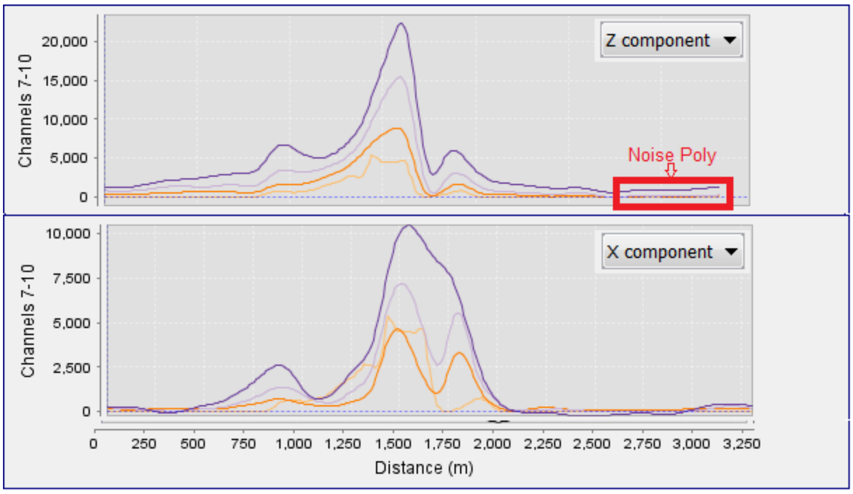
9 Click Close and then toggle **View on Section** for **Surface Topography**

10 Click OK to close or Apply to keep the **Field Visualisation Manager** open.

11 Right Click in section and choose **Set Layer Visibility** and untoggle **Section Markers** to unclutter display (see polygon figure on next page).

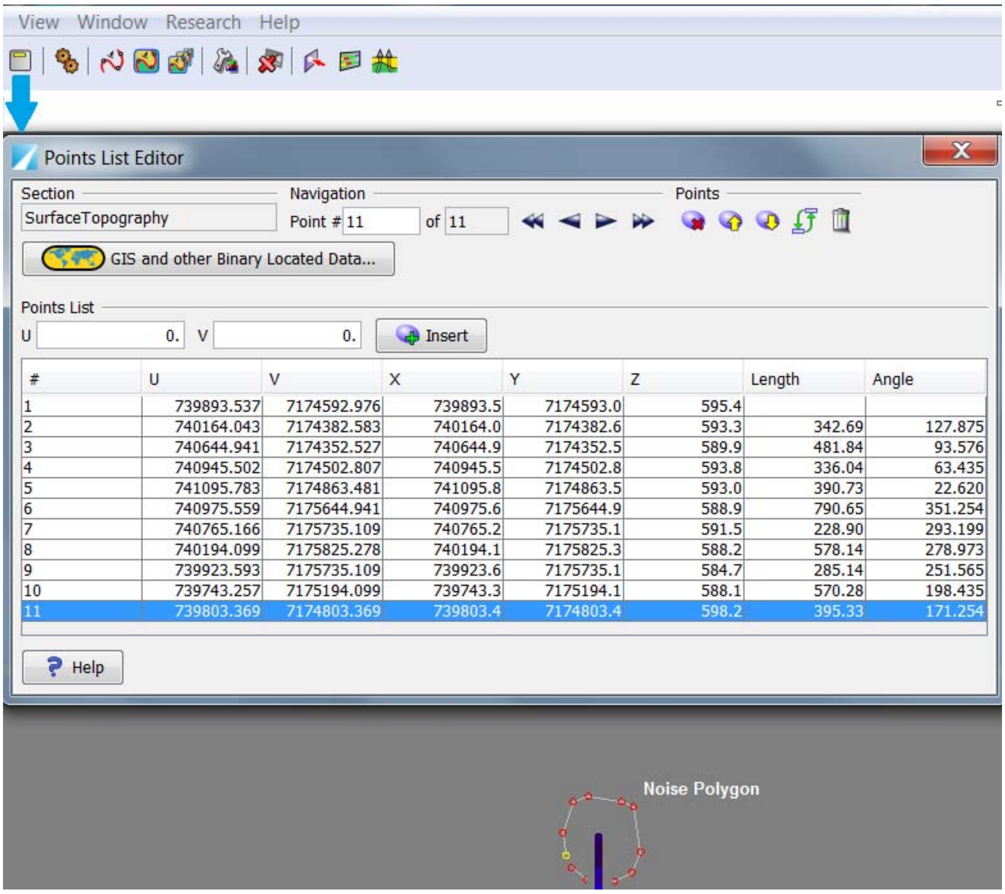


12 Identify by inspection an area of low signal; the last 600 hundred metres at the north end of Section S11260 is ideal; examine the profile data at late time in the lowest profile panel to confirm.



13 Select the upper most green pen on the **2D Toolbar** to the left of the **Explorer** panel as shown below

14 Draw a polygon with the green pen tool around this area of low signal on the **Surface Topography** section. The polygon does not need to be manually closed. The points are stored temporarily in the **Points List Editor** as shown below.

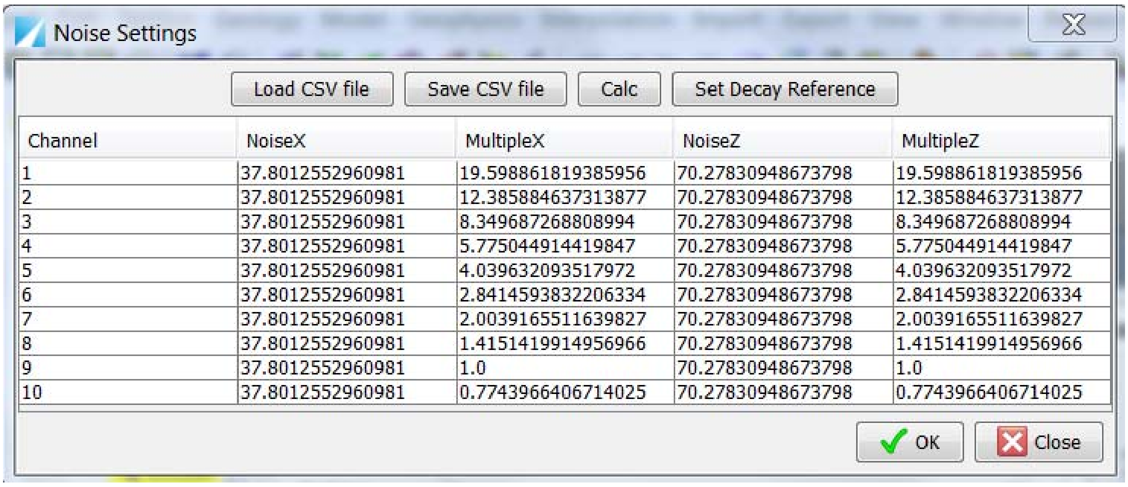


15 Open the **EM Modelling** wizard and Click on the **Noise Settings** button.

16 Click the **Calc** button to calculate RMS noise within the digitised polygon. This calculates the StdDev of each channel (time gate) for both X and Z components from the original line data (loaded EM database).

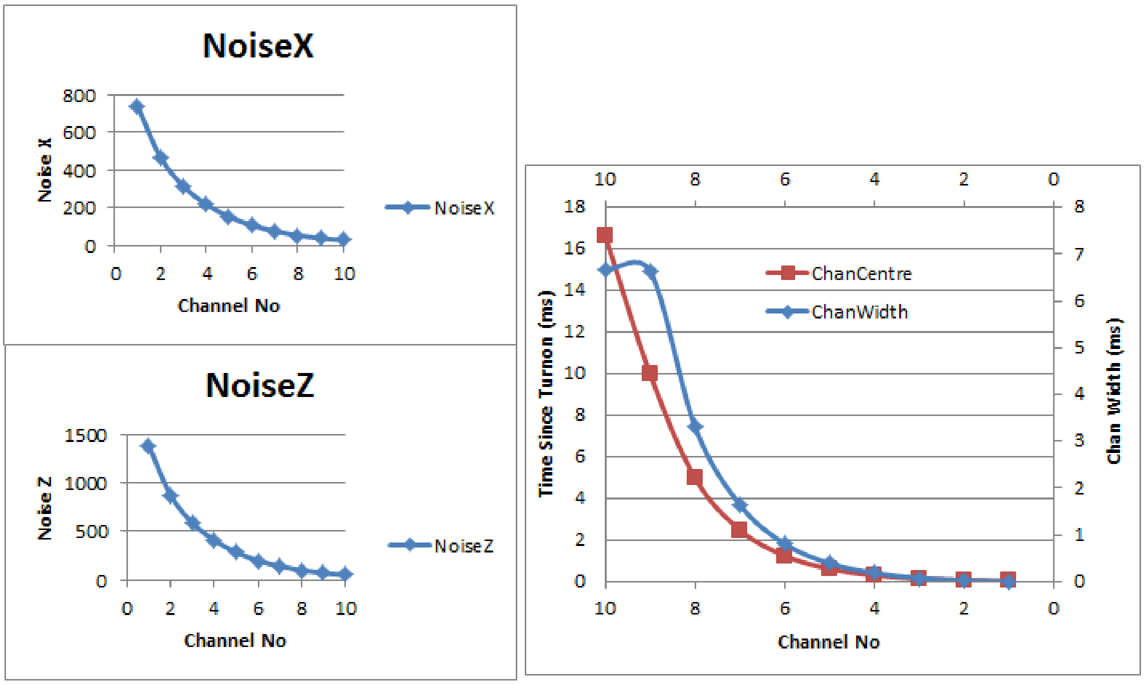
17 Click the **Set Decay Reference** button and choose the earliest of the late time channels (**Channel 9**) where confident the measured signal is dominated by noise.

This computes a multiplier for each channel equal to *sqrt(ts/tn)* where *ts = time since turnoff for the chosen channel* and *tn = time since turnoff for the channel we are calculating*. The NoiseX or NoiseZ values are then set to the value of the chosen late time channel for all X or Z channels in the group. When computing noise for inversion the value NoiseX*MultipleX*Peak Moment is the noise value applied to each measured channel.



Channel	NoiseX	MultipleX	NoiseZ	MultipleZ
1	37.8012552960981	19.598861819385956	70.27830948673798	19.598861819385956
2	37.8012552960981	12.385884637313877	70.27830948673798	12.385884637313877
3	37.8012552960981	8.349687268808994	70.27830948673798	8.349687268808994
4	37.8012552960981	5.775044914419847	70.27830948673798	5.775044914419847
5	37.8012552960981	4.039632093517972	70.27830948673798	4.039632093517972
6	37.8012552960981	2.8414593832206334	70.27830948673798	2.8414593832206334
7	37.8012552960981	2.0039165511639827	70.27830948673798	2.0039165511639827
8	37.8012552960981	1.4151419914956966	70.27830948673798	1.4151419914956966
9	37.8012552960981	1.0	70.27830948673798	1.0
10	37.8012552960981	0.7743966406714025	70.27830948673798	0.7743966406714025

18 Compare your estimated noise values with those we supplied. It may be difficult to obtain the same noise estimate for this small subset as the values we have calculated are selected from the full Bryah Basin survey.

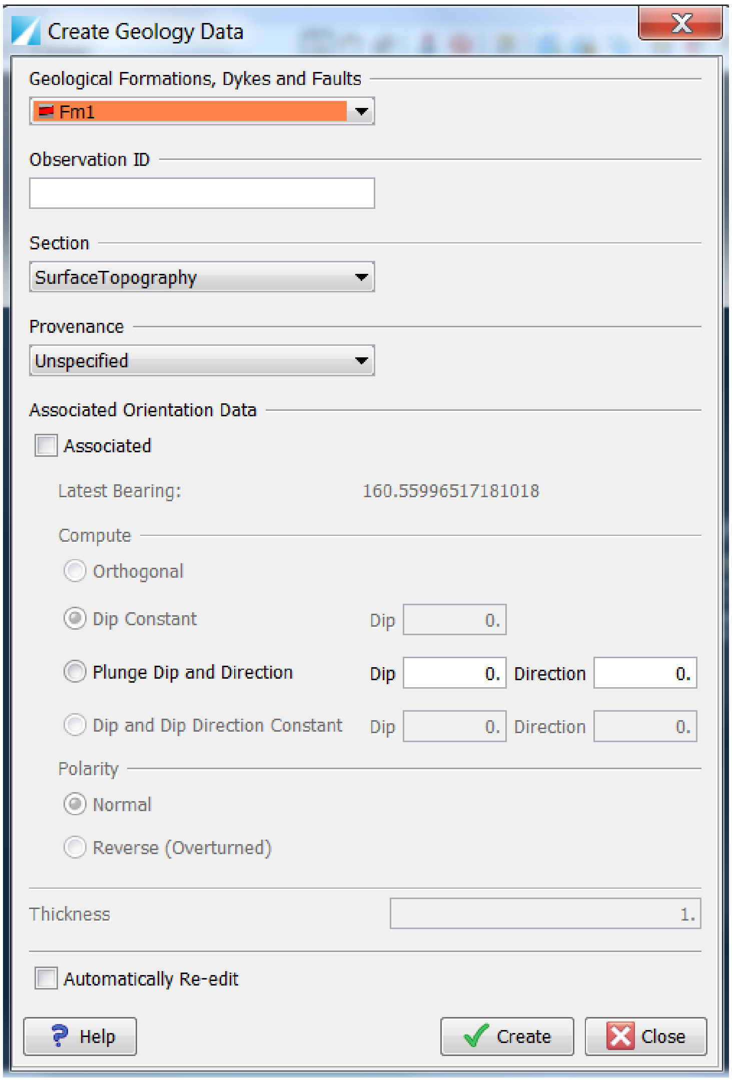


The noise estimates graphed by channel take the form of a decay curve - noise increases from late to early time as gate widths decrease. The gate widths are usually designed to increase by approximately the square root of time.

To save this polygon as a record of the area used to estimate noise, assign it to formation **Fm1** created at the beginning of Tutorial T1 and save your project. This allows you to save a record of any number of polygons that you have used to estimate EM system noise within your EM survey; you can reuse them as required.

19 Select the **Create Geology Data** glyph on the main menu toolbar

The following dialog is displayed



20 Choose **Fm1** from the **Geological Formations**, ... drop down list.

21 Click **Create** at bottom of dialog to save polygon as a formation contact. The **Points List Editor** is now cleared and the polygon points turn to the **Fm1** colour.

22 Click **Close**

To reuse the saved polygon to calculate EM system noise you must reload the polygon points into the **Points List Editor**

23 Double click on the **Fm1** polygon to reload the contact points into the **Points List Editor**.

24 Dismiss the Create Geology Data dialog

25 The **Fm1** polygon points are now in the **Points List Editor** and the **Noise Settings Calc** operation can be used

26 Save your project

From the main menu choose **Project > Save As**.

This ensures that the new sections created are captured in your project so that you can continue to the next stage without having to repeat any of the above steps again.

We suggest (using our example project folder **`d:\tutorial_e`**):
`d:\tutorial_e\SPECTREM\DeGrussa_Detail_MyT3`

Tutorial T4: Calculate Apparent Resistivity

Parent topic: **Tutorial E (Airborne EM Forward Modelling and Inversion)**

This tutorial describes how to calculate Apparent resistivity and conductivity. The calculation uses each data channel to estimate resistivity and conductivity from the surface down. Effectively the calculation sees deeper with each increase in delay time. This is a simple fast approximate method designed for a quick evaluation of your EM data in 2D map form.

We save only the apparent conductivity results for a suitable subset of channels to a Mesh grid and visualise them on the Surface Topography using a pseudocolour look up table, a log stretch and point size of 2 or 3. We examine the results coverage and statistics at early and late time to ensure they are sensible and that our estimated noise statistics are satisfactory.

Load your project

1 Open your project using the saved version from the previous section if not already open. It can be selected from the Recent Projects list in the main Project menu. From the main menu choose (using our example project folder **`d:\tutorial_e`**):

Project > Recent Projects
`d:\tutorial_e\SPECTREM\DeGrussa_Detail_MyT3`

Alternatively you can choose to begin with the **T3_Completed_Project** provided.

Choose **Project > Open**

In the **Open a project** dialog box navigate to:

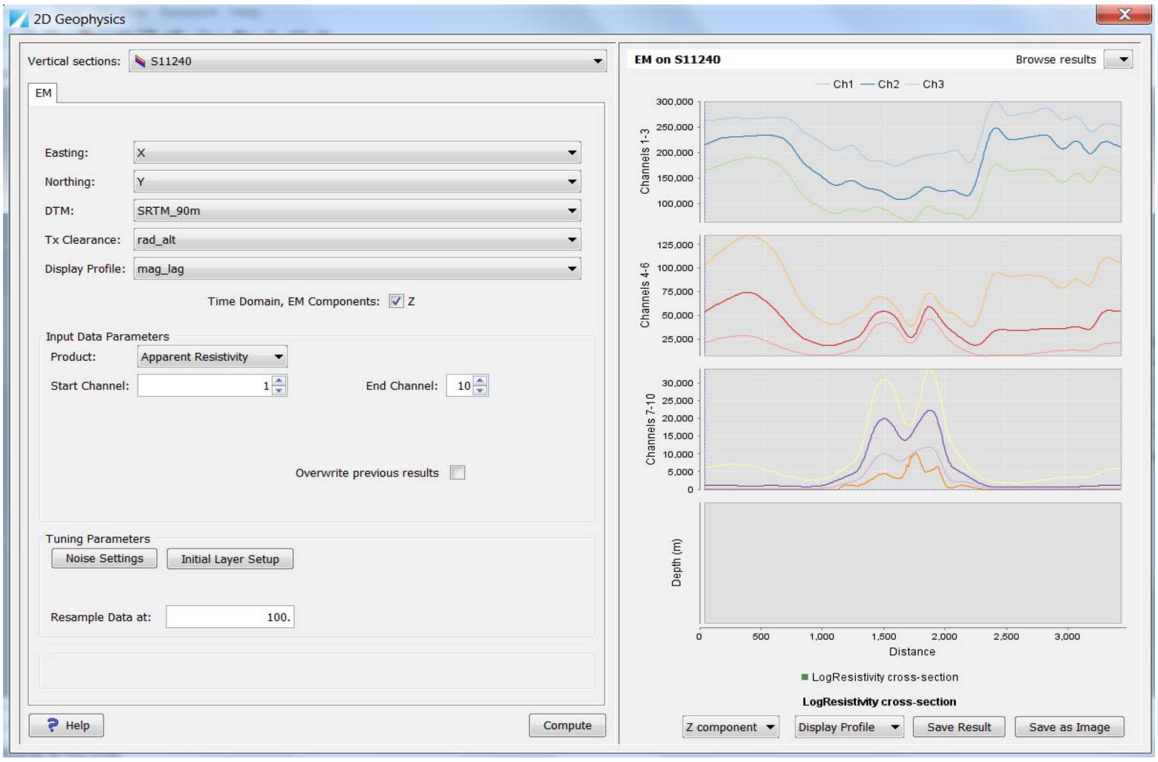
`d:\tutorial_e\SPECTREM\DeGrussa_Detail_T3_Completed\DeGrussa_Detail_T3_Completed.xml`

2 Save a copy of this project in your own data area.

From the main menu choose **Project > Save As**

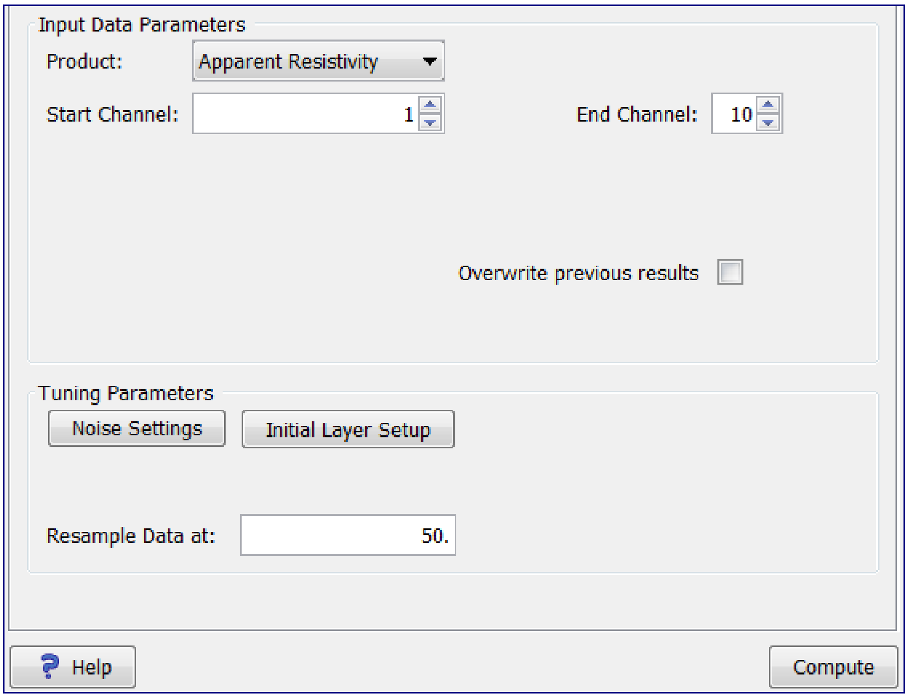
Save your project work as **DeGrussa_Detail_MyT4** in your current working folder.

3 From the Main menu choose **Geophysics > EM Modelling > Launch EM Modelling**



Choosing The Apparent Resistivity calculation parameters

The required Apparent Resistivity parameters are shown in the **Input Data Parameters** panel below:



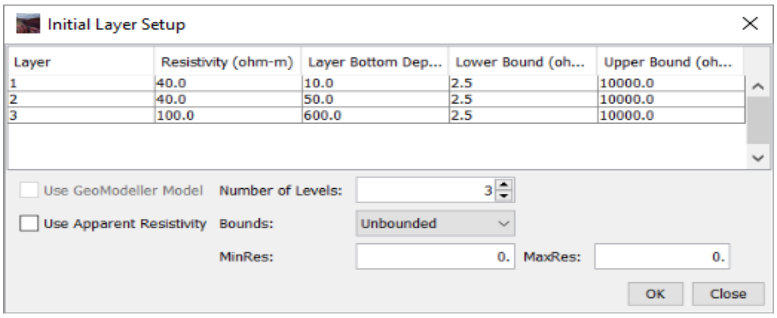
Set the parameters as follows:

1 Select Start Channel and End Channel;
 - *Use all channels 1 - 10 (the default)*

2 Toggle **Overwrite previous results** if you need to recalculate after changing parms.

3 Check that **Noise Settings** are populated correctly as described in **Tutorial T3**.

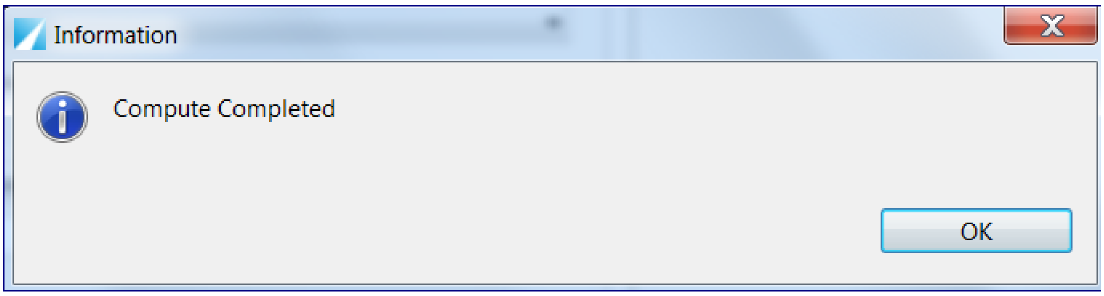
4 Set the **Initial Layer Setup**; this is not a critical component for this calculation.
 - *accept the default layer setup unless you have a priori information.*



5 Resample Data at: 100m

This is the length of a moving average filter. The measured data is often oversampled ie 10Hz. This moving average filter smooths the data, reducing the sampling rate (sample interval) which speeds up the calculation and visualisation process. We effectively down sample the response to say one sample every 100m. Leave as the default for this training.

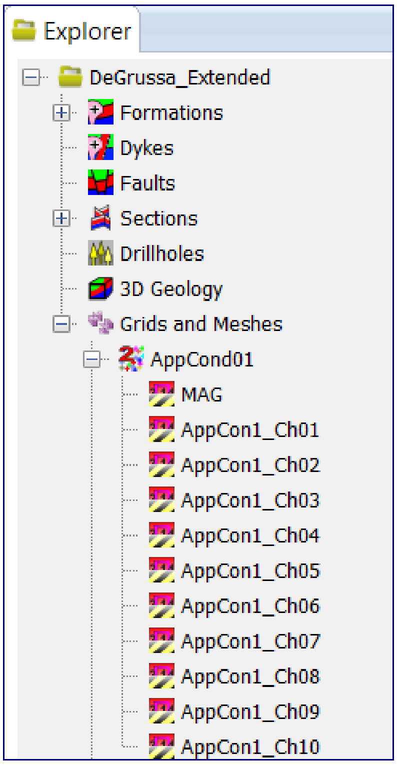
6 Click **Compute** to run calculate Apparent Resistivity and Conductivity. When completed (it is very fast) the following dialog appears:



7 Click **OK**

8 Click **Save to Mesh** at the bottom of the Profile and Section display panel to save the ***Apparent Conductivity*** results to 3D GeoModeller's **Grids and Meshes** tree. We do not import the ***Apparent Resistivity*** as conductivity is easier to interpret in EM. We are normally looking for conductive features.

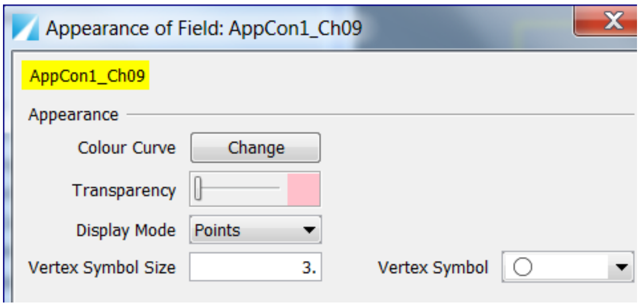
9 Click **OK:** A Mesh with the database name **AppCond01** will be created in the Grids and Meshes tree as shown below



10 Click **+** to open the Mesh tree and display the mesh fields.

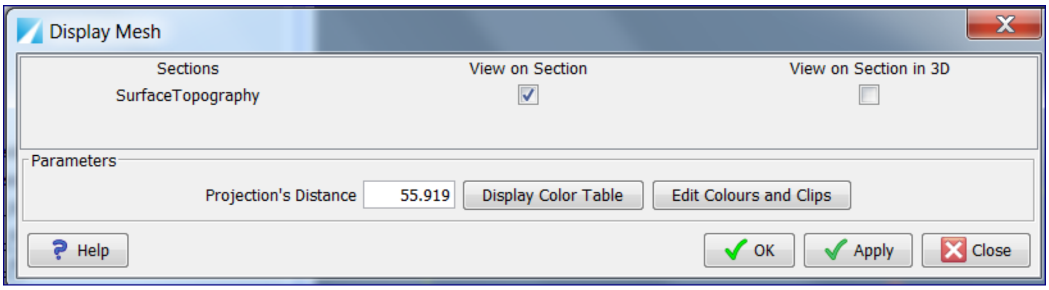
11 Right Click on the first channel **AppCon1_Ch01,** select **Appearance** and set Vertex Symbol size to **2**.

12 Repeat the above for the second last channel **AppCon1_Ch09**

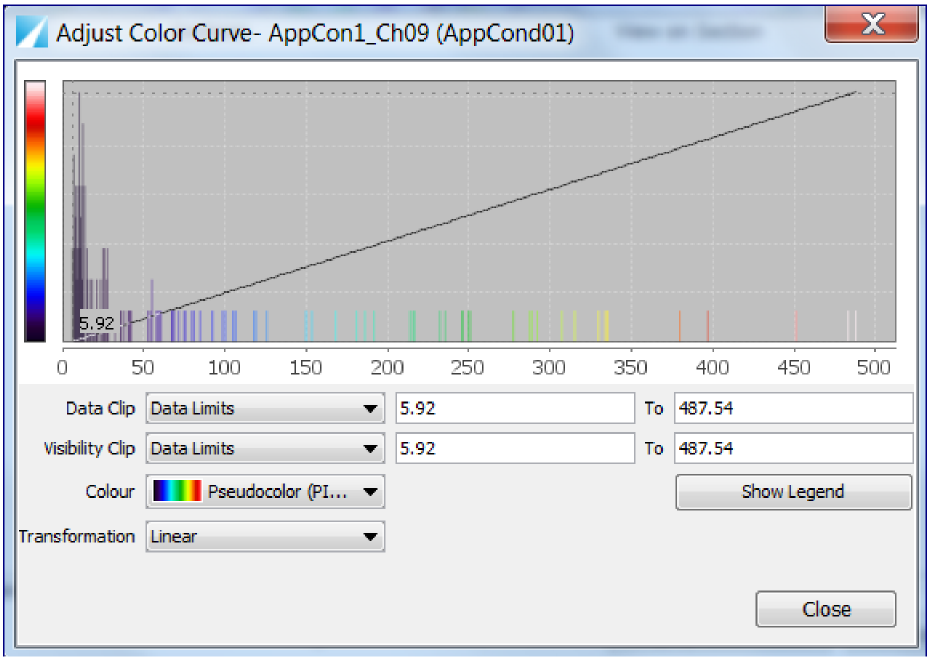


13 Right Click on **AppCon1_Ch09** and select **Field Visualisation Manager**

14 Toggle **View on Section** for **Surface Topography** section



15 Click on **Edit Colours and Clips** and choose Colour LUT Pseudocolor (PITS) and use the default Data Limits stretch with a Linear transform as shown below:



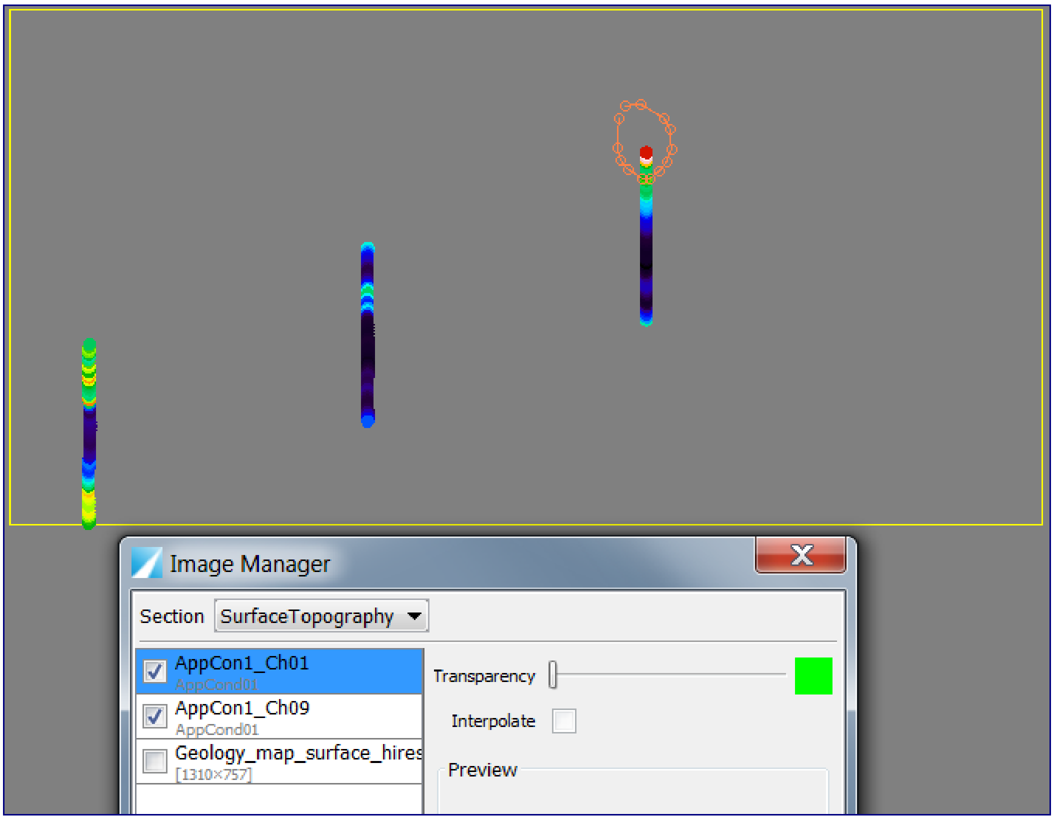
16 Repeat the above for last three operations for **AppCon1_Ch01**

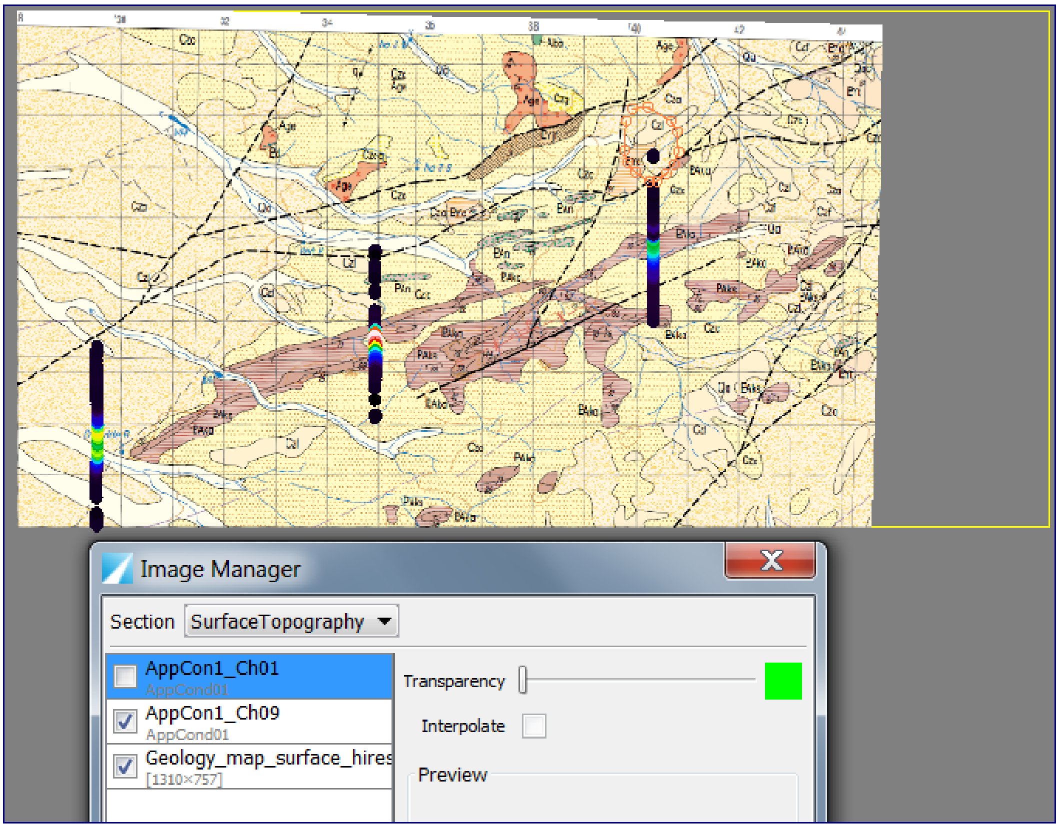
17 Right Click in the 2D Viewer and select **Image Manager**

18 Resize the Image Manager dialog to be as small as possible

19 Deselect and select **AppCon1_Ch01** to see the differences between the first (Ch01) and second last (Ch09) Apparent conductivity channels. The late time channel Ch09 shows the late time conductors associated with the mapped shale unit ie turn on the Geology map as shown below.

20 Right Click in 2D Viewer Surface Topography section and choose **Set Layer Visibility** and untoggle **Section Markers** to unclutter display if section lines are displayed





21 Save your project

From the main menu choose **Project > Save**.

This ensures that changes are captured in your project so that you can continue to the next stage without having to repeat any of the above steps again.

You should have previously saved it to the name suggested below at the start of this tutorial section

If you did not save it as directed at the start of T4 then you must copy the completed project using Windows Explorer and rename it to (using our example project folder `d:\tutorial_e`):
`d:\tutorial_e\SPECTREM\DeGrussa_Detail_MyT4`

In this instance you cannot use **Save As** as the **AppCond** project subdirectory containing your apparent conductivity run is stored inside the project and will not be preserved by a **Save As** operation.

Tutorial T5: Setting up MPI

Enabling MPI processing

Parent topic: **Tutorial E (Airborne EM Forward Modelling and Inversion)**

In order to make EM inversion practical in a 3D geology modelling environment we make use of all the available computer resources available in the modern desktop or laptop computer. This can be done by having one process that employs multi-threading, or multiple processes executing in parallel to share the CPU load. We have chosen the latter and use INTEL MPI. MPI can be configure to run on multiple computers across a network as well as on single laptops or desktops.

An Intel ***i7*** processor chip has 4 CPUs each with hyper-threading and appears to have 8 CPUs. However, in practice performance degrades on a single desktop of this type if you allocate MPI more than 4 CPUs .

GeoModeller's 1D and 2.5D AEM inversions make extensive use of this service.

In 1D inversion each line of EM data is given to a separate MPI process so performance increases linearly with the number of processors.

In 2.5D inversion the situation is more complex and the various tasks such as the 2D forward solver and other heavy matrix computations are split equally between the available processors. The speed increase in 2.5D is approximately 1.4 times for each doubling of the number of processors. To enable MPI on your computer you must activate a daemon using the *Intel* tool **smpd**.

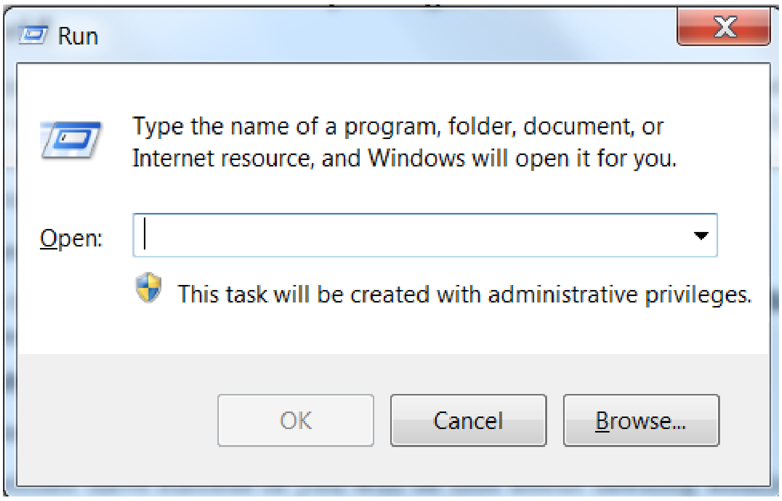
After installing Geomodeller on your computer you must activate the **smpd** daemon process once and set up a username and password so that an EM inversion job can run in parallel.

You must have administrative privileges to install and run this service on your computer!

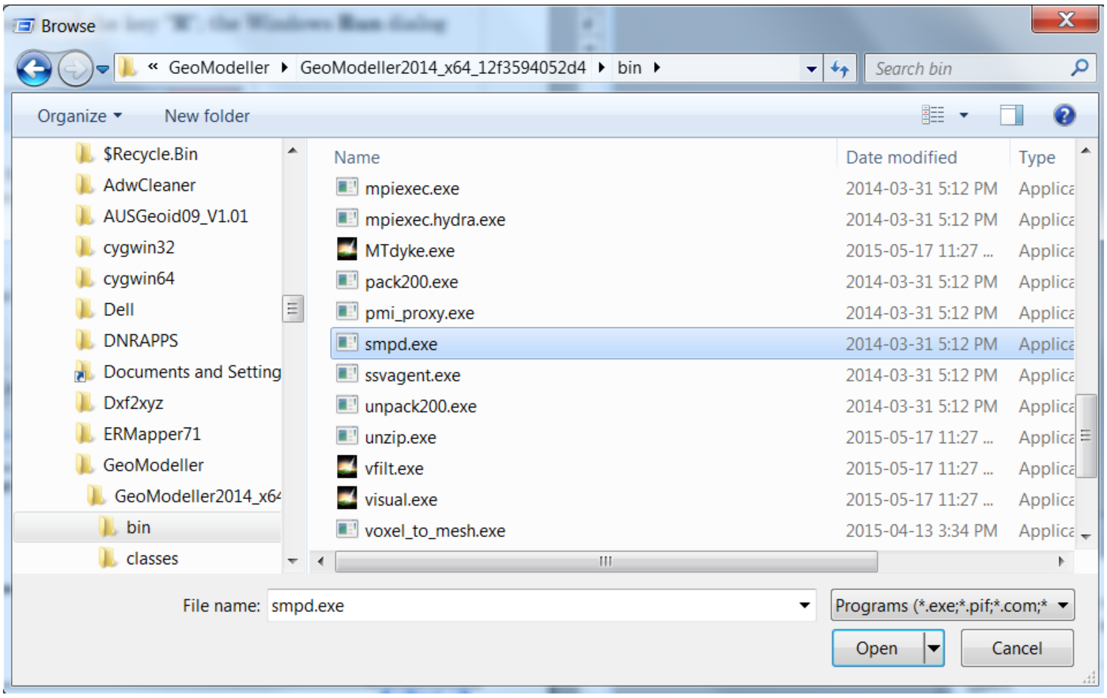
If you cannot successfully install MPI, you can restrict the computations to just one processor or CPU but you will suffer significant performance penalties. Currently this must be done from the CMD tool or using a batch file. This is discussed fully in the user manual.

The suggested procedure for installation is:

1 Press the **WIN** key on your keyboard and the key “**R**”; the Windows **Run** dialog will open as below. It only appears like this if you have administrative privileges.

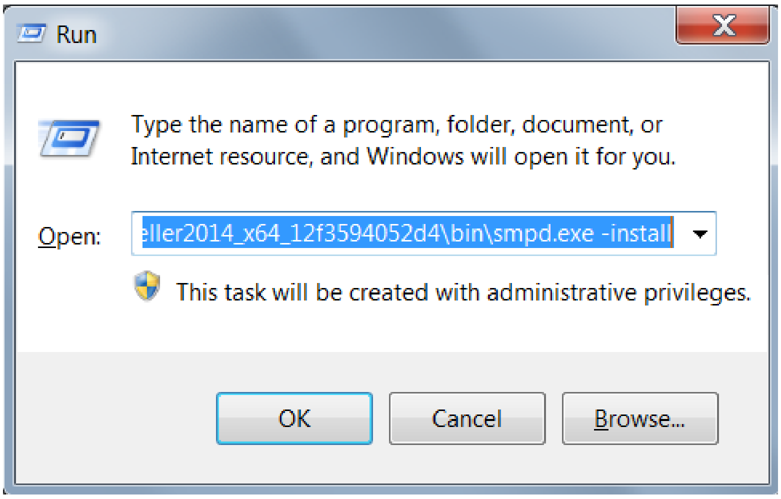


2 Click the **Browse** button and navigate to your GeoModeller installation **bin** directory and select **smpd.exe**



3 Click **Open**

4 Click in the **Open:** filename box, go to the end of the line i.e. **smpd.exe** and add the string **-install** as shown below.



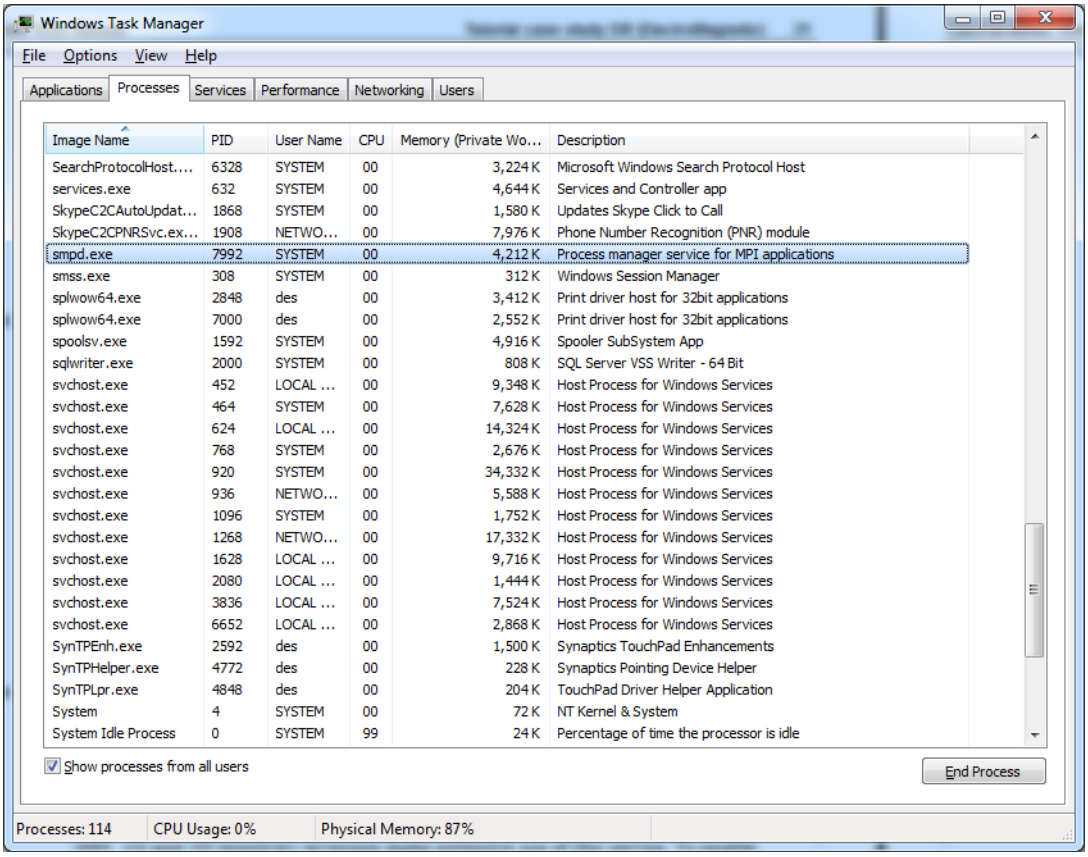
5 Click **OK**

At this point there will be a number of possible reactions depending on how your computer security options are configured.

- You may see a request to allow access to either Public or Private networks for smpd. You only require Private.
- You may be prompted for an administrative password.

6 Once the operation is completed check that you have an **smpd** process running using Task Manager

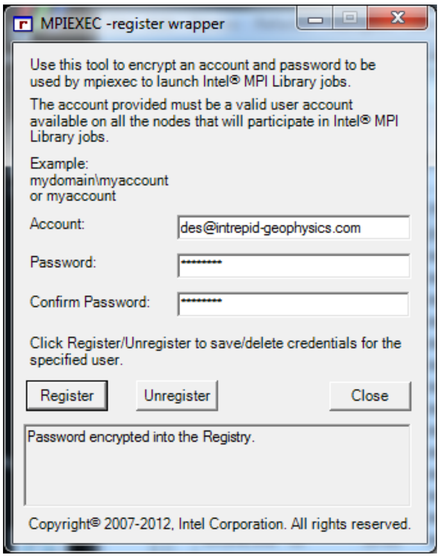
To check that this service is running, ask for all processes and examine the process list in alphabetic order around the letter **S**, to verify the process has started.



7 Repeat Step 1: Press the **WIN** key on your keyboard and the key "**R**"; the Windows **Run** dialog will open as in Step 1. It only appear like this if you have administrative privileges.

8 Click the **Browse** button and navigate to your GeoModeller installation **bin** directory and select **wmpiregister.exe**

You must now register yourself as a user of the MPI service.



9 Enter: **username** and **password.**

10 Click **Register.**

11 Click **Close**

Note: You may have to repeat the process above if your previous registration has been deleted. This can happen if you uninstall GeoModeller and install a new version.

MPI Trouble shooting advice:

If you have competition between various packages trying to control the **smpd** service, open a command window and check which version of smpd you are using by executing the following command:

>> smpd -V ENTER

```
Intel(R) MPI Library for Windows* OS, Version 4.1 Update 1 Build
5/22/2013 6:46:30 PM
Copyright (C) 2007-2013, Intel Corporation. All rights reserved.
```

A later version, as per below, is already running!!

```
Intel(R) MPI Library for Windows* OS, Version 5.0 Update 3 Build
1/28/2015 4:16:07 PM
Copyright (C) 2007-2015, Intel Corporation. All rights reserved.
```

You may then see a message when the background EM job fails.

Aborting: unable to connect to Buster, smpd version mismatch.

If possible kill the mis-matched **smpd service** and try to restart it using the one provided.

Tutorial T6: 1D EM Inversion - Time Domain

Parent topic: Tutorial E (Airborne EM Forward Modelling and Inversion)

With Geomodeller 2014, there is support for both 1D inversion and 2.5D forward and inverse modelling of AEM data. This tutorial focuses on 1D inversion.

1D inversion is relatively rapid and is a recommended starting point for shallow broad scale geological cover (regolith). It provides a quick look at what the EM signal conveys about the immediate near surface geology assuming a series of relatively flat geological layers. It is an alternative and usually a more accurate representation of the shallow geological cover than that available from the grid products provided to you by the contractors. These are usually conductivity depth images (CDI's) produced by a 1D mathematical transform.

1D Inversion provides a measure of misfit with the observed data that is generally not available with CDI transforms.

However 1D Inversion can give poor results when the 1D assumptions are not met and this is where the 2.5D inversion excels.

T6 Overview

Parent topic: Tutorial T6: 1D EM Inversion - Time Domain

In this tutorial we:

1. Load your project and choose **1D Resistivity Inversion** from the drop down **Product:** list
2. Set up the 1D Tuning parameters
3. Set up to run the 1D Inversion for all sections using 3 MPI nodes
4. Visualise the 1D Inversion results in 2D and 3D
5. Discuss the geological model interpretation for Section S11250
6. Show how we assign Resistivity Properties to the geological formations
7. Compute a 2.5D Forward model and examine the misfit with the observed

Load your project

1. **Open your project using the saved version from the previous section** if not still open. It can be selected from the Recent Projects list in the main Project menu. From the main menu choose (using our example project folder `d:\tutorial_e`):

   Project > Recent Projects
   `d:\tutorial_e\SPECTREM\DeGrussa_Detail_MyT4`
2. Alternatively you can choose to begin with the **T4_Completed_Project** provided.

   Choose **Project > Open**

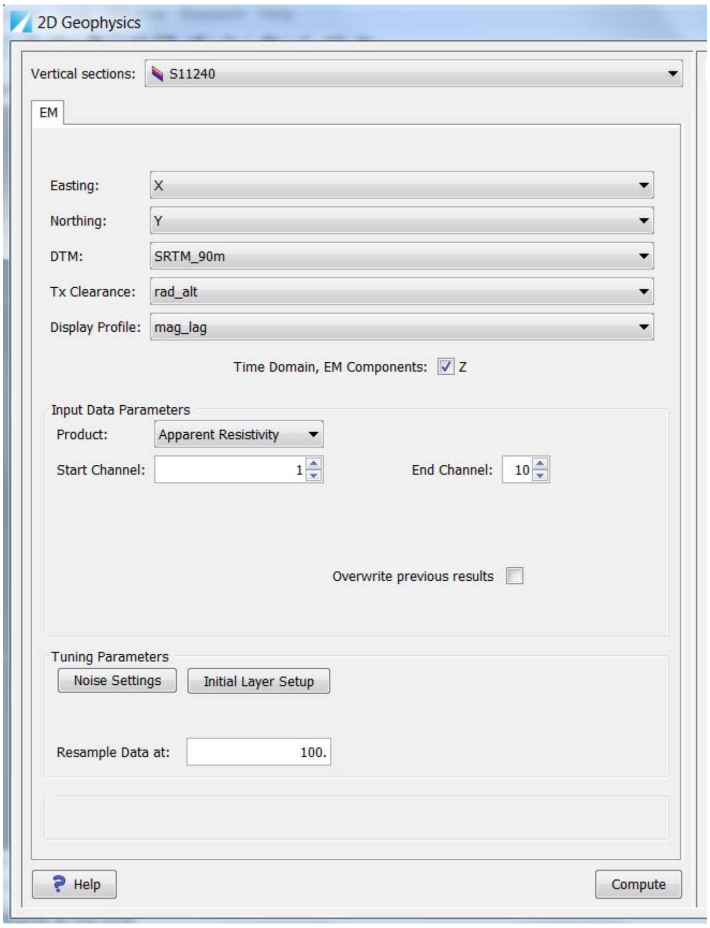
   In the **Open a project** dialog box navigate to:

   `d:\tutorial_e\SPECTREM\DeGrussa_Detail_T4_Completed\DeGrussa_Detail_T4_Completed.xml`
3. **Save your own copy of this project.**

   In this instance you cannot use **Save As** as the **AppCond** project subdirectory containing your apparent conductivity run is stored inside the project and will not be preserved by the **Save As** operation. Use Windows Explorer to copy the project directory to your own working area and then rename it to **DeGrussa_Detail_MyT6A**

   An alternative is to use the **Save As** operation and then copy the the **AppCond** directory from **DeGrussa_Detail_T4_Completed** to **DeGrussa_Detail_MyT6A.**

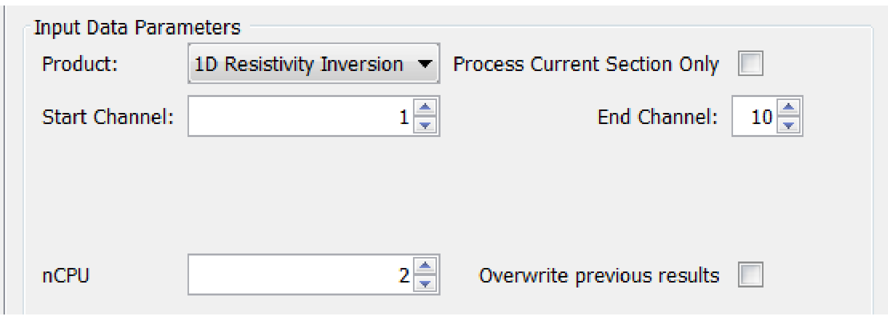
4 Choose **Geophysics > EM Modelling > Launch EM Modelling** from Main Menu



The controls for setting up a 1D Resistivity Inversion are relatively straight forward.

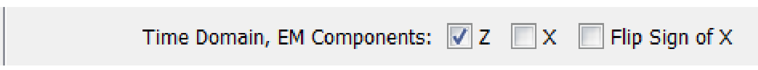
Input Data Parameters

1 Choose **1D Resistivity Inversion** from the **Product:** dropdown



The component selection above Input Data Parameters will default to Z only as shown below.

We only support 1D Inversions for the measured vertical component Z because of the underlying 1D assumptions.



2 Do NOT toggle **Process Current Section Only**. We want to invert all sections.

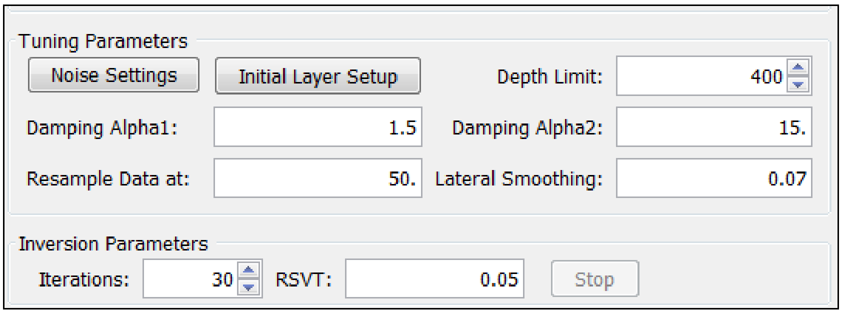
3 For Channel Selection accept defaults: **Start Channel 1** and **End Channel 10**

4 Choose **nCPU = 3**; this allows MPI to invert all 3 sections in parallel.

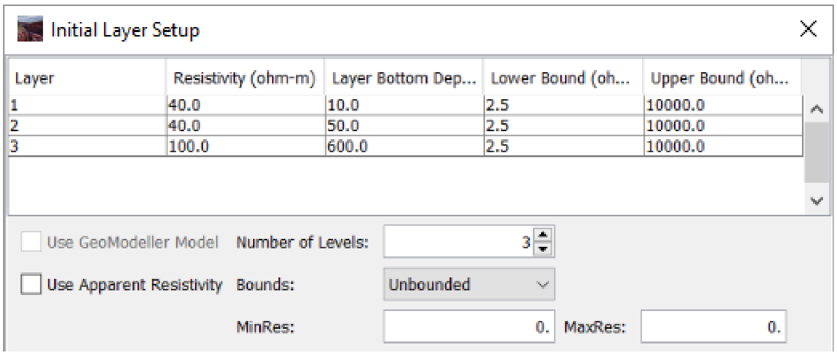
5 Do NOT toggle **Overwrite previous results**; this option triggers an overwrite of the previous 1D Inversion Run

1D Inversion Tuning Parameters

Tuning parameters may need to be adjusted depending on the survey system being used and also on the geomorphological and geological properties of the survey environment. The tuning parameters are described in detail below.



1 **Initial Layer Setup**: This defines a rough starting model for the 1D inversion which is later resampled to a more detailed model as illustrated in the context sensitive Help at the base of the **EM Modelling Wizard**.



- Leave the current 3 layer starting model as the default. You might change the layer depths, resistivities and allowed ranges if you have a priori knowledge of conductivities from existing drilling. However the software is smart enough to adapt to different layer conductivities and depths automatically if the chosen starting model does not fit the observed data.
- The **Use GeoModeller Model** option is shaded out as currently no other starting model is supported in 1D Inversion. In the future it is planned to allow use of a starting or reference model from the GeoModeller project as is currently possible in 2.5D.

2 **Depth Limit**: **400m**

This does not restrict the calculated model calculation to this depth. It simply truncates the resulting inversion model at this depth when displaying and reporting the inversion output. Leave as the default for this training.

3 **Damping Alpha1** and **Alpha2**: **1.5 and 15**

These are weights applied to the first and second vertical conductivity derivatives. Larger values will give smoother vertical sections. Leave as default for this training.

4 **Resample Data at: 50m**

This is the length of a moving average filter. The measured data is often oversampled ie 10Hz. This moving average filter smooths the data, reducing the sampling rate (sample interval) which speeds up the calculation and visualisation process. We effectively down sample the response to say one sample every 100m. Leave as the default for this training.

5 **Lateral Smoothing**: **0.05**

Lateral smoothing misfit ratio; Smoothing is applied during 1D inversion such that the final result is within the selected misfit when compared to running an inversion on individual points. Expressed as a ratio.

- Ratio = (unsmoothed-smoothed)/unsmoothed).

6 **Number of Iterations: 30** (default)

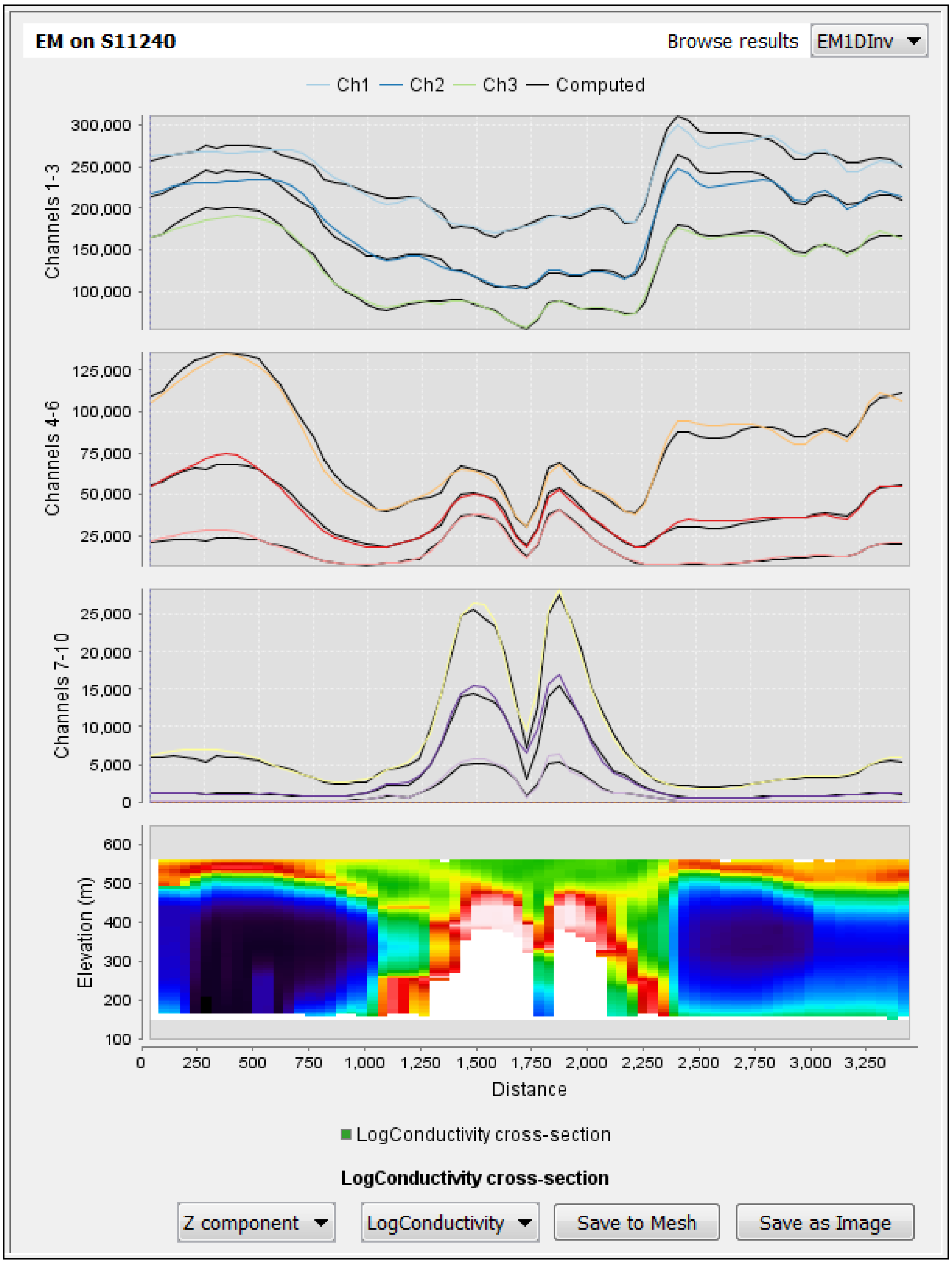
Maximum number of iterations for inversion

7 **RSVT = 0.05** (default)

Relative Singular Value Truncation. Allows the user to dampen changes in non-sensitive cell conductivities for each data point during the initial stages of the solution. Should be 2 to 3 times the value of the expected Signal to Noise ratio. Percent expressed as a fraction.

8 Click **Compute** to start inversion. Progress is logged in the console window below the 2D and 3D Viewers. Computation for 3 sections will take ~5 mins.

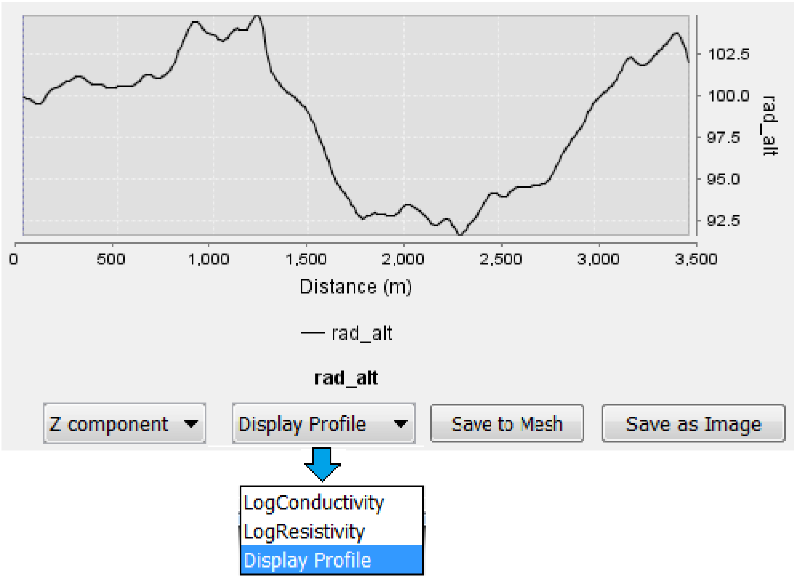
9 Wait for the **Completed** dialog to pop up. On completion the results for the first section, **S11240**, will appear in the right hand profile and section panel.



10 The user can cycle through the results for each section using the cursor Up/Down arrow keys once the **Vertical sections** dropdown list at the top of the main left panel has the focus or simply choose a section from the list.

- The 3 panel profile display shows the inverted profiles in black over the resampled measured data. It is clear the Misfit is very good.
- Clicking in the profile panels and hovering over a profile gives feedback on the measured and inverted profile values and their location along section.
- The **LogConductivity** section is displayed below the stacked profile display. However apart from the upper shallow cover the geological structure is unclear indicating a breakdown in the 1D assumption.
- Clicking in the section and moving the cursor provides feedback on location and log conductivity value. The 1D inversion results have been interpolated from vertical columns of results below each station.

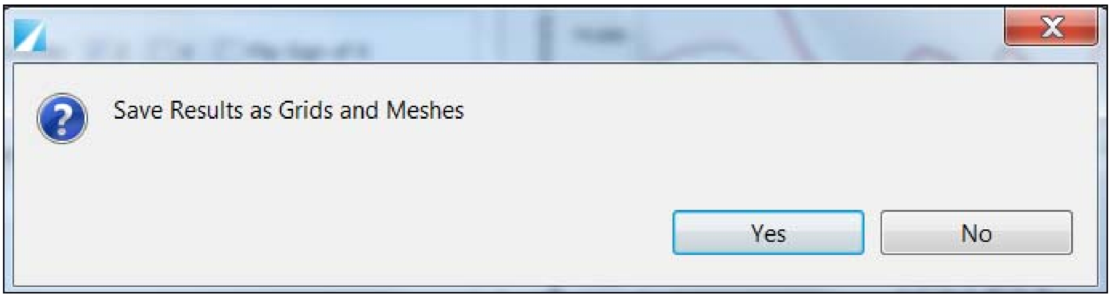
- Clicking on the **LogConductivity** dropdown below the section window allows the user to display a LogResistivity section or an extra profile of the chosen **Display Profile** field i.e. **rad_alt**.



- Click on **Save as Image** to save a snapshot of the profile and section display panels.

11 Press **Save to Mesh.** You are asked to confirm the saving of results to the **Grids and Meshes** tree. EM modelling results are saved into a **Mesh Grid point vertex** structure for further visualisation and analysis using Mesh Grid tools.

12 Click **Yes** to save results



- Note: At the completion of the 1D Inversion all the inverted section results (if more than one) are compiled into a single results file. When saved to **Grids and Meshes,** all of the section 1D Inversion rsults are stored in one vertex mesh. This allows display and analysis of results with one operation.
- The vertex mesh grid is named **EM1DInv01_SmthSecs**

13 Save your project

From the main menu choose **Project > Save** or click the **Save** button on the main toolbar

This ensures that changes are captured in your project so that you can continue to the next stage without having to repeat any of the above steps again.

You should have already saved with the name (using our example project folder): **`d:\tutorial_e\SPECTREM\DeGrussa_Detail_MyT6A`** at the start of this tutorial section.

DO NOT USE **Save As** at this point as you will lose the **AppCond** and **1DInv** subdirectories from your project.

Discussion

There is a behind the scenes logging process that captures elements of the computational performance of this process and the inversion RMS error.

The following is an extract from the MPI information logs for the above task.

```
----------------------------------------------------------------------------------------
Number   Line Number
    1       11240
Processing Line 11240
Formed Data File EM1DInv_1_L0011240.xyz  Line 1 of 1 at node 0
Opened Line File EM1DInv_1_L0011240.xyz
Air_Lay_Inv completed inverting Line 11240 with RMS error  6.73%
  ----------------------------------------------------------------------------------------
Number   Line Number
    2       11250
Processing Line 11250
Formed Data File EM1DInv_1_L0011250.xyz  Line 1 of 1 at node 1
Opened Line File EM1DInv_1_L0011250.xyz
Air_Lay_Inv completed inverting Line 11250 with RMS error 18.65%
----------------------------------------------------------------------------------------
Number   Line Number
    3        11260
Processing Line 11260
Formed Data File EM1DInv_1_L0011260.xyz Line 1 of 1 at node 2
Opened Line File EM1DInv_1_L0011260.xyz
Air_Lay_Inv completed inverting Line 11260 with RMS error 18.77%
----------------------------------------------------------------------------------------
All lines in the data set were inverted
The time taken is equal to   0 hours   5 minutes  51 seconds
----------------------------------------------------------------------------------------
```

A more detailed log is available for each section in the project subdirectory:

`EM1DInv\EM1DInv_1\Inversion_01\Log_Files`

A quick way to navigate to this directory is to:

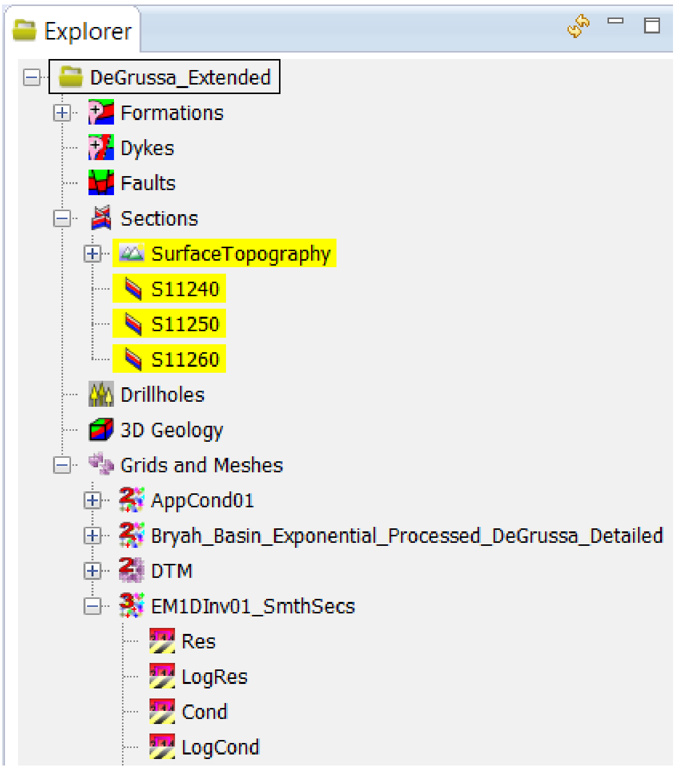
- Right Click on the top of the **Explorer** tree and select **Show in Folder** and then navigate down to the above subdirectory.
- The detailed log contains information for each 1D column inversion

Mesh Grid Visualisation - 1D Inversion

Parent topic: Tutorial T6: 1D EM Inversion - Time Domain

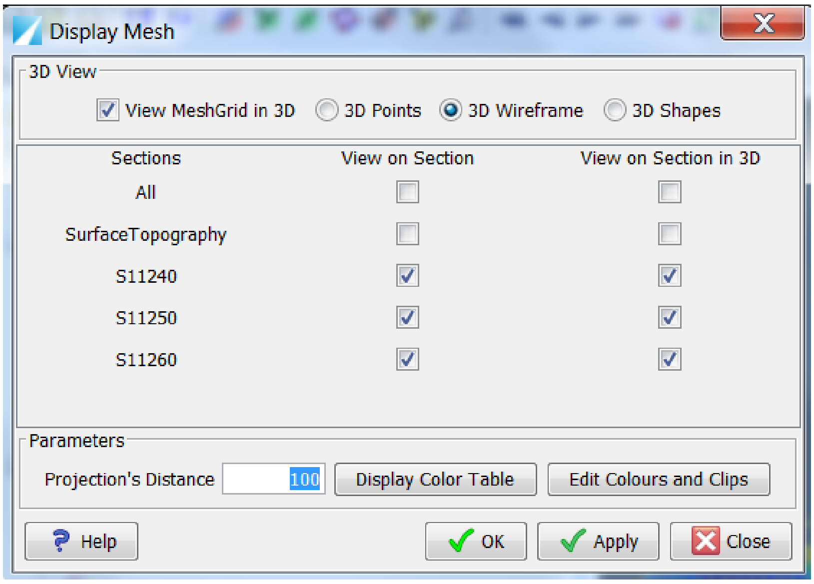
1 Open the section viewers for sections **S11240, S11250, S11260**. You can do this by Double Clicking each section in the **Explorer Sections** tree or by Right Clicking on the **Explorer Sections** item and choosing **Open All 2D Viewers.** Do not use the latter if you have a large survey with more than 50 flight lines.

- Right Click on **Explorer** > **Sections > Background Colour** and set to dark grey
- Open the Grids and Meshes tree in Explorer. A Mesh with the database name **EM1DInv01_SmthSecs** will be listed in the Grids and Meshes tree as shown below



2 Right Click on the **LogCond** channel**,** select **Appearance** and set Vertex Symbol size to **0.5**.

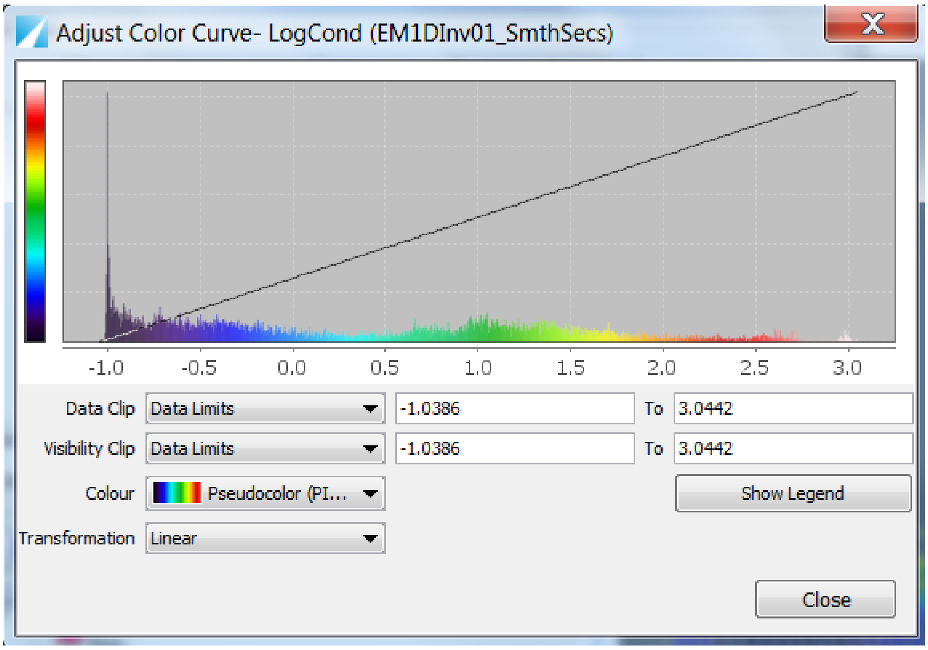
3 Right Click on **LogCond** and select **Field Visualisation Manager**



4 Toggle**View MeshGrid in 3D** and toggle **3D Wireframe**

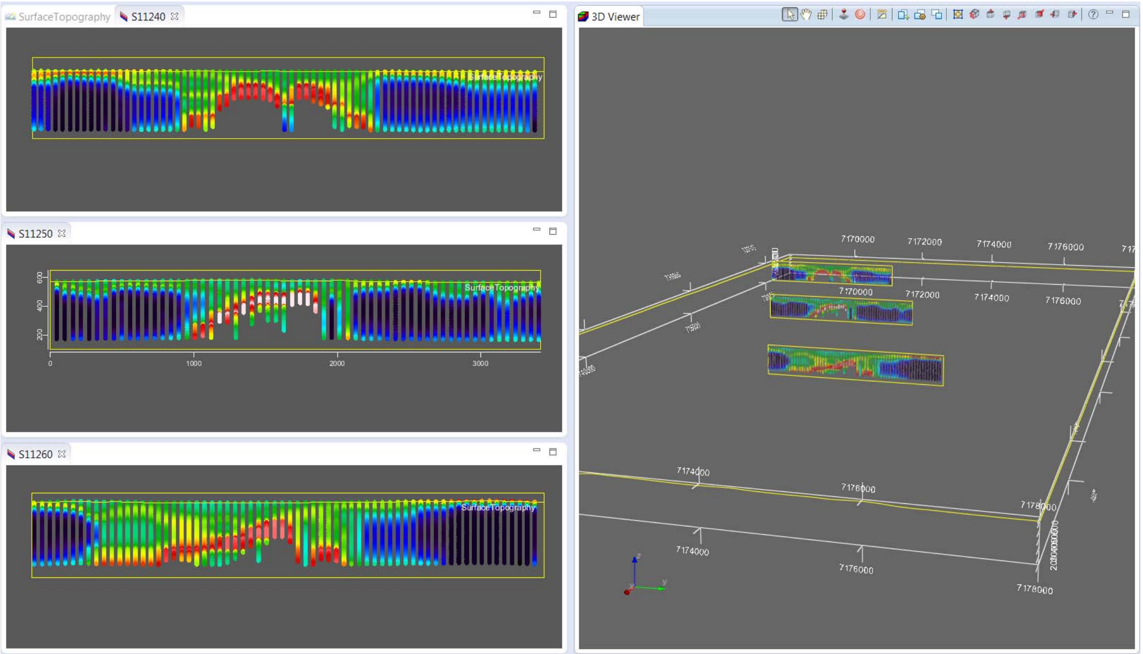
5 Toggle **View on Section** for **All** and untick **Surface Topography**

6 Click on **Edit Colours and Clips** and choose Colour LUT **Pseudocolor (PITS)** and use the default Data Limits stretch with a Linear transform as shown below:



7 Click **Close** and then Click **OK** in the previous dialog to trigger the display

8 Examine the results in the 2D and 3D Viewers.



Note that results are plotted as points and not interpolated to ensure there no artifacts from interpolation

9 Save your project

From the main menu choose **Project > Save** or
from the toolbar choose **Save** or
press CTRL+S.

We must now load a previously saved project as we want to review a geological interpretation that has been previously constructed using the 1D EM Inversion and the surface geological map.

10 Choose **Project > Open**

In the **Open a project** dialog box navigate to (using our example project folder **`d:\tutorial_e`**):

`d:\tutorial_a\SPECTREM\DeGrussa_Detail_T6_AGeolMod\DeGrussa_Detail_T6_AGeolMod.xml`

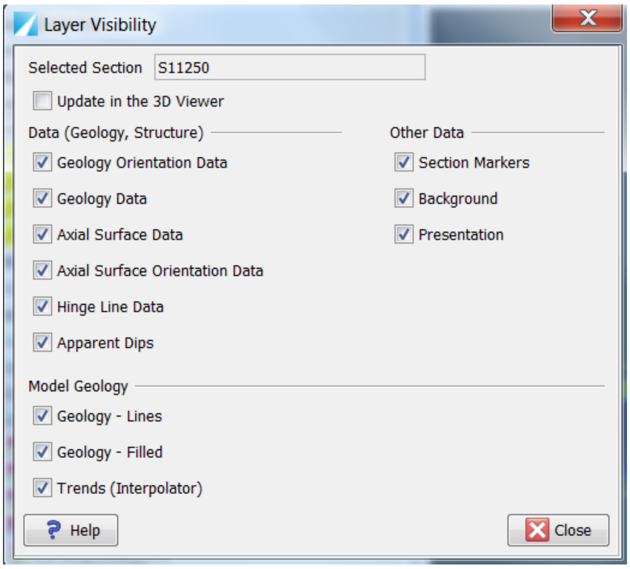
We will use this project temporarily to examine a preliminary geological model and run a 2D Forward model. If you would like to save your own working copy then use Windows Explorer to copy this project directory to your work area and rename the directory to **`DeGrussa_Detail_T6_MyAGeolMod`**. Load this copy into GeoModeller.

Note: We do continue with this project in the next Tutorial.

11 Select **Section S11250**; note that we have interpreted geology for this section. The geology is based on the surface map and on the results of the 1D inversion.

To better visualise the 1D EM inversion results you can hide items on the section display using the **Set Layer Visibility** table.

12 Right Click in the 2D Section window and select **Set Layer Visibility**

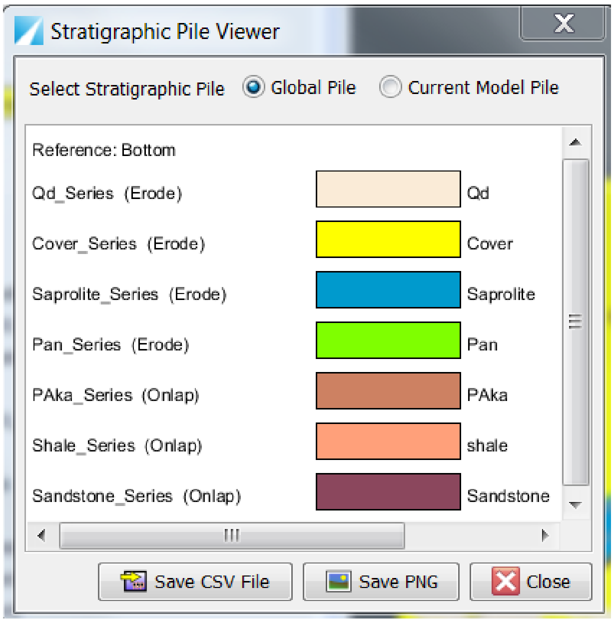


- We can hide the geological Data and the geological Model by deselecting **Geology Data, Geology Lines** and **Geology Filled**. You must remember to turn these options back on afterwards otherwise the geology display options will appear not to be working! Leave the dialog open while you experiment with the toggle switches in this table
- We can also choose just to remove the computed Model data by Right Clicking in the 2D Section and selecting **Erase All Model Geology**
- Alternatively we can hide the displayed 2D Mesh grid data in the 2D Viewer using the Image Manager as shown in T4: Apparent Resistivity

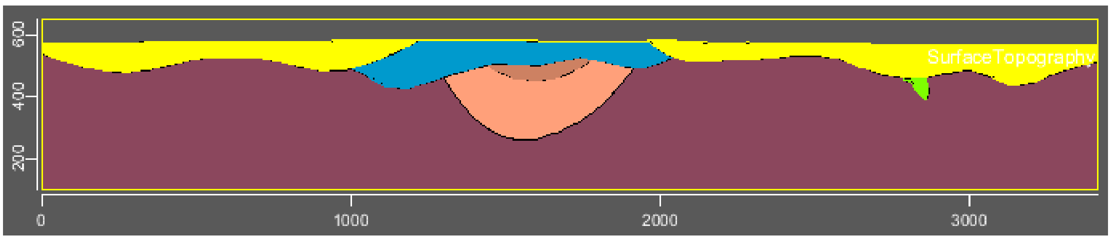
Creating the Geology Model for Section S11250

We have created a rough geology model for section S11250 from the 1D Inversion and the 2D surface geology map using the following steps. DO NOT execute the following steps as we do not have time to teach this geological model building exercise. Follow your trainer as the individual steps are discussed.

- Set up a stratigraphic pile based on the surface geology map with the addition of a regolith layer in the area mapped as outcropping shale and sandstone outcrop. We have done this because the 1D inversion indicates weathering like resistivities in the outcropping area and the more conductive lower sediments do not penetrate to the surface.



- Digitise the Quaternary drainage on the surface cuttins section S11240
- Digitise the base of conductive cover from 1D Inversion; Cover is an Erode Layer
- Digitise boundaries for the **PAka** and **PAks** (Shale) from the surface geological map. We choose a synclinal structure based on the folding indicated on the geological map and we use some orientation data from the surface map.
- Digitise a small outcrop of **Pan** the younger volcanic Fm to the north and assign **Erode**.
- Add a **Saprolite** Erode layer to explain the lower resistivities over surface outcrop.
- The computed section geological model is shown below and is considered to have a low reliability



- We have finished the geology model building overview and now you will execute the following steps.

We now assign resistivities to the individual formations using the 1D Inversion Resistivity results

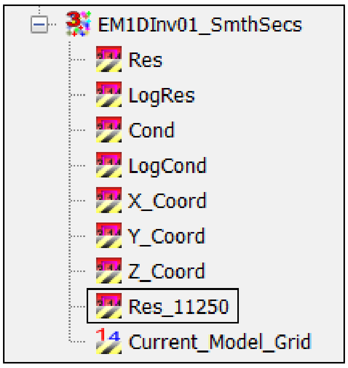
The procedure is as follows:

1 Right Click on mesh grid, **EM1DInv_01** and choose **Add Current Model Field**

- **Current_Model_Grid** appears as a field in the **EM1DInv_01** mesh grid

2 Right Click on mesh grid, **EM1DInv_01** and choose **Create Coordinates (X,Y,Z) fields**

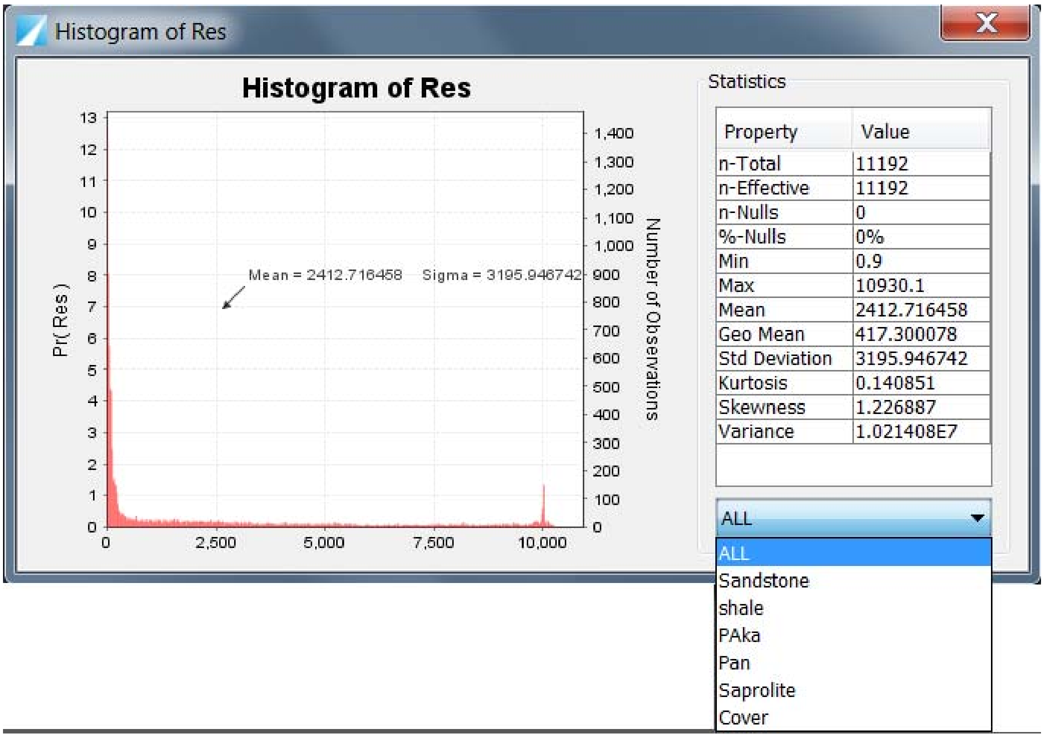
- **X_coord, Y_coord, Z_coord** fields appear in the **EM1DInv_01** mesh grid



3 Save your project

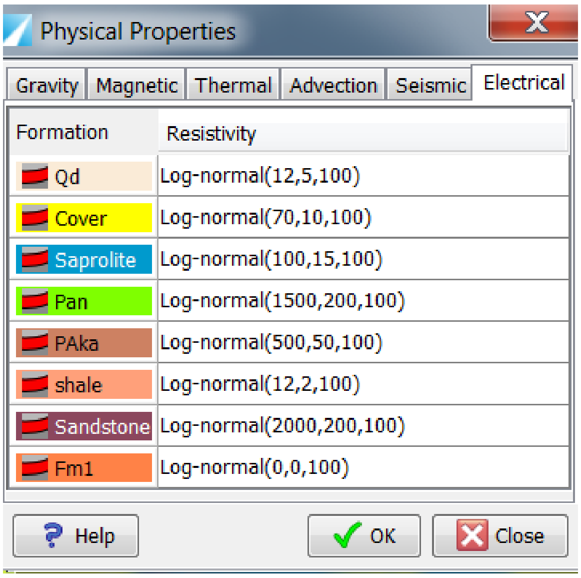
From the toolbar choose **Save**

4 Right Click on Res (Resistivity) field in **EM1DInv_01** & select **Histogram**



5 Examine the statistics for each formation in turn and choose a resistivity. Keep values on the low side as resistivity data are highly skewed; usually the Geometric Mean is a better indicator of the true resistivity.

6 Select **Geophysics > Define Physical Properties**, click on the **Electrical** Tab and enter the Mean and StdDev for each Formation based on the estimates from the Histogram tool.



- Because our geological model is for just one section, S11250 our 1D Inversion results for all sections will not give accurate statistics. We should run the 1D inversion for this section only or filter the results in the mesh grid to obtain just those for section S11250. Since the section is S to N we could do this with a calculator formula filter based on the X coordinate in our mesh grid.

  i.e. *If(((X_Coord > 734300) AND (X_Coord < 735700);Res;NaN)*

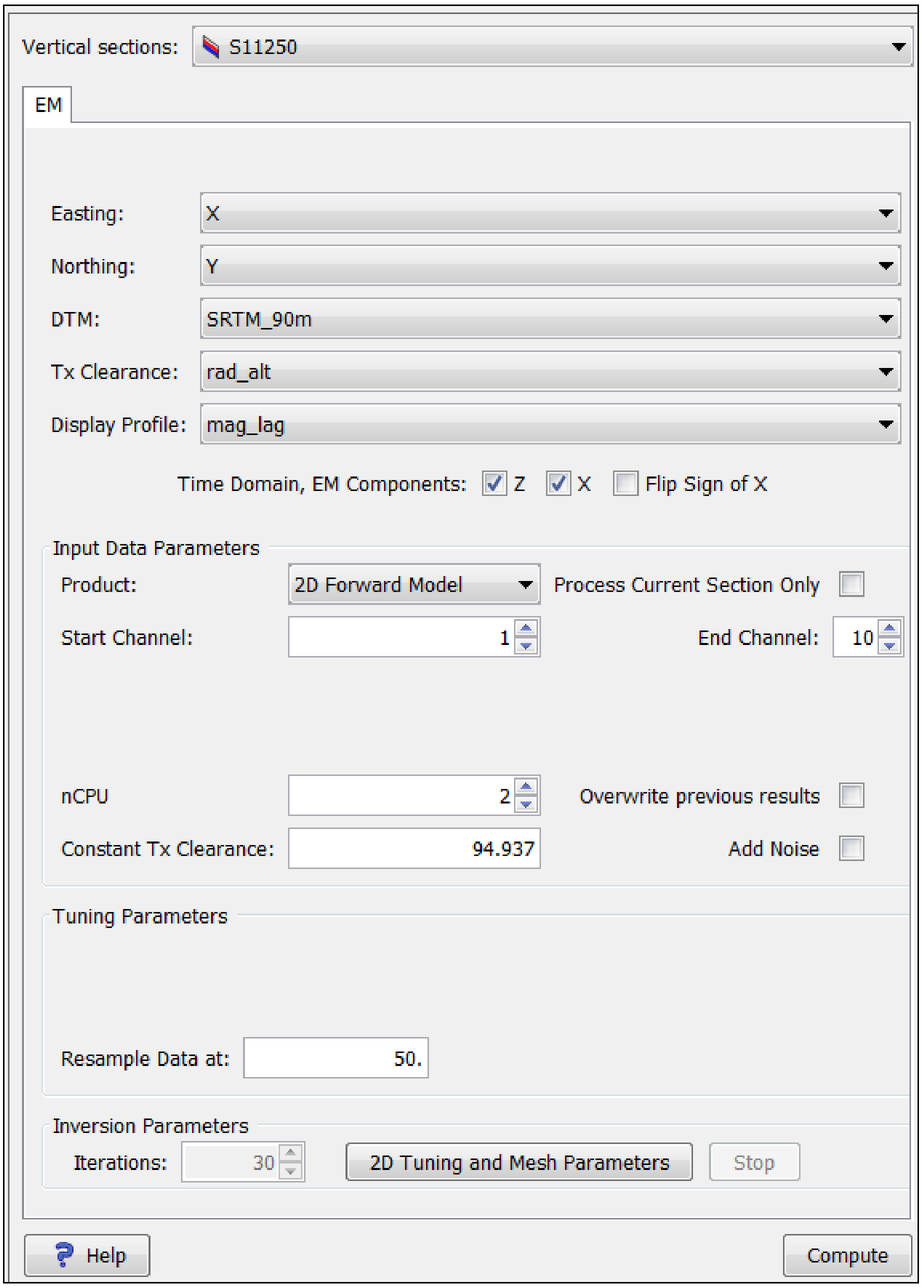
  We will not pursue this here. The recorded results in the completed project for this Tutorial are accurate enough

Compute a 2.5D Forward model for Section S11250

1 Launch the **EM Modelling Wizard**

2 Select section **S11250**

3 Choose **2D Forward Model** and toggle **Process Current Section Only**



The parameters that must be considered are:

1 **EM Components: X and Z**, the default

2 **Start and End Channel: 1 to 10**, the default

3 **nCPU: 4**, fast as we can

Note: On an 8 core hyper-threaded machine two virtual cores are created for each physical core; under MPI only the 4 physical cores are useful; using more than 4 cores results in reduced performance

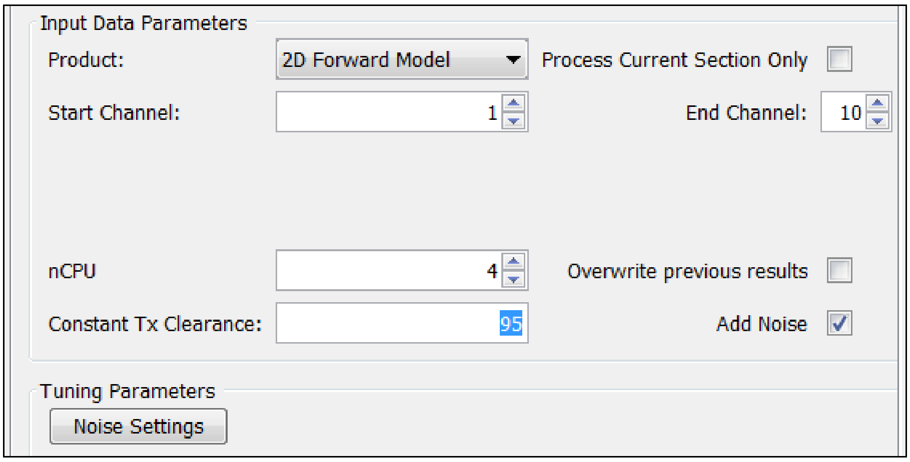
4 **Constant Terrain Clearance: 95,** just bigger than the default which is automatically chosen so that the bird does not hit the ground (DTM); if we want to use the survey drape the Clearance value must be entered as negative.

5 **Depth Limit: 400m**

6 **Resample Data at: 50m**

7 **Add Noise**

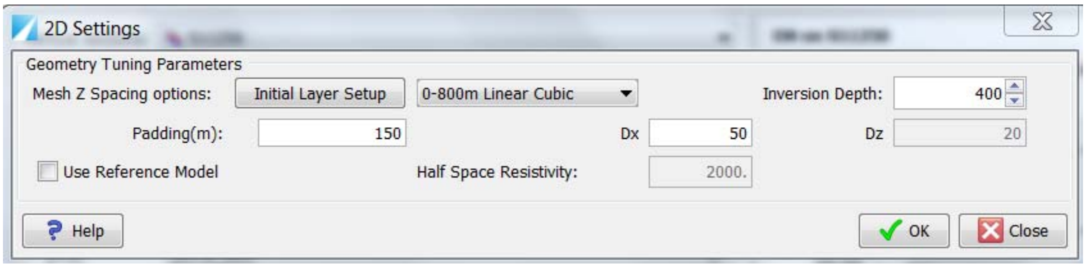
We have the option of including system noise in our forward model calculation by selecting the **Add Noise** toggle. This exposes the **Noise** button available for the other products. We can use our previously defined survey noise or adopt another noise model.



8 **Overwrite previous results**

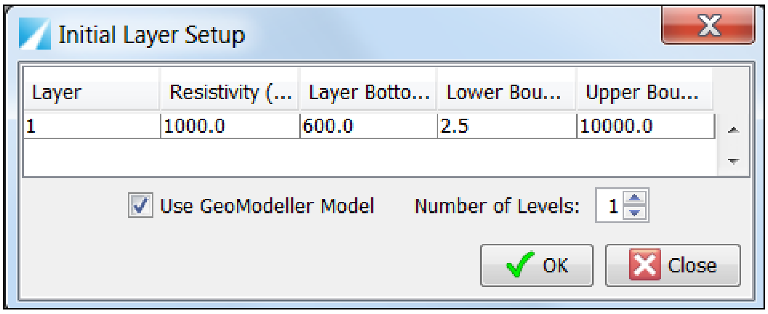
We also have an **Overwrite previous results** toggle for overwriting the previous forward model results run.

9 Open **2D Tuning and Mesh Parameters** and set the following parameters



10 **Mesh Z spacing options:**

- Click **Initial Layer Setup: Toggle *Use GeoModeller Model*** so that the forward model is done on the current GeoModeller geological model with resistivity properties set. The **Layer** setup table is not used.
- Click **OK** to accept



- Choose **0-800m Linear Cubic** from the second dropdown. Options are:
  - **0-800m Linear Cubic** (the default) or
  - **0-500m Compound Depth** or
  - **User Supplied** (Turns on the **Dz** entry box; user sets a fixed value for **Dz**)

11 **Inversion Depth: 400m**

12 **Padding: 150m**, the default

13 **Dx: 50m**, compatible with our 1D inversion resolution.

14 **Use Reference Model** (only relevant for 2.5D inversion)

15 **Half Space Resistivity** (only relevant for 2.5D inversion)

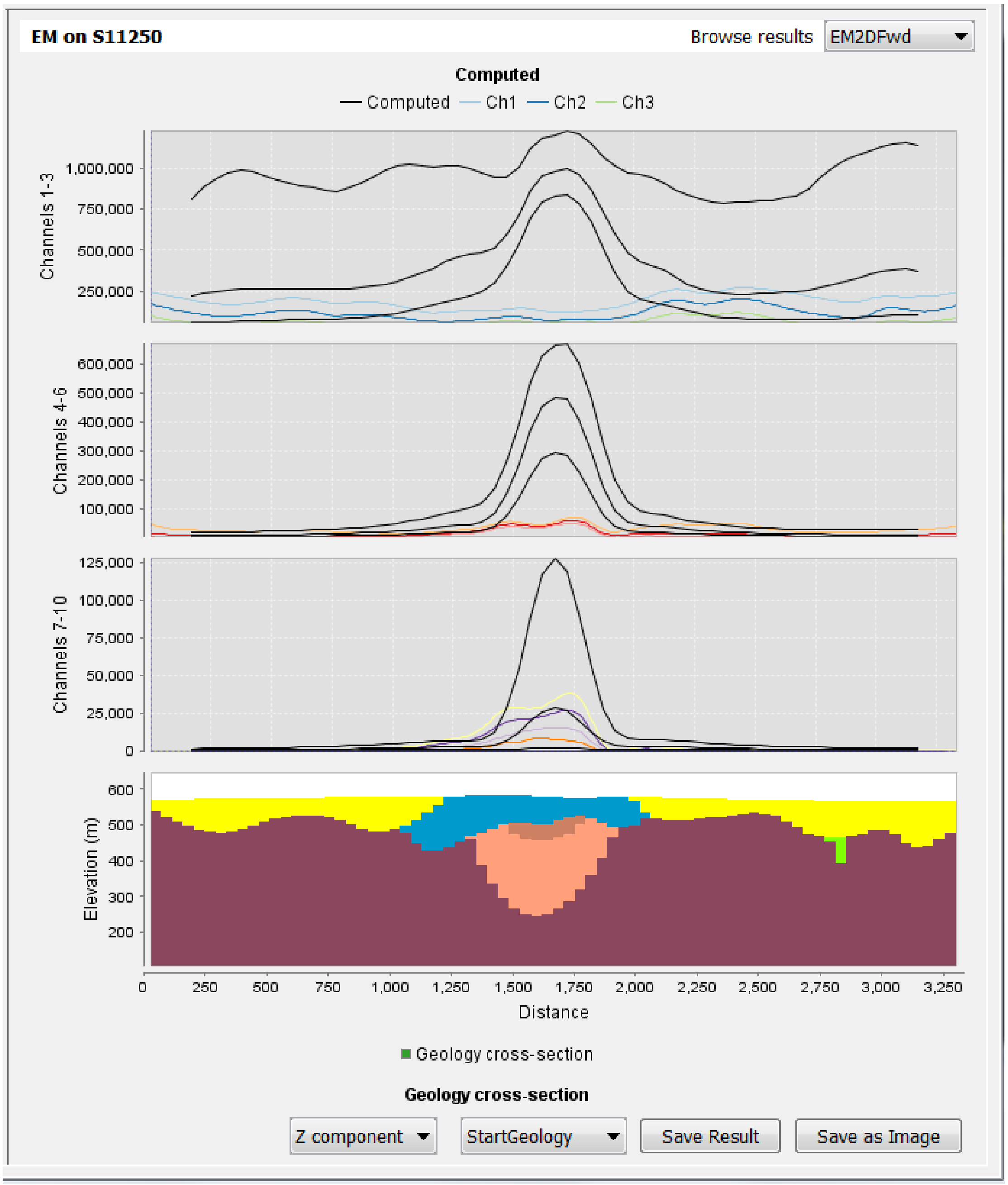
16 Click **Help** to see details of the **Mesh Z Spacing Options**

17 Click **OK** to accept settings and close dialog

18 Click **Compute**

19 Click **Yes** to **Run it as a background Process**; you are advised that it will use the current GeoModeller geological model.

- Progress will be logged to the window below the 2D and 3D Viewers
- On completion the results will be visible as black profiles (over coloured observed) with the starting resistivity section (**StartResistivity**) or geology model (**StartGeology**) available below.
- The result is a very poor fit to the measured data and illustrates the problems of Forward modelling. The property distributions can be very variable even within single units making accurate forward modelling of observed data extremely difficult to achieve. Hence the need for 2.5D or 3D inversion
- Forward modelling is also useful for evaluating the response of commercially available EM systems over a particular target style i.e. choosing a suitable AEM system with the most suitable characteristics for a planned survey.



20 Choose **StartGeology** and then **Browse results** of other Forward models (**Em2DFwd_03** to **06**) for **Section S11250** using the dropdown at top right of above panel. Check the forward profile results in black relative to observed and compare with the changes in **Start Geology**. Examine the X and Z component profiles.

21 Save your project ; From the toolbar choose **Save**

Tutorial T7: 2.5D EM Inversion - Time Domain

Parent topic: **Tutorial E (Airborne EM Forward Modelling and Inversion)**

With Geomodeller 2014, there is support for both 1D inversion and 2.5D forward and inverse modelling of AEM data. This tutorial focuses on 2.5D inversion.

1D inversion is relatively rapid and is a recommended starting point for shallow broad scale geological cover (regolith). It provides a quick look at what the EM signal conveys about the immediate near surface geology assuming a series of relatively flat geological layers.

However 1D Inversion will give poor results when the 1D assumptions are not met and this is where 2.5D inversion excels.

By comparison with 1D, 2.5D inversion is much slower and is memory and CPU intensive but the results are often excellent. For example, the 1D inversion of section S11250 (3.5kms) takes 5 minutes using one MPI node whereas 2.5D inverts in ~1 hour using 4 MPI nodes and the fast option.

2.5D inversion makes use of both X and Z components and two component inversions are particularly effective for towed bird systems such as SPECTREM and TEMPEST.

For systems where the transmitter and receiver are close together and very close to the loop centre (VTEM and SkyTEM) it becomes more difficult to obtain benefit from dual component (X and Z) inversion. In these systems the X component suffers from low amplitude and noise problems related to loop geometry.

T7 Overview

Parent topic: **Tutorial T7: 2.5D EM Inversion - Time Domain**

In this tutorial we:

1. Load your project and choose **2.5D Inversion** from the drop down **Product:** list
2. Set up the 2D Tuning parameters
3. Run a 2.5D Inversion for one section using 4 MPI nodes if time permits
4. Visualise the 2.5D Inversion results in 2D and 3D and compare with 1D.
5. Examine how 2.5D inversion using a starting or reference model built using mapping and 1D inversion results impacts the final outcome.

Load your project

1. Open your project using the saved version from the previous section if not still open. It can be selected from the Recent Projects list in the main Project menu. From the main menu choose (using our example project folder `d:\tutorial_e`):

   Project > Recent Projects
   `d:\tutorial_e\SPECTREM\DeGrussa_Detail_MyT6A`

   Alternatively:

   If there is insufficient time for users to run a 2.5D inversion of their own then begin with the DeGrussa_Detail_T7_Completed project provided!

   Choose **Project > Open**

   In the **Open a project** dialog box navigate to (using our example project folder `d:\tutorial_e`):

   `d:\tutorial_e\SPECTREM\DeGrussa_Detail_T7_Completed\DeGrussa_Detail_T7_Completed.xml`

2. Save your own copy of this project. Use Windows Explorer to copy and rename as **DeGrussa_Detail_MyT7** in your current working folder. Load the project into GeoModeller.

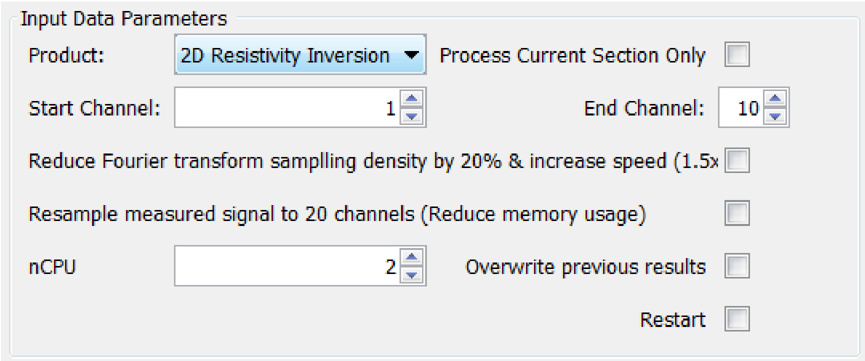
Compute a 2.5D Inversion for Section S11250

1 Launch the **EM Modelling Wizard**

2 Select section **S11250**

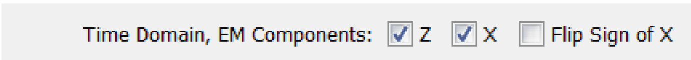
2D Inversion Input Data Parameters

1 Choose **2D Resistivity Inversion** from the **Product:** dropdown



2 The component selection automatically defaults to **Z** and **X** when two components have been loaded from the survey database. Some systems (SkyTEM) use an opposite sign convention for the **X** component and hence the **Flip Sign of X** toggle.

- Accept the component defaults



3 Toggle **Process Current Section only** (that is all we have time for).

4 For **Channel selection** accept the default: **Start Channel 1; End Channel 10**

5 **Reduce Fourier transform sampling density by 20% & increase speed (1.5x)**

ON: Toggle **ON**, we want to finish as quickly as possible. This reduces the no of points per decade during fourier transformation with very little loss of accuracy.

6 **Resample measured signal to 20 channels (Reduce memory usage)**

OFF: For systems such as VTEM there may be up to 40 measurement channels and some data redundancy. Processing a large number of channels impacts memory usage. We provide the option of reducing the number of channels to 20 to reduce memory usage. This has no impact for 10 channel SPECTREM so accept the default **OFF.**

7 **nCPU: 4**

Set the number of MPI nodes to the number of physical cores. This increases memory usage but should be OK on an 8GB laptop with nothing else running.

Note: On an 8 core hyper-threaded machine two virtual cores are created for each physical core; under MPI only the 4 physical cores are useful; using more than 4 cores results in reduced performance

8 **Overwrite previous results: OFF**

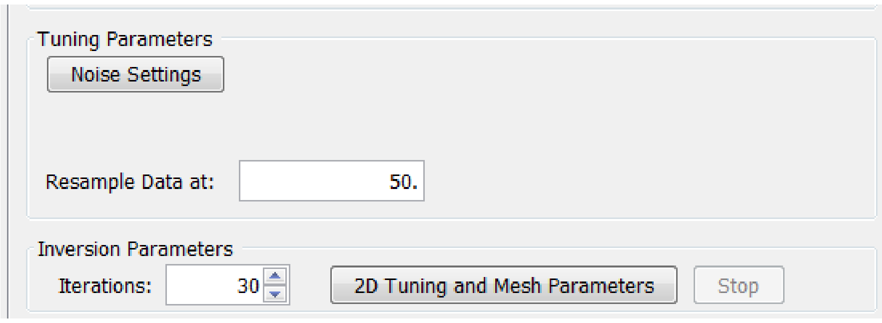
This enables you to overwrite a previously failed or poor quality inversion run. When overwrite is **OFF** the previous run directory is renamed using a numeric suffix: i.e. EM2DInv (new/current), EM2DInv_01, EM2DInv_02 with higher numbers being more recent runs.

9 **Restart: OFF**

This option allows you to restart an inversion run from its last iteration if it stopped prematurely or did not fully converge. The inversion settings do not change. The number of iterations under Inversion Parameters must increase i.e. 30 to 40. You can also change the number of MPI nodes.

2D Inversion Tuning Parameters

Tuning parameters may need to be adjusted depending on the survey system being used and also on the geomorphological and geological properties of the survey environment. The tuning parameters are described in detail below.



1 **Noise Settings** remain unchanged

2 **Resample Data at: 50m**

This is the length of a moving average filter. The measured data is often oversampled ie 10Hz. This moving average filter smooths the data, reducing the sampling rate (sample interval) which speeds up the calculation and visualisation process. Here we are effectively down sampling the response to one sample every 50m.

3 **Iterations: 30**

Leave as the default. The inversion can be restarted if convergence is incomplete i.e. the convergence graph has not stabilised - flattened out.

4 **Stop**

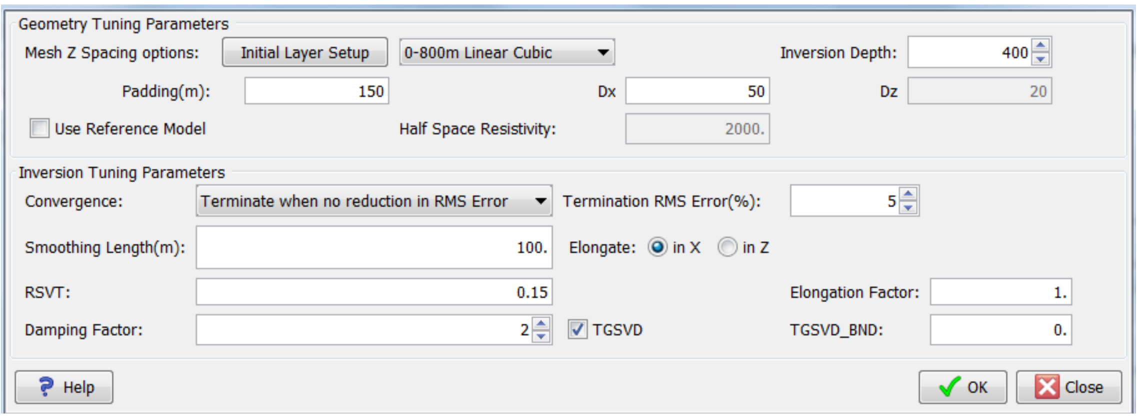
Use this option to stop the 2D inversion at the next iteration when running from the GUI. If running from batch mode then the user must edit the file **`Stop_File_00.fmt`** in the inversion directory:

`EM2DInv\EM2DInv_01\Inversion_01\Line_0031270`

Change the file contents from **Do Not Stop** to **Stop**.

2D Inversion Tuning and Mesh Parameters

1 Click on **2D Tuning and Mesh Parameters**



2 **Mesh Z spacing options:**

- Click **Initial Layer Setup:**

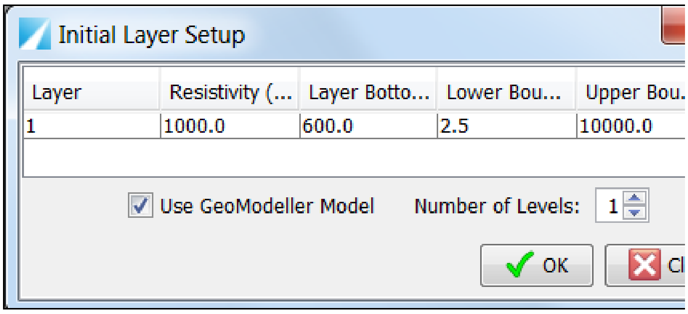
  There are two options:

  - Toggle **Use GeoModeller Model** to use the current section geological model and resistivity properties

    OR

  - Setup a single Halfspace Layer as shown below using 1 Level.

- Choose the second Halfspace option



- Click **OK** to accept

3 Choose from the **0-800m Linear Cubic** dropdown

- **0-800m Linear Cubic** (default) or
- **0-500m Compound Depth** or
- **User Supplied** (Turns on the **Dz** entry box, set a fixed value for **Dz**)

Leave Selection as the default option.

4 **Inversion Depth: 400m**

5 **Padding: 150m**, the default

6 **Dx: 50m**, compatible with our 1D inversion resolution.

7 If you chose **Use GeoModeller Model** mesh in **2.** above then you have two options:

- Toggle **Use Reference Model** to use the GeoModeller model and properties as the inversion reference model; a computed model must exist for the section chosen.
    - In this case choose the **Half Space Resistivity** for the starting model i.e. 1000 ohm-m.

  OR

- Do not toggle **Use Reference Model;** in this case the GeoModeller model and properties will be used as the starting model in the 2D inversion. This the least preferred option as it may unduly influence the course of the inversion and inhibit convergence.

Note: We are not using either of these two options here but just the simple half space defined in the Initial Layer dialog

8 Click ? **Help** to see details of the **Mesh Z Spacing Options**

9 **Terminate when no reduction in RMS Error** (default)

10 **Smoothing Length: 100m** (2xDx default)

11 **Elongation Factor:** 1 (no geometric anisotropy)

12 **RSVT: 0.25** (default is 0.15) - see context Help for more information

13 **Damping Factor: 2**

14 **TGSVD: ON** (default)

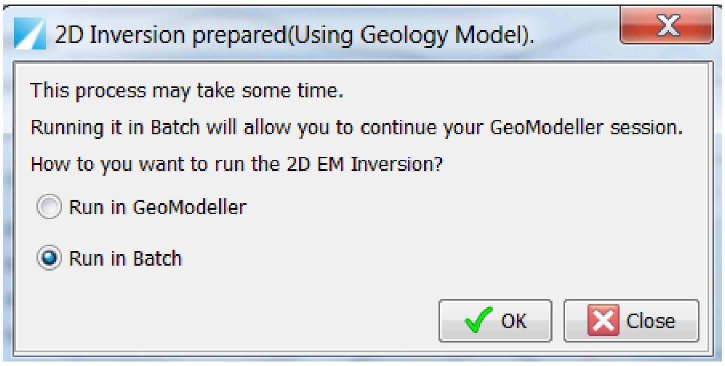
15 **TGSVD_BND: 0** (default)

16 Click on **? Help** for more detailed context sensitive Help on the above options.

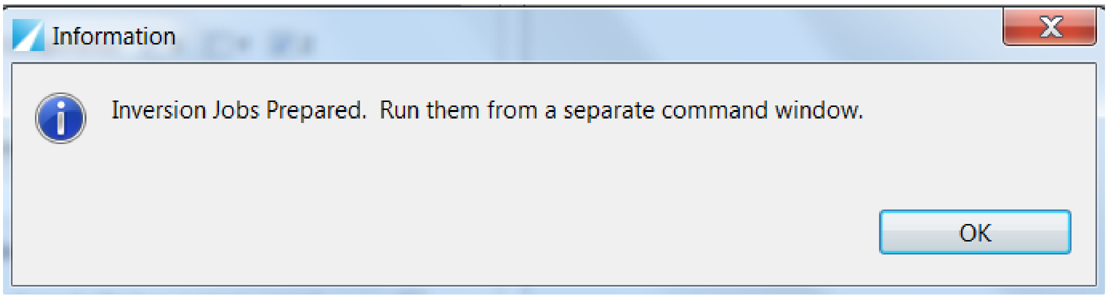
17 Click **OK** when complete.

18 Click **Compute** to run the 2D Inversion

- The following dialog opens asking whether you wish to **Run in GeoModeller** or in **Run in Batch** mode.
- Choose **Run in Batch** and Click **OK**



19 The following prompt will appear and a CMD window will open in the inversion directory from which you can run the batch job



20 Click **OK** to confirm you will run a batch file from the **CMD** tool

21 Go to the CMD window and type:

`RunAll.bat` ENTER

It is better to run 2.5D inversions from a batch file as running within GeoModeller and logging to the console blocks any other GeoModeller activity. Inversion iteration results cannot be visualised nor the Misfit graph opened.

The other advantage is more memory is available for 2.5D inversion. The user can still restart GeoModeller and reopen the project to review inversion progress as it runs. You may be inverting multiple sections in one batch process.

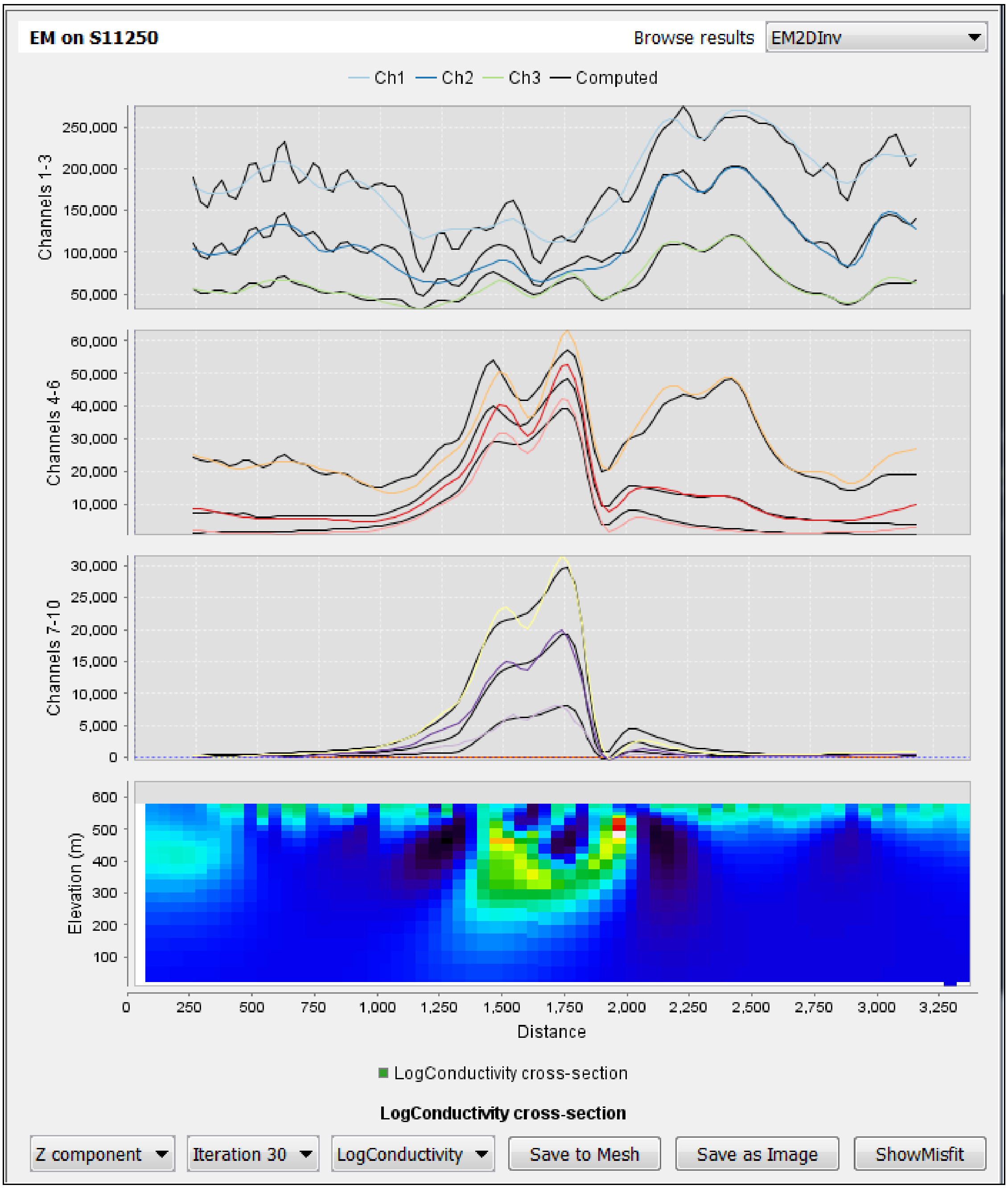
The procedure is:

- Run the EM modelling GUI
- Select 2D Resistivity Inversion
- Select a Section and Iteration to review the state of the LogConductivity section and profile misfits.
- Examine the misfit graph for an update on inversion convergence.

2.5D Inversion Visualisation and Analysis

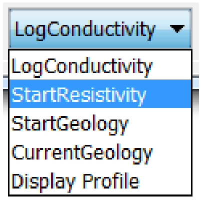
If running interactively then once the inversion is complete a dialog will popup and the right side profile and section panels will populate with results for the inverted section in similar fashion to 1D. See S11250 below.

If running in batch mode then the CMD tool log will indicate successful completion. You should then start GeoModeller, load the Modelling wizard and select **2D Resistivity Inversion** in the **Product:** dropdown.



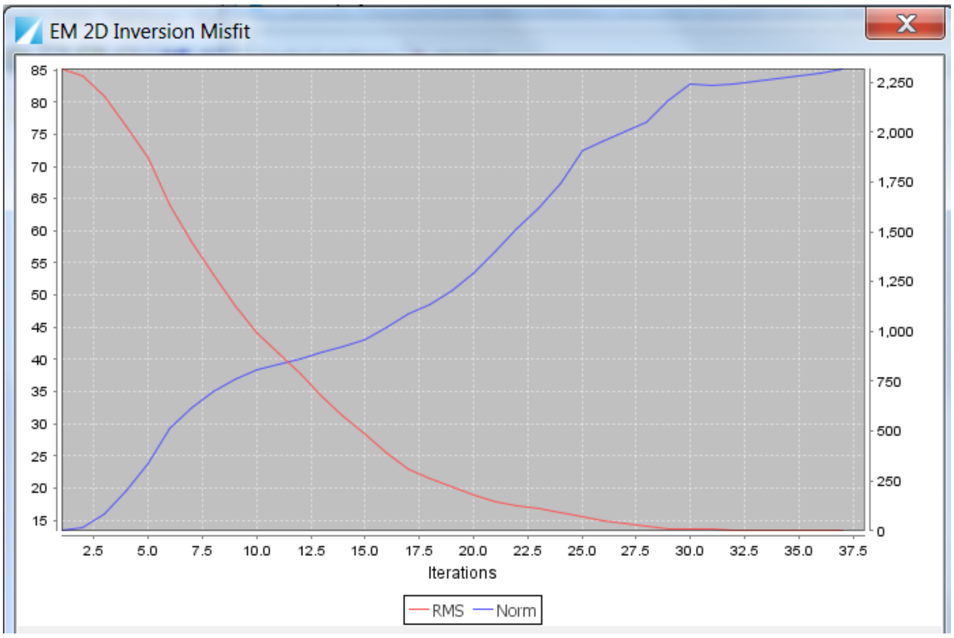
The 2D inversion visualiser has a richer set of controls and buttons to aid results analysis. These are described and illustrated below:

- As for 1D, the predicted/inverted black profiles are shown over the measured coloured profiles at the same scale so the interpreter has visual feedback on the misfit.
- The **Component** pull down can be used to select the component (X or Z) displayed in the profile viewer
- The **Iteration** pull down allows the user to browse inversion progress by iteration in both the Profile viewer and the LogConductivity section.
- The **Log Conductivity** pull down allows selection of the following products:



  - **LogConductivity** will load the inversion LogConductivity model for the currently selected iteration
  - **StartResistivity** will load the section Resistivity model used as the reference or starting model in the current inversion
  - **StartGeology** will load the section Geology model used as the reference or starting model in the current inversion.
  - **Display Profile** will turn the section view into a profile view so that the interpreter can see the TMI or other response on the same section.
- **Save to Mesh** saves the Resistivity/Conductivity inversion model for the last iteration of the current section to the Mesh Grid as a 3D point vertex mesh.
- **Save as Image** saves a snapshot of the profile and section panels for the current display.

- **Show Misfit** displays the RMS Misfit and Model Norm graph for the current section inversion.



Normally we would click **Save Result** to save the section inversion results to **Grids and Meshes**. For this tutorial we wish to explore previously saved results as we do not have time to run 2D inversions on all the sections.

1 Save your project

From the toolbar choose **Save**

2 Open the saved project for Tutorial T7

Choose **Project > Open**

In the **Open a project** dialog box navigate to (using our example project folder **`d:\tutorial_e`**):

`d:\tutorial_e\SPECTREM\DeGrussa_Detail_T7_Completed\DeGrussa_Detail_T7_Completed.xml`

We will now compare the results of 1D and 2.5D inversions on these three sections using the techniques we have been using in the previous Tutorials.

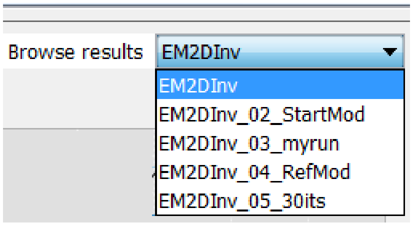
We make more use of the Mesh Grid displays where we are free of interpolation artifacts and have better control of scale.

In this environment we can also overlay drillhole data and look at image backdrops of previous CDI inversions.

You should now be sufficiently familiar with the display architecture to do this without detailed step by step instructions.

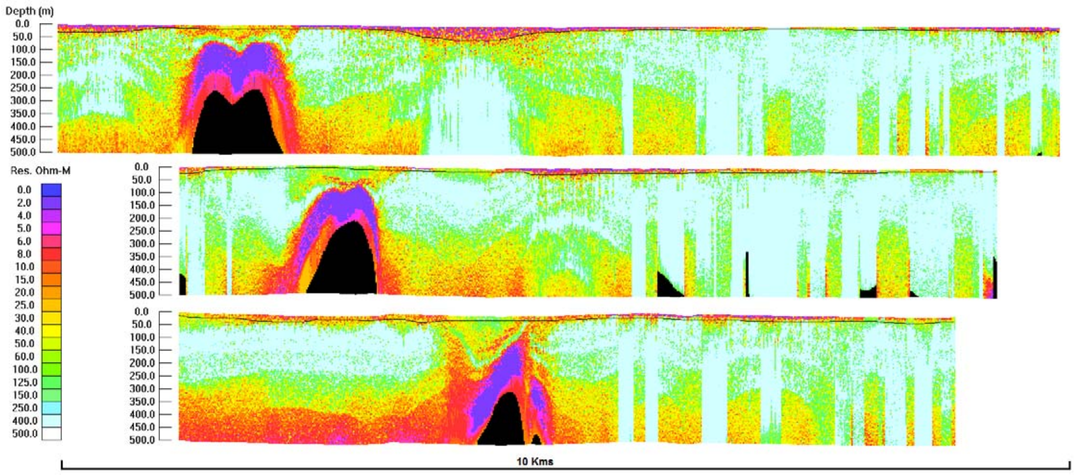
We also make use of a recently added option, **Browse results**, which allows us to look at previous inversion runs in the EM Modelling wizard.

This option appears on the Top right of the Profile results panel.

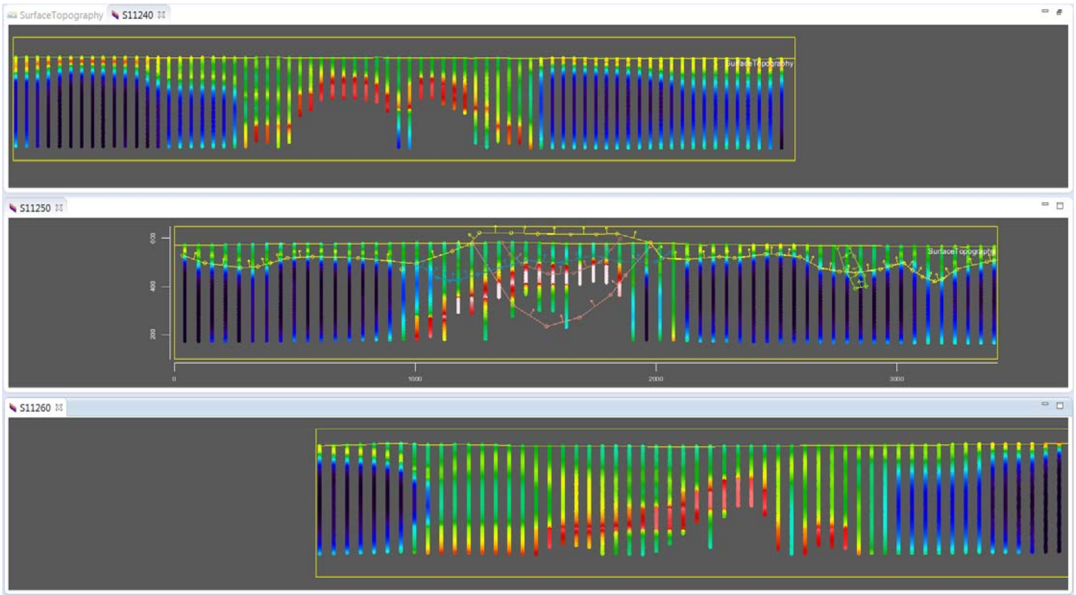


A Resistivity CDI compilation of the 3 section extents in this Tutorial, derived from the SPECTREM deliverables, appears below.

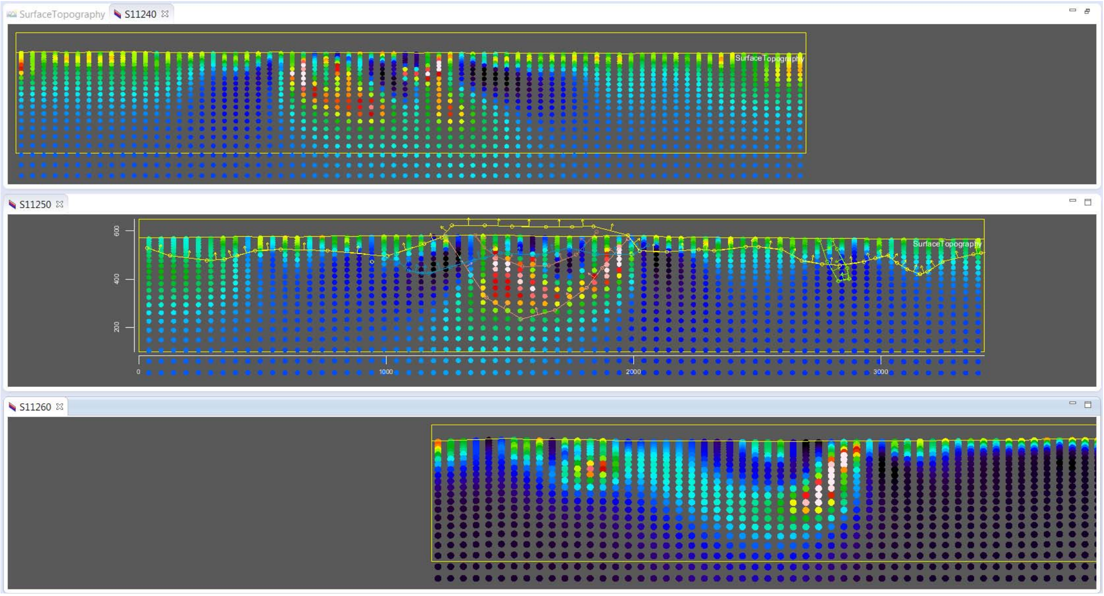
This is followed by a comparison of the 1D and 2.5D Inversion LogConductivity stacked section compilations of the 3 sections in this Tutorial from Grids and Meshes as displayed in the GeoModeller 2D Viewer.



Bryah Basin CDI (Resistivity), Sections S11240, 250, 260 to match this project



Bryah Basin 1D LogConductivity, 2D Stacked Sections S11240, 250, 260



Bryah Basin 2.5D LogConductivity, 2D Stacked Sections S11240, 250, 260

Conclusion

The superiority of the 2.5D inversion results over the CDI and 1D inversions is very clear in this complexly folded geological example. Reasonably accurate 2D geological sections can be constructed from the 2.5D conductivity sections

Construction of an accurate 3D geological model might be constructed from the 2.5D conductivity sections if the AEM survey line spacing was ~500m. The 5km AEM survey line spacing and the geological complexity makes this difficult in this case.

References:

English, P. and Johnson, S., 2010. Groundwater investigations in palaeovalleys in the Murchison region, Western Australia, paper presented at Groundwater Conference: 31 October to 4 November 2010, Canberra: http://www.groundwater2010.com/documents/EnglishPauline2.pdf

English PE, Johnson S, Bastrakov EN, Macphail MK, Kilgour PL and von Behrens M 2012a, 'Murchison demonstration site report – Palaeovalley groundwater project', Record 2012/06, Geoscience Australia, Canberra.

English PE, Lewis S, Bell J, Wischusen J, Woodgate M, Bastrakov EN, Macphail MK, Kilgour PL., 2012 Water for Australia's arid zone – identifying and assessing Australia's palaeovalley groundwater resources: summary report, Waterlines Report Series No 86, August 2012

English, P., 2013. Groundwater investigations in palaeovalleys in the Murchison region: Finding hidden water resources for remote townships and expanding mining activities. AusGeo News Issue 109, 3-9. http://www.ga.gov.au/webtemp/image_cache/GA21444.pdf

Munday T, Ley-Cooper Y, Johnson S, Tyler I., 2013 A regional scale fixed-wing TDEM survey of the Palaeo-Proterozoic Bryah Basin, Western Australia: Providing insights into a setting highly prospective for VMS Cu-Au and mesothermal Au Systems, 23rd International Geophysical Conference and Exhibition, 11-14 August 2013 - Melbourne, Australia

Tutorial T8: Riverland Frequency Domain 1D & 2.5D Case Study

Parent topic: Tutorial E (Airborne EM Forward Modelling and Inversion)

The RESOLVE survey was first acquired in 2002 for the Bureau of Rural Sciences, and is known as the Riverland and Tintinara, SA survey. This data was reprocessed and inverted in 2004 for the CRC LEME as part of the South Australia salinity mapping and management support project.

T8 Overview

Parent topic: Tutorial T8: Riverland Frequency Domain 1D & 2.5D Case Study

In this tutorial we:

1. Load the Riverland RESOLVE Frequency Domain survey subset project
2. Examine geological and geophysical backdrops on the Surface Topography section
3. Open the EM Modelling dialog and examine 1D and 2.5D inversion results on the 10 Lines/Sections of the subset
4. Project drillholes to the sections and compare 1D and 2.5D inversions with drillhole geology and conductivity logs.
5. Sample inversion conductivity results into drillholes for comparison.

Note: This tutorial does not require any product generation work to be carried out by the user. It is an example of a groundwater/salinity study along the Murray River using the RESOLVE frequency domain system.

Spend the remaining time studying the products using the GeoModeller visualisation tools and read the accompanying reports generated by the CSIRO and Geoscience Australia researchers.

References

Brodie, R.C., Green A.A., and Munday, T.J., 2003. Constrained inversion of RESOLVE airborne electromagnetic data, Riverland and Tintinara East, South Australia: Data calibration report. CRC-LEME Restricted Report 190R.

Brodie, R.C., Green A.A., and Munday, T.J., September 2004. Constrained inversion of RESOLVE airborne electromagnetic data, Riverland, South Australia CRC LEME OPEN FILE REPORT 175.