EMIGMA XV.x – Modeling Tutorial

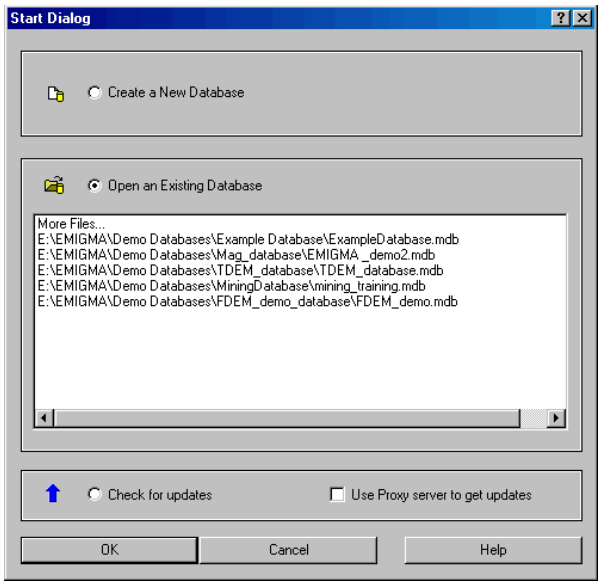
Modelling in EMIGMA

Getting Started

If you are familiar with EMIGMA, you may skip down to the modeling section.

`Start -> Programs -> EMIGMA XV -> EMIGMA XV`

To **Create a New Database** - Select **`Create a New Database, OK`**
Browse for the path to save your new database file and give it a name.



To **Open an Existing Database** - Select **`Open an Existing Database`** and either choose your database from the list or browse for your database file by selecting **`More Files`**….

Creating or Accessing a Survey

To perform modeling, you must have a survey constructed in your database. When creating a survey, EMIGMA stores all of the required parameters inside the database. Thus, once created, the user no longer needs to specify the data system or the survey configuration. Additionally, depending on the survey parameters, EMIGMA knows which algorithms to use.

You may create a survey in a number of ways. If you open a database, then you may have numerous surveys already available and they can be used directly or modified. You may create an entirely new hypothetical survey or you may import data and through the import process, the survey is defined and saved to the database.

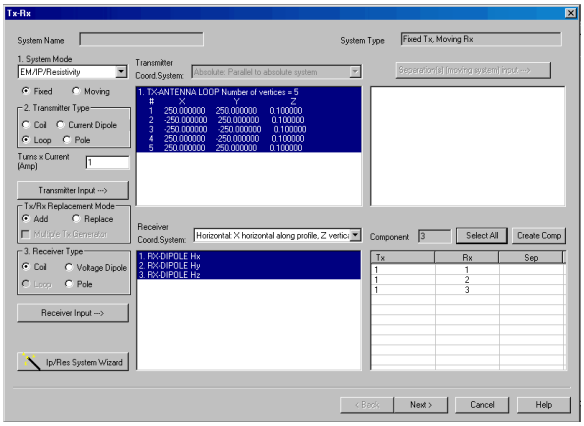
Create A New Synthetic Survey.

In an existing project, select Add Survey, then select the System Mode

EM/IP/Resistivity
Gravity
Magnetics
MT
CSAMT (with 3D source)
Land CSEM
ZTEM
VLF or VLF-R
MMR

If you wish to create a more general airborne natural field system such as AFMAG, select MT and delete the electric field receivers.

Depending upon the System Mode, certain types of transmitter and receivers are allowed and depending upon the System Mode – Fixed Transmitter or a Moving Tx-Rx is allowed



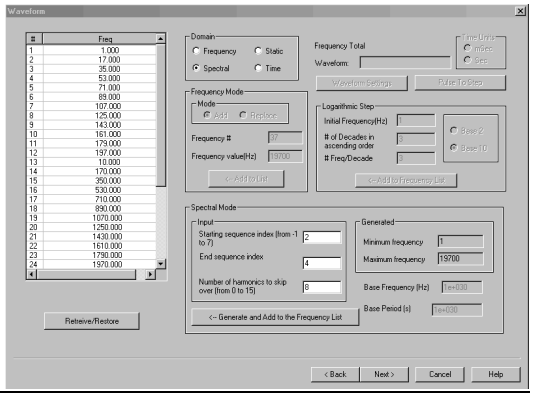
Transmitter Types
Coil – here a point source is used either electric or magnetic
Loop – the loop must be continuous and end at the same location
Current Dipole – a wire current source of selected length and geometry
Pole – for IP or Resistivity – a point source with a return pole at a selected distance and location

Receiver Types
Coil – here a point receiver is used either electric or magnetic
Voltage Dipole – a wire receiver with grounded ends if in conductive material
Pole – for IP or Resistivity – a point receiver with a pole at a selected distance and location

Component
Matching Tx's with Rx's and separations (when a moving system is defined.)
For some surveys not all transmitters have all receivers.

Click **Next>**

Waveform Selection



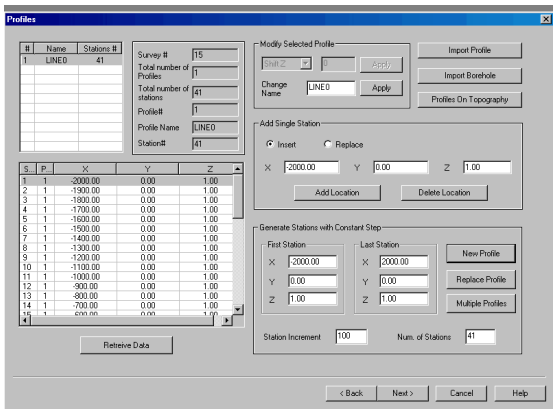
Here the user will select whether you wish to calculate a ***Frequency Domain*** model, a ***Static*** (DC) model or a ***Time Domain*** survey.

If selecting, ***Time Domain,*** for the first model the user must first specify a spectral survey which will compute the necessary frequencies to compute the time domain model which depends upon base frequency and the desired upper bandwidth. (*see Transform manual*). After the first model, you may adjust your model and compute to the time domain directly.

Click **Next>**

Profiles Selection

Now the user will be requested to create profiles and data stations. You may create individual profiles or utilize the Multiple Profile interface to build an entire survey grid.

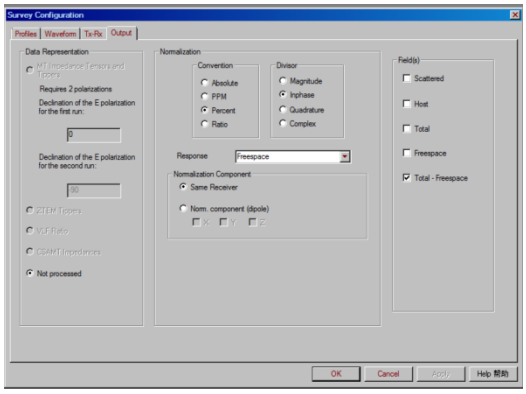


There are also specialized tools on this interface for importing profiles or defining borehole profiles.

Click **Next>**

Output Selection

Now the user will be requested to select the types of output fields that are desired.



In the example above are the selections for a standard dipole-dipole FEM moving array. Here the data is to be normalized to the Inphase of the primary field and computed in units of Percent. The output fields are Total-Freespace and to the freespace of the same component as the data.

This selection is important for modeling where all of the Field(s) can be computed. For example, the background as well as the secondary (scattered).

Special Data Representations are provided by computation automatically

Magnetotelluric Impedances and Tippers
ZTEM Tippers
CSAMT impedances
VLF ratios

In the special case of Spectral Surveys, no selection is allowed. The software automatically computes all response that are be required for any type of time domain data whether magnetic or electric.

Click **Finish >**

This now takes you to the model selection.

See ModelGui

Then you may compute your first model.

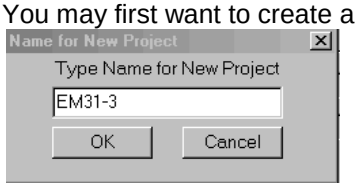
Importing Field Data



Import Data

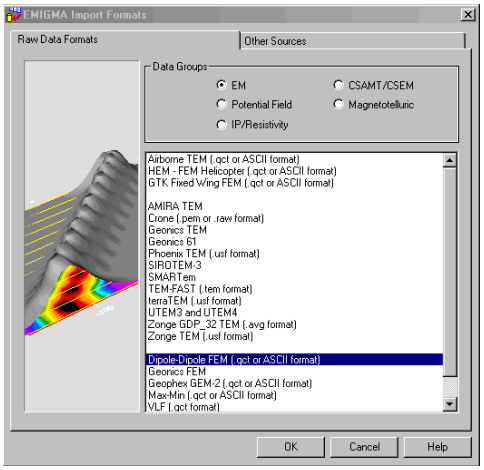
Select the **`Import Icon`**

You may first want to create a new survey



Click **`OK`**

Select from the **Data Groups,** then the type of data you want to import from the resulting list.
Here, we will utilize EM31-3 data as an example.



Click **`OK`**

Follow the steps on the pages that appear.
Use the HELP button to guide you.

Database Organization

Organization
Multiple datasets and models can be contained in a single database file. Multiple organizational levels are provided allowing for a variety of organization criteria depending on the user's preference. As examples, the user may organize by interpretation project, data type or simply organize all data and projects in one database file. The user may organize in a single project (one organizational level in the database file) several data sets for more ready analyses of the different data types and integration of models between data types. This framework will soon lead to integration of data types when viewing data within EMIGMA.

There are three levels of organization in the Database:
Projects in Database
Surveys in Project
Data Sets in Surveys - Measured, Processed, Simulated and Inversion data sets sit here.

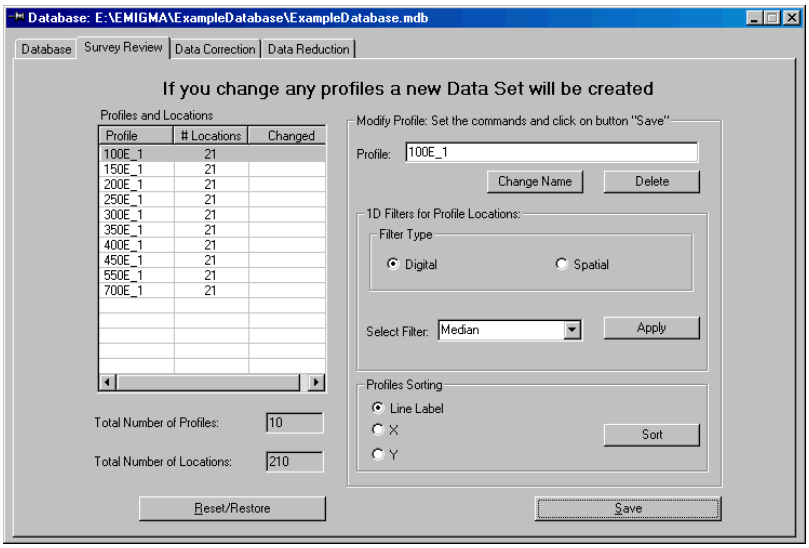
You can change the name of any Project, Survey or Data Set.
You can also delete any Project, Survey or Data Set.

Configuration
Certain properties of the Survey that are in the Profile, Waveform, TX-RX and Output sections can be viewed and modified.

Model
The Prisms/Plates/Polyhedra/Sphere and Layers sections can be accessed here and modified.
The names of the output inversion files can be seen here with some processing capabilities.

Grids
View the grids that are attached to a data set. The user can export the grids to several formats. It also possible to perform processing on a grid.

Survey Review Page



Selecting profiles
Use your cursor to select a profile or multiple profiles. Hold down the shift key to select multiple profiles. Selected profile(s) will appear in the Modify Profile box.

Profile Sorting:
If your profiles are imported in the order contained in the data file or as a result of merging. The user may sort the profiles by Line label, X or Y position.

Reset/Restore:
If you make a change that you want to undo, you can restore your original profiles.

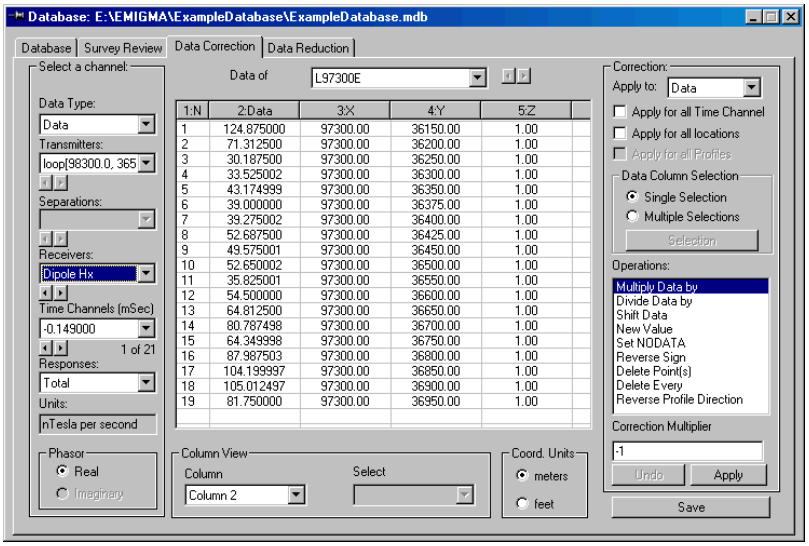
Deleting a Profile:
Select one or more profiles and select the **`Delete`** button

Changing a Profile Name:
If you are not happy with the label associated with a profile, select it from the list, enter a new name and click the **Change Name** button

1D Filters for Profile Locations:
The locations in a profile can be sent through a filter to adjust the location positions. A number of different digital and spatial filters are available. Data filtering tools are in the tool box.

Data Correction Page

The Data Correction Page allows you to edit the data values as well as the X,Y, Z(altimeter),GPSZ and Fiducial/Station values of a data set.



Column View

defines the columns that are displayed

Selecting a data channel: On the left, select the Data Type, Transmitter, Receiver, Time Channel/ Frequency, Response and Phasor of the data to correct

Correction

Apply to:

You can choose to apply to some or all
-time channels/frequencies
-locations
-profiles

Data Column Selection:

When Multiple Selections is chosen, changes will apply to only the specified data channels

Operations:

Select From

-Multiply Data
-Divide Data
-Shift Data
-New Value
-Set NODATA
-Reverse Sign
-Delete Points
-Delete Every
-Reverse Profile Direction
-Delete Frequency
-Delete Receiver
-Delete Transmitter
-Delete Separation
-Delete Time channel
-Delete Error channels
- Add GPS Z channel
- Add fiducial/station channel

Specify the value used for the operation if necessary.
e.g. **Correction Multiplier** for the **Multiply Data** operation.

Click **Apply**

Once you are satisfied with your corrections, select **Save**



The database design of EMIGMA allows all tools to be fully integrated and to share/access the data within the database. Thus, there is no need to open and save flat files or additional spreadsheets. There is also no need to save a Database .mdb file, once it has been created. EMIGMA continuously updates the .mdb file as changes are made.

Model Building

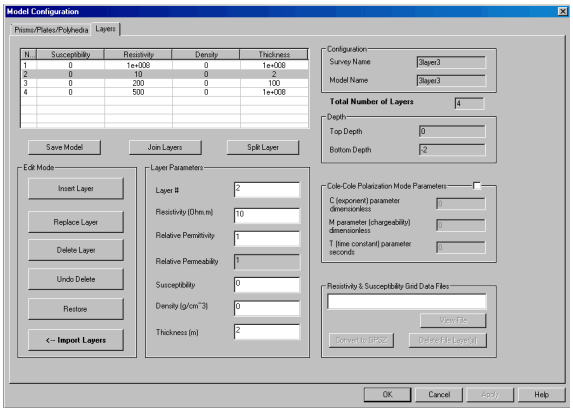
Almost all forward modeling (model response simulation) in EMIGMA is based upon some form of an Integral Equation technique. In the paragraphs below most of the various algorithms will be described.

There are several way to build models in **EMIGMA. The most direct method is through the Modelgui.**



This capability is accessed through the Model button on the main database page. When this function is accessed, two interfaces are provided. The first in the layered background interface critical to all EM/IP applications but can be used for both magnetics and gravity.

Layers

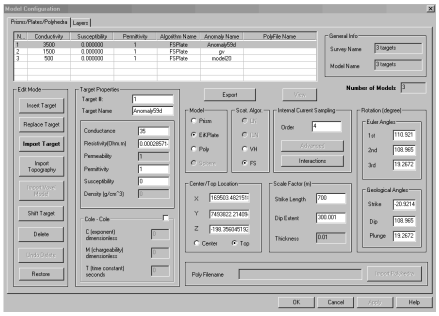


Layers can be defined by the resistivity, thickness, electrical permittivity, magnetic susceptibility and density. Also, the layers can be made polarizable through setting Cole-Cole parameters which is applicable for all EM modeling. The top layer is an air layer by default but can be set with suitable parameters for other applications such as marine or underground. For example, for surveys on the seabed one might set the top layer to be the conductivity of sea water.

Insert Layer: Set the required layer number and its parameters and then **Insert Layer** into the stack.
Replace Layer: Select the required layer, change its parameters and then **Replace Layer** into the stack.
Delete Layer: Select the required layer, and then **Delete Layer** to remove from the stack.

You can Import Layers from any another survey in the database. **Import Layers.** If you need to import layers from another database, first import the survey in the other database which contains the layered model. Then import the layered model from the newly imported survey.

Prisms/Plates/Polyhedras/Spheres



The other tab in the modelgui is for the insertion/editing/deletion/viewing of 3D anomalies.

Thin-Sheets (plates): There are two algorithms provided, FS (freespace) and VH. Both algorithms allow two spatial parameters (length and depth extent) normally used for strike length and dip extent and a conductance strength (conductivity x thickness). Multiple plates can be inserted into the model but FS and VH cannot be mixed in one model. The model primitives may be used with any type of EM or IP survey.

The location of the plate is defined through either its Top or Centre. If one edge of the plate is level to the ground surface (z=0) then the Top point is the center of the top edge. If the surface of the plate is parallel to the ground surface then the Center point is the center of this surface. These definitions are common for plates and prisms.

The orientation of the plate (or prisms) is defined via 3 angles (Euler angles) and for convenience these are interpreted geologically as Strike, Dip and Plunge angles. The plunge angle is not a true geological plunge but is rather the third Euler angle.

FS (freespace) algorithm: This is an algorithm which assumes an inductive response only. The algorithm can be used in two manners. One manner is the direct modeling in time domain which assumes a theoretical waveform with infinite bandwidth and the other (default) with a defined bandwidth for the system. Both methods include the response of the background layered but no interaction between the background and the plate is computed. This algorithm is based on the mathematical development of Annan but the mathematics bears no relation to the old UofT algorithm. The algorithm's response is specified by the number (order) of eigenfunctions or eigencurrents between 1 (dipolar) and 11. You can use higher eigenfunctions but they do tend to become unstable above 11. The plate model may be inserted into a sequence of conductive layers and the combined response is computed but only the superimposed responses of the plate and layered models. If there is a galvanic (current channeling) response to the target, a thin equivalent prism may be also used and the two scattered solutions added in the Data Reduction tab.

VH algorithm: This is an algorithm is based upon the theoretical developments of P.W. Walker. The algorithm computes the interaction of the plate with the induced currents in the host as well as the inductive response. This algorithm can be used if the currents induced in the host (layered background) produce a significant response. The sampling of the currents on the plate is restricted to 441 points. The limitation of this algorithm is primarily seen when the aspect ratio of the plate (L/W) becomes high.

Prisms: This algorithm allows the use of one or multiple rectilinear prisms. The prism locations and orientations are defined as with the plates but in addition to depth and width, a thickness is defined. There are 2 algorithms provided with prism primitives, LN (Localized NonLinear) and ILN (inductive LN). Both are rapid techniques for computing the integral equation solution (secondary fields). The LN technique can be used for a wide range of EM/IP techniques but is a very good technique for IP/Resistivity model. This technique can also be used for magnetic surveys where it computes the full solution and not the traditional weak solution as with other codes. For EM, the prisms can be conductive or resistive compared to the background, have an anomalous electrical permittivity, magnetic susceptibility and polarization effects (Cole-Cole). The response computed is both the current channelling response as well as the magneto-static effect when the prism is magnetic. Thus, this algorithm is appropriate for resistivity and IP surveys, most long grounded current source surveys (i.e. CSAMT, CSEM), MMR, MIP and for many TEM applications. It is also excellent for MT/ZTEM/AFMAG surveys. For TEM, it is suitable for resistive structures, weak conductors, polarizable effects and structures in conductive backgrounds. The ILN provides some enhanced inductive responses over the LN.

Interactions: While, generally in geophysical model simulations, it is assumed that the interaction between bodies and cells is assumed to take place naturally by the use of a general numerical technique, in practice this does not occur as the self interaction of each cell in the finite difference/finite element/IE grid dominates the computation accuracy. The in most numerical techniques, the computed response is actually the sum of the response of each grid cell. The LN technique for a single body is not affected by this issue as the operator analytically includes current interactions within a body. But, the interactions between bodies is another matter. Generally speaking in many if not all codes, 2 separated bodies will not interact. This is one benefit of the LN technique in that it allows extensions for interaction and the effectiveness of these interactions has been tested to a great extent.

Note: Prisms in magnetic, gravity and resistivity surveys: In DC surveys, the response of a prism can be calculated analytically which is the manner provided by default in EMIGMA. For magnetics, there are 2 analytic solutions, one being the more traditional weak scattering which does not consider B to have zero divergence and the other the full solution considering all the governing equations.

Galvanic and Inductive Scattering (*a brief introduction*): In simple terms, a structure under an EM excitation can be excited to re-scatter/backscatter/produce a secondary field under several different physical phenomena. First, and the most common except with larger, very conductive structures, is when the currents which are induced in the background materials by the transmitter interact with the anomaly. This is described by charges and is governed by variations in resistivity, permeability, permittivity and polarization characteristics.

The second phenomena which is most prevalent in detecting strong conductors from loop sources is induction caused by the magnetic fields from the source interacting with the surfaces of the conductor. This is caused by conductivity and variations in permeability. Another effect often ignored is when the source field is essentially static and the target is permeable. This is simply the result of Gauss' law. Thus, this happens in the inphase of low frequency FEM data and during the on-time in TEM data. The LN algorithm can handle these phenomena except when induction is strong. The purpose of the ILN algorithm was to attempt to increase the range of inductive responses. However, it is not meant for very strong induction but merely moderate induction.

Polyhedras: For the LN and ILN algorithms for EM as well as the algorithms for magnetic and gravity models, the prisms can be generalized to more arbitrary shapes. These shapes can be obtained in a variety of manners and we will give some illustrations here.

a) Converting a prism to a polyhedra and editing in the Visualizer: There are two common procedures in this case. In the first, case, the prism is dipped, converted to a polyhedra and then has the top sliced off a prescribed depth to represent a common geological modification of an anomalous structure. Second, the prism is converted to a polyhedra and then the poly editing tools are utilized in the visualizer to modify the prism to conform to the shape required.

b) Importing a polyhedra: There a three procedures which are common in this case. In the first case, synthetic polyhedra is built using the Poly Generate tool on the main EMIGMA toolbar.  There is a wide range of capabilities available here and help is provided within this tool. The second method is to import a CAD file. These capabilities are also provided in the Poly Generate tool. The third method is to import topography which is available in Poly Generate but also directly on the Prisms/Plates/Polyhedra tab.

c) Sample points: The software takes the number of sample and has its own rules as where to distribute these sample points within the polyhedra.

Spheres: This algorithm is developed from Debye's expansion theorem for a sphere but is not limited to only a few terms as in conventional geophysical literature. Recently, this has been updated from only be allowed with a dipole source (**J** or **M)** to allow the user of either a loop or a grounded dipole source. The algorithm should converge readily with the code restricted to a maximum of 200 harmonics.

Mixing Targets with Different Algorithms: Any combination of prisms and polyhedra can be mixed in a model. VHplates can also to added to these combination. FSplates have to be run separately but can be added to other models with other algorithms in post processing using the Data Reduction tab.

Internal Sampling for Prisms and Polyhedra: Like any other numerical technique some sort of grid sampling is required. For IE (integral equation) techniques only the internal secondary sources need be considered and thus only the inside of the object is digitized (gridded). In normal IE techniques, an interaction matrix is computed and then this matrix (scattering matrix) is inverted to compute the secondary sources. For the LN and ILN, a technique has been devised (Habashy et al, Groom and Murray, Alvarez and Groom, etc) to compute the secondary currents and magnetic polarization vectors directly. These secondary sources are then utilized simply and directly through the greens functions to calculate the secondary measurements at the receivers. The internal sampling allows the user to select how many internal sources are utilized and thus enable them to study the convergence of the solution.

LN and ILN are integral equation techniques. Such techniques calculate the secondary internal current and magnetic sources caused by the prisms in the model. If the number of sample points is prescribed without details then the points are distributed according to the aspect ratios. Otherwise, the user may prescribe the sampling as desired through the *Advanced* button. Generally, the solution will converge with as the sample points increase but may diverge if a sample point becomes too close to one of the corners. This result is predicted by theory but we will not enter this subject here. For the ILN algorithm, the solution is not stable for strong induction nor for large number of sample points. Use of the algorithm must be done with care checking for the stability of the solution with the number of sample points.

Interactions for Prisms and Polyhedra: No interaction between targets is provided for the plate algorithms but there are 3 types of interaction provided for prisms and polyhedra. In almost all simulation algorithms, the self interaction terms of each target are dominant in the calculations and the interactions between targets is lost. To overcome this typical numerical computation issue, we have developed interaction capabilities that ensure proper interaction between targets.

***Superposition**: no interactions calculated and the total response is the sum of the individual targets*
***Far Field**: the targets are not close but their scattered fields produce an additional reaction from each target.*
***Near Field**: the targets are close and secondary currents or magnetic polarizations flow between targets.*

Model Building with the 3D Visualizer



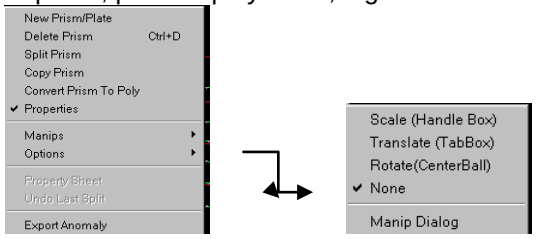
Build and edit models in the Visualizer (3D VisRD). Select the Data Set and choose the Viz icon. You may select multiple data sets in order to examine variations in different models or to enable model building versus your data. We would suggest viewing our EMIGMA introduction video.

There are a number of basic controls here.

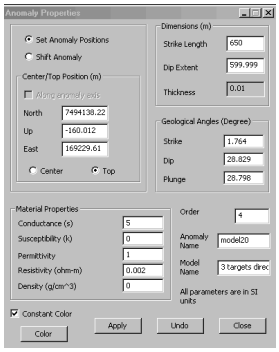


Starting from 5th from the far left, *"Show Data", "Toggle Profiles", "Toggle Transmitter(s"), "Create New Anomaly", "Import Anomaly", "Copy Prism (poly) ", "Split Layer", "Toggle Axes", "To next time window or frequency", "Back window or frequency", "Scale data", "Contour Data", blank, blank, "Show Source Field Distribution", blank, "Pick (allows you to pick an object and also gives coordinates of a location in the view)", "Hand controls (rotation, zooming) ", "To Home", "Set Home", "Full Scale", "Zoom"*

You can then select the prism, plate or polyhedra, 'right click'



(additional tools) and select Properties to bring up the Anomaly Properties window.



From this window, you can modify location, orientation, and attributes of the anomaly and upon Apply see the result in the 3D visual window.

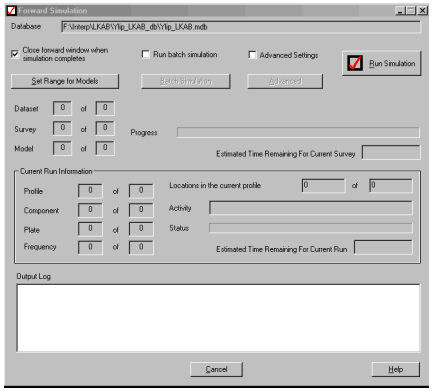
You can import layers, models, polyhedras and topography from datasets in your current database.

Additionally on the right mouse or other capabilities such as copying, splitting, rotating, extending targets. You can also build or modify models through the Model button on the Database Page.
I**MPORTANT** - Once you have made your changes in Viz, be sure to **`Save to Database`** to update the database, before running a simulation. If you do not Save to Database, your changes will not be updated.

Simulation

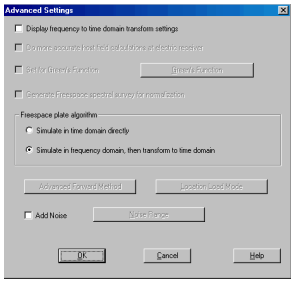


Select the Run simulations icon (red checkmark) and follow the directions. You can choose to overwrite the selected Data Set or create a new Data Set. The Forward Simulation window will be displayed.



This interface provides controls to the super-engine which controls the modules which actually compute the synthetic responses. It provides progress reports in the middle section and in the white box to the bottom, information useful to the developers.

Run Batch Simulation: opens up a window which allows you to input multiple models to be run in the background. The idea with this tool is that you can create/edit multiple models either in ModelGui or in the Visualizer and save these models to individual datasets. Batch mode will then run all of these models in the background for you and save the results to the database for later examination.



The Advanced Settings allows you to make adjustments to the default simulation. These enhancements depend on the algorithm. But, the main issues are to allow the controls for the transform to view, control the number of stations simulated in any sub-run to control memory, set a grid of greens functions for downhole transmitters, add noise and finally to control the FS algorithm as mentioned above.

After the Survey is loaded and any advanced settings made, select the **`Run Simulation`** button within the Forward Simulation window. Note that you can cancel a simulation in the middle of a calculation should this be required.

Model Suite Generation (*Set Range for Models*)
Select a dataset, click the Simulation Check and then select *Set Range of Models*
There are 2 choices, *Layers and Plates*,
You can define a suite of models to build and run automatically. Choose **`Set Range for Models`** - Select Layers or Plate. Prism suite generation will be added in the future.

Layered Earth Models - Up to 5 layers are allowed, and the number of layers to modify is taken from the starting Data Set. You can set the Resistivity, Relative Permittivity, Susceptibility and Thickness of each layer (thickness of bottom layer is set to be infinitely thick to approximate the basement).

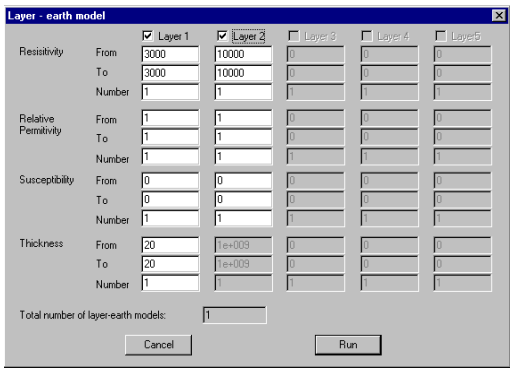
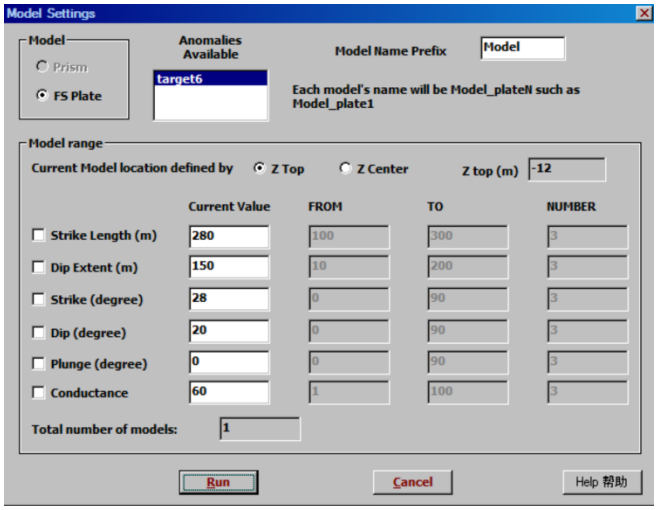


Plate Suites - You must start with a Data Set that contains a Plate in order to build suite of plate models. Currently you are allowed only one plate in the model suites. If there are multiple plates in the data set, then select one plate to begin. You can vary the length, width, strike, dip, plunge and conductance. The reference position can be either Z Top point or Z Centre point. The algorithm utilized for simulation will depend upon the algorithm set for the plate selected.



Upon completion of the model runs, there will be a set of new datasets and these can be viewed or analyzed as with any other model simulation.

Data Representation/Display



3D Visualization - with VisRD


Grid Presentation


XY Plotting - with EiKPlot



Pseudo Show


Contouring - with EMContour



PEX Show


Survey Editor


Multi Grid


Gridding and Interpolation


Data Spreadsheet

Other tools accessible in EMIGMA for those who are licensed



Conductivity Depth Imaging


Source Distribution


XHole Tomography


Frequency to Time Domain Transform (manual transformation controls)



3D Magnetics, Gravity, Resistivity, CSEM, CSAMT Inversion



1D FEM, TEM, Resistivity, CSEM, CSAMT and MT Inversion Tools

Exporting Data



Export a data set to a

- QCTool file
- EMIGMA database
- Compressed database
- ASCII file
- GEOSOFT file
- GeoTutor file
- Survey lines to KML file (GoogleEarth)
- Survey lines to DXF file (AutoCAD)

