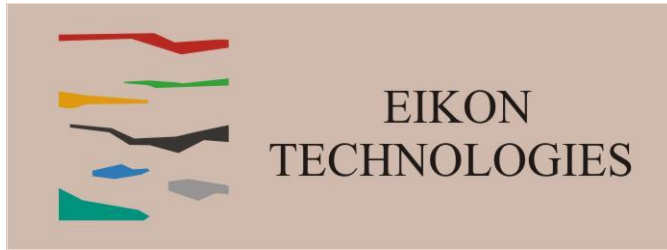


EMIGMA V10.x Premium Series



EMIGMA for Magnetics

March 2023

Comprehensive Software for a very economical price!

Suitable for Ground, Airborne and Borehole data!

True database design with full integration of survey, processed and modeled data! Many datasets per database with integration between different types of data. Many models/inversions stored per dataset.

Extensive built-in support through 'Help Topics' and 'Tutorials'!

EMIGMA for Magnetics is a sophisticated geophysical data interpretation product, which is available in the EMIGMA *Complete* packages (Premium or Professional series), as a standalone product or as an add-on to other EMIGMA software licenses. It is also included in all airborne EM licenses.

The Premium package includes ground, airborne and borehole magnetic applications, whereas the Professional package is only for ground surveys.

EMIGMA offers an advanced suite of features for importing, processing and modeling of magnetic data.

The DC magnetic and gradient data can be imported using a variety of formats such as ASCII, Geosoft formats and QCTool (QCT). Additionally, data import from manufacturer-specified formats is also supported. Furthermore, for airborne applications, import of multi-sensor and gradient data is also included in ASCII, GRD and QCT formats. Our QCTool product supports Geosoft GBN and GDB, Scintrex native formats, Micro-g/Lacoste air/sea formats, Geometrics, GEM and SeaSPY formats. QCTool Basic is included with your license.

For data processing, EMIGMA/QCTOOL offers various features such as diurnal correction, IGRF correction, tie line leveling as well as gradient removal for trend analyses.

QCTool

However, potential field data processing can be done much more efficiently using our supplementary software, QCTool. QCTool is a powerful data processing and analysis tool for a variety of data, including magnetics. Additionally, for airborne applications, a magnetic compensation package is available for QCTool users including vector and gradient compensation and new tools for lower flying instruments such as drones. Additionally, there are additions for multiple sensor arrays including towed and stingers configurations and a marine package.

EMIGMA

The true scope of EMIGMA's functionality is only realized when utilizing the advanced features—some of which are not usually available for commercial potential field software.

The gridding and interpolation features are quite unique. Firstly, as part of EMIGMA's design, the grid cells need not be square, but rectangular with user-selected aspect ratio. This is a very important feature for modern surveys as data is often collected in very high density along the profile/survey line direction with a much larger distance between survey lines. In order to make use of this high density (along the survey line), the grid needs to be orientated such that one grid direction is along the survey line direction and the grid size is sufficiently small for the inline data sampling. Secondly, when collecting geophysical data, our aim is to focus on local differences in the data. Therefore, a local region interpolation technique is more appropriate instead of a technique that essentially uses global basis functions (splines) such as the Minimum Curvature technique.

Additional gridding features of EMIGMA include the creation of a suitable, user-defined grid for FFT-processing. Similarly, this option also allows for finer grid size in the survey line direction to ensure high resolution is maintained during data processing. For FFT-processing, the tools include the use of a sophisticated tapered Tukey filter and advanced routines such as first, second and arbitrary higher-order derivatives calculation, upward/downward continuation with derivatives, wave number/wave length filtering as well as enhanced Reduction-to-the-Pole (RTP) techniques. Moreover, the RTP feature offers several types of techniques including several advanced applications for accurately analyzing survey data acquired near the equator and another for data acquired away from the equator.

All FFT-processing routines allow for the generation of associated derivatives. FFT-processed grids can also be used to remove filtered data from the original data such as removing low wave number or upward continued grids. EMIGMA allows the generation of any derivative the user might desire.

Furthermore, EMIGMA offers a host of modeling capabilities that facilitate importing of topography files, simple and complex polyhedra files from CAD or AutoCAD modeling as well as synthetic 2D/3D model generation features. Models can be exported to .dxf (AutoCAD), .asc (Vulcan) and .str (Surpac) formats for easy integration with other modeling software. Similarly, maps can be imported from GeoTIFF, DXF, and KML (Google) formats and exported to these formats using measured and processed data.

Another powerful feature of the package is the Forward Simulation (also known as 'forward modeling') capability, which offers several scattering algorithms to accurately simulate the magnetic response. The algorithms are categorized into two categories:

- 1) Born or Weak Scattering - This is the traditional approach for modeling magnetic anomalies, which assumes that the magnetization vector is parallel to the Earth's magnetic field and the magnetization is directly proportional to the variation in susceptibility. For this algorithm, three options are available:
 - a) Numerical Method - This is the standard option, which integrates over the anomaly
 - b) Analytic Method - This method solves the scattering problem analytically, thereby producing a converged solution much faster.
 - c) Far field - This applies to interactions between different anomalies such as when a small anomaly is close to a large anomaly or when there are several small anomalies in close proximity of each other.

- 2) Localized Non-linear (LN) or Strong Scattering - The LN algorithm represents a much-improved understanding of the scattered field in that it not only considers the interaction with the Earth's field, but it also takes into account the so-called demagnetization effects within a single strongly magnetic body. For 2D modeling, it assumes that for a long magnetic body, the magnetization vector is not always parallel to the source field. Due to Gauss's law, the divergence of B must be zero, which implies that the magnetic field must bend when entering a long body, and therefore, with a longer strike extent, more bending must take place. By applying this approach to DC magnetics, the integration equations are solved semi-analytically to find a solution very rapidly. In fact, when the sampling density (of the anomaly) is increased, the processing speed increases only linearly with the sampling, unlike traditional algorithms.

Moreover, this algorithm offers three options to characterize the type of interactions, which include Near field, Far field and Superposition. The Superposition option simply models the response by summing the contribution from each source, Far field includes interactions between bodies at a distance and Near field when strongly magnetic bodies are in contact. The effectiveness of this algorithm is a testament to the superior modeling capabilities of EMIGMA along with its fast processing speeds, both of which are simply unrivalled.

Furthermore, EMIGMA allows for the modeling of Remanent Magnetization. The interface handles this by inserting a user-defined remanent magnetization vector into the anomaly and then calculating the resultant field by integrating over an integral. The remanent effect may be used on its own or in combination with other magnetic effects.

Also, EMIGMA's 3D inversion is another important feature of the package. The inversion methods allow the user to invert not only the measured data but also the processed FFT-data (including first- and second-order derivatives) as well as measured derivatives (airborne). Three algorithms are provided. All techniques allow rectilinear cells with user-defined dimensions, arbitrary grid azimuth, and varying cell thicknesses with depth. Additionally, the topography can be utilized in the inversion allowing for one to invert for the effects of topography as well as for structures located within the topography.

Linear Fast CG (Matrix) – Utilizes a linear, physical operator based Conjugate Gradient technique, which divides the grid into cells and limits the number of data points and (grid) cells for fast convergence. A classical physical matrix operator is utilized but new inversion techniques for large matrices are implemented.

Linear CG (slow) – Uses the linear Conjugate Gradient technique to find a solution for larger data sets and larger number of grid cells without any limitation on the number of data points or the number of cells while still utilizing a matrix operator from first principles. This technique utilizes large matrix inversion techniques using large virtual, swapped memory.

Non-linear CG – Starts with an initial model and then finds the best fitting model using a line search method. The given function is minimized using an iterative process, which is a more traditional approach for geophysics. This method does not invert the physical operator, but rather performs a search through model space. This is similar to the approach used in other commercial software.

Even though, potential field inversions suffer from an inherent non-uniqueness, EMIGMA's 'Linear Fast CG' and 'Linear CG' techniques, however, provide a more reliable solution due to the inversion of a physical operator matrix combined with the use of susceptibility constraints such as expected susceptibility ranges but also information from drill cores or surface samples. Thus, they are more suited to find a global minimum as compared to the traditional search through model space. Also, as the user is allowed to choose a starting model and smoothing parameters, it is quite easy to study the characteristics of the inverse solution. This constrained approach is a state-of-the-art technique offered with our EMIGMA for Magnetics package or with any of our licenses, which include the Magnetics option. Other comparable 3D inversion software packages utilize the 'Non-linear CG' technique, which has been found to be ineffective due to its gradient search approach. Furthermore, this approach is a bit out-of-date as it does not take full advantage of the advances in computing power and memory size enhancements over the last decade.

Additionally, the inversion feature provides useful tools in order to constrain the inversion:

- i) Geological Structures - Users may import or define structures by including drill log information or surface susceptibility distribution by specifying the position, susceptibility and radius of the objects, which can be saved and imported later, as needed
- ii) Inversion Settings Log – Settings such as susceptibility constraints, topographic information (if available), search volume settings, type of method, etc can be saved easily as a log file and then imported later for subsequent runs
- iii) Preliminary Forward Models – Can be easily imported (normally based on geological knowledge) as a starting model
- iv) Coarse Grid - Ability to use a coarse inversion grid as a starting model for a more refined inversion model
- v) Structures within topography – This is particularly important for data acquired in mountainous environments and for airborne data. If data is imported with elevation information, the 'topography' option can be utilized during the inversion process. Furthermore, the user can also import topography of the survey area directly into the model. Therefore, the topographic structure becomes part of the inversion model.

EMIGMA is also equipped with additional interpretation tools such as 3D Euler Extended Deconvolution and 2D Werner solutions for depth estimations. The post-processing option for the 3D Euler solutions is used to perform an inversion for the magnetization source vectors, thus, providing an estimate for the strength, depth, location and orientation of the main dipole response of the anomalies.

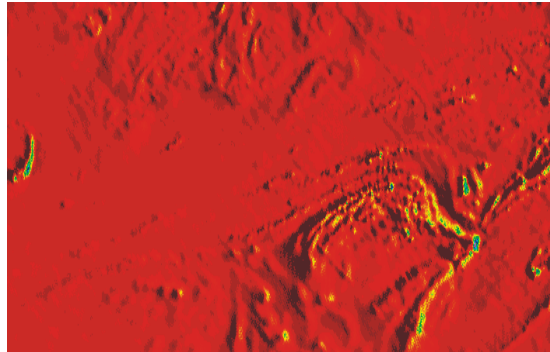
Data Import

- DC Magnetic and DC Magnetic Gradients (ASCII format)
- Instrument formats
 - Scintrex Smartmag/EnviMag, NavMag/EnviCs
 - Pico ground or airborne data in binary format (.P*)
 - Crone borehole data (with or without derotation)
 - Geometrics, GEM, Micro-g/Lacoste through QCTool
- Total Magnetic Intensity, TMI gradients and DC 3-component vector
- QCTool format (.qct)
- Geosoft grid file (.grd); GBN and GDB formats through QCTool
- Ground, Airborne and Borehole data (with derotation)

Data Processing

- Diurnal correction
- IGRF correction
- Tie line leveling
- Gradient removal
- FFT-processing suite includes:
 - Wavelength/wave number filtering
 - Upward/downward continuation
 - Derivative calculation
 - Analytic Signal
 - Horizontal Analytic Signal
 - RTP (3 approaches for data collected near the Equator and one for far from the Equator)

- 1D, 2D spatial digital filters
- Data Correction tool (offers many useful features for editing and processing data)
- Survey Editor (2D-viewer for editing or planning surveys)



Data Display and Analyses

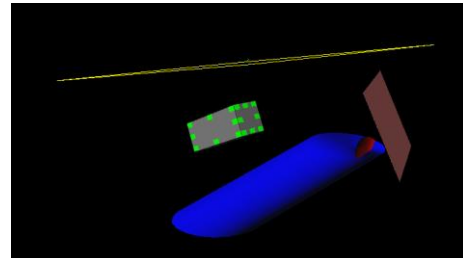
- Gridding with 5 algorithms: Natural Neighbor, Delaunay Triangulation, Shepard, Minimum Curvature and Thin-Plate-Splines
- 2D contour viewer
 - Displays gridded data including RTP, Analytic Signal and Horizontal Analytic Signal derivatives
 - Supports export to raster and Georeferenced formats including KML and DXF
- 3D contour display
 - Displays gridded data as a smooth 3D surface
 - Export to raster and 2D/3D vector formats supported
- Line Plots and data Residual Plots (2D Plotter). The most sophisticated geophysical plotting tool available.
- 3D Visualization
 - 3D model building and visualization with associated measured and simulated data
 - 3D visualization of 3D inversions and Euler solutions
 - Inversion slicing and exporting of slices

Gradients

- Derivation of FFT gradients
- Leveling with vertical gradients
- Enhanced contouring with horizontal gradients
- Modeling of gradients
- Inversion using gradients

3D Modeling

- 3D Visualizer
- Modeling of large data sets
- Geophysical model building tool in 3D space
 - Unlimited prism and polyhedra targets
 - Import of polyhedron objects using DXF (AutoCAD), ASC (Vulcan), TRI (Surface Mesh) formats as well as Poly (.xyz) and QCTool grid (.egr) formats
 - Easy export to DXF, ASC and STR (Surpac) formats
 - Useful for various applications such as UXO, Geotechnical and Archeological studies

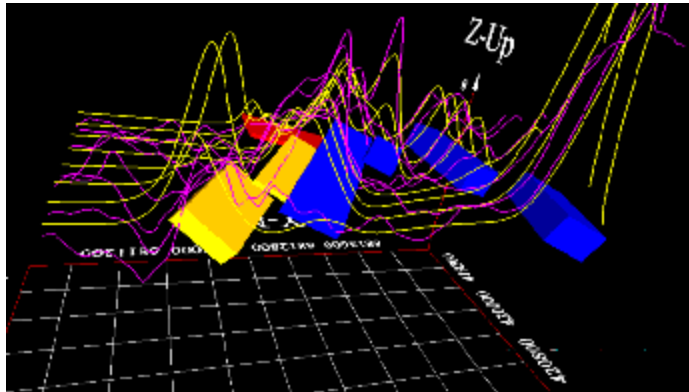


- Fast and accurate 3D simulations using:
 - Advanced algorithms for superposition, near-field and far-field interactions
 - Remanent magnetization effects
 - Demagnetization effects (within a body) – geoengineering, iron ore,
 - Direct quasi-analytic derivative calculation
 - Model suite generation options
 - Batch Mode simulation and 'Noise Range' features



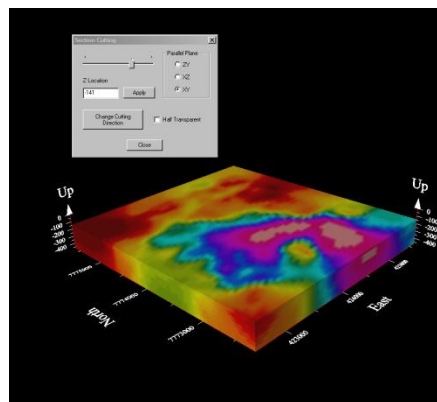
single
UXO

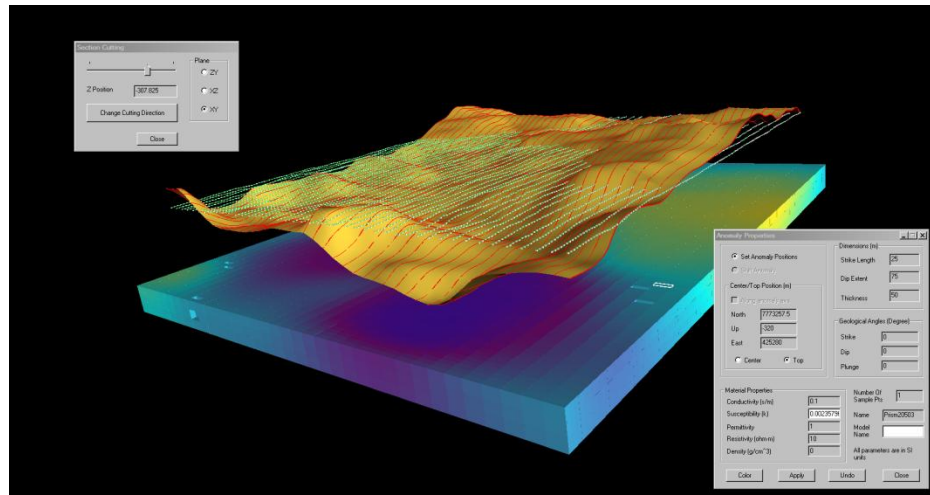
- Susceptibility Contrast
 - Sensitivity to small and large susceptibilities
- Topography effects
 - Supports import and modeling/inversion of topographic files in ASCII column XYZ and QCTool grid (.egr) formats, thus allowing for non-uniform depth effects of topography



3D Magnetic Inversion

- Improved constrained inversion techniques employing both measured and processed derivatives
 - Sensitivity to geology and topography effects
 - Removal of non-susceptible cells
 - Pre- and post-inversion removal of grid cells, extrapolation of data -
- NEW FEATURES**
- Full 3D gridded inversions
 - User-defined search settings and 'Save settings' features for subsequent model enhancements





3D Euler Deconvolution

- 3D Extended Euler solutions for profile and gridded data (FFT-derived derivatives or measured derivatives may be used)
- 2D Werner solutions
- Post-processing with 2D and 3D visualization
- Derivation of Magnetic Vector Inversion from post-processed solution for highly magnetic and polarized structures

