

Mag3D Inversion

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Data Inversion

$$d = F(m)$$

$d \rightarrow$ **data vector of dimension N**

$m \rightarrow$ **model vector of dimension M**

- F - physical relationship describing the data as a function of the earth model - *In practice an approximation*
- Approaches
 - ✦ Direct Matrix Inversion - historical
 - ✦ Optimized Inversion - modern practical approach

Data Selection and Search Area

General information -- Search area

Input file: C:\Emigma\Emigma\6.3\Examples_Release\3DMag_inv

Survey

Maximum survey area

-200 <= X <= 200 -150 <= Y <= 150

Selected survey area

-200 <= X <= 200 -150 <= Y <= 150

Components

X Y Z Total

Number of data

221 per component

Area to search a model

Center (m): Size (m): Euler angle (degree):

x 0 x 360 Strike 0

y 0 y 270

z -67.5 z 135

Get search area from

Customize A .pev file A permeability distribution (.mag) file

A dataset

File name:

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- Data file .pev
- Survey Area
- Data Subset
- Data component
- Search Area
 - ◆ *where is the anomaly expected ?*
- A) User specified
- B) From a set of prisms
- C) From a distribution file

Inversion Style

General information -- Grid

Inversion method:

Matrix Optimization

Grids of search area:

Maximum total number of grids allowed: 120

Number of grid points along X direction: 5

Number of grid points along Y direction: 3

Number of grid points along Z direction: 1

Total number of grids: 15

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Matrix or Optimizaton

Matrix Inversion

direct inversion

$$d = F m$$

d → vector of N – dimension

F → Matrix of N × M – dimension

m → vector of M – dimension

Optimized Inversion

recursive inversion

minimizing a functional

Matrix Inversion

$$H_{\text{ext}}(r) = \int G(r, r') J(r') dr'$$

$$J(r') = (m(r') - m_0) H_{\text{ins}}(r') = \chi(r') H_{\text{ins}}(r')$$

Matrix inversion approach

Method

Full solution Iterative LN solution (1) Iterative LN solution (2) Born solution

Born solution: Invert M x M matrix to obtain J and use Born approximation to solve for permeability.

Susceptibility constraints

<= X <=

Cells with susceptibility value equal to 0 will not be output to permeability distribution (.mag) file.

Search parameters

Maximum iterations

Susceptibility tolerance

Data usage: %

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Techniques

◆ Full solution

- ✦ no assumptions

◆ Iterative LN

- ✦ removing non-permeable cells

◆ Iterative LN

- ✦ Internal H = LN H
- ✦ Born starting model

◆ Born Solution

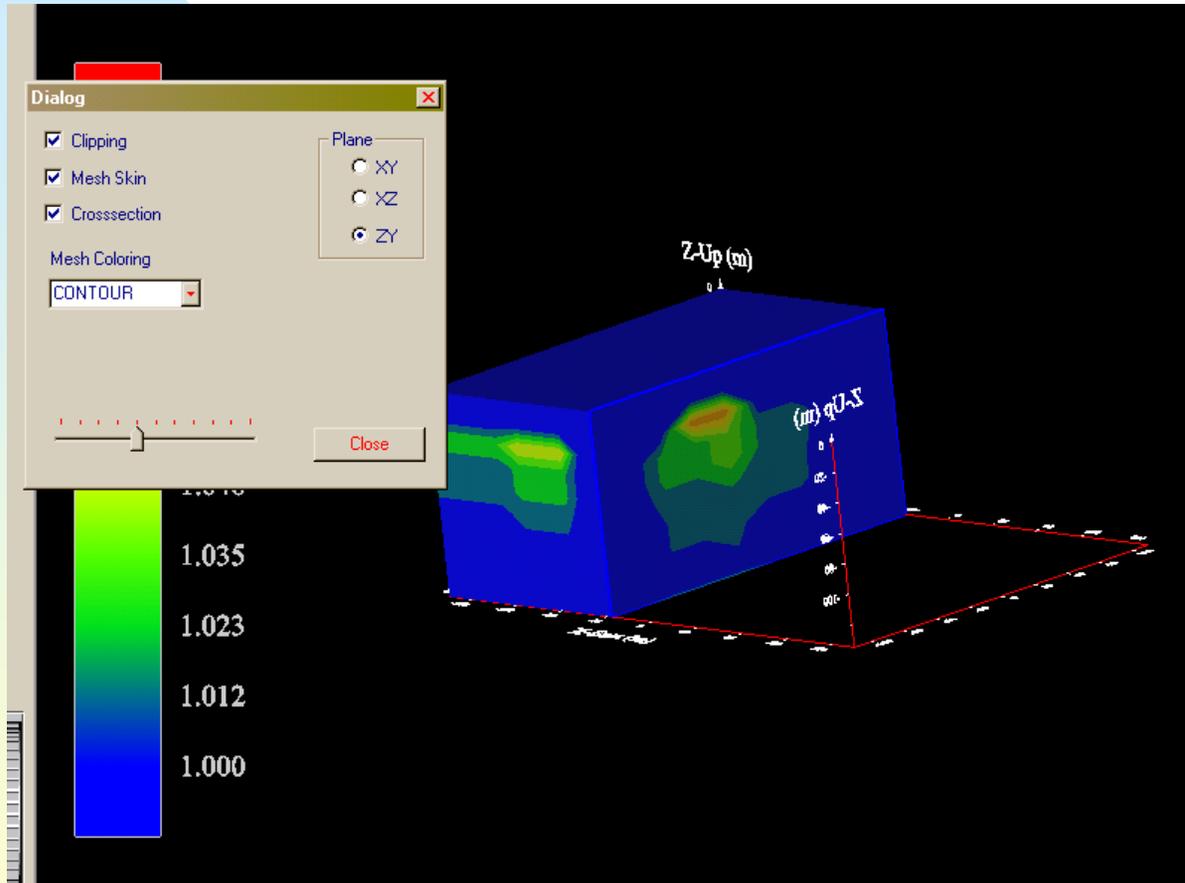
- ✦ Internal H = Background H

Inversion Output

The screenshot displays the 'Inversion Output' software interface. It features a 'Run status' window with the following text: 'Permeability Tolerance= 2.079693592401768E-008', 'Completed nx-ny-2nz inversion ...', 'non-permb. cells (final) >> 49', 'Initial Misfit (zero model) >> 5.602011920930103', 'Final Misfit >> 1.930879859255055', 'RMS Error >> 4.485203500787201', 'Final Grad_Misfit >> 74.704883294964520', and '... Terminating Matrix Inversion'. Below this is a 'Progress' bar. The 'Auxiliary files' section includes input fields for permeability distribution files and output fields for the .mag and .grd files, each with a 'Browser' button. The 'Output to database' section has fields for 'Project name:', 'Survey name:', and 'Data set name:'. An 'Action' panel on the right contains buttons for 'Invert', 'Clear run status', 'View .mag output', 'View .grd output', and 'Write .pev file'. At the bottom are buttons for '< Back', 'Finish', 'Cancel', and 'Help'.

- Start Inversion
- Mag File
 - ◆ distribution of anomalies
- Grd File
 - ◆ for Meshviewer
- Output to .pev file
 - ◆ maximum 499 prisms

Meshviewer



Optimized Inversion

General information -- Grid

Inversion method

Matrix Optimization

Grids of search area

Maximum total number of grids allowed: 2000

Number of grid points along X direction: 20

Number of grid points along Y direction: 14

Number of grid points along Z direction: 4

Total number of grids: 1120

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General concept

- ◆ *Start with an initial guess and go looking for the best fitting model*

Critical factors

- ◆ *Good forward simulation*
- ◆ *good minimization technique*
- ◆ *good starting model*
- ◆ *good data*

Optimized Inversion

$$\phi(\mathbf{m}) = \lambda \phi_d(\mathbf{m}) + \phi_m(\mathbf{m})$$

$\phi(\mathbf{m})$ - functional to be minimized

$\phi_d(\mathbf{m})$ - data misfit

$\phi_m(\mathbf{m})$ - model misfit

λ - Lagrangian multiplier - regularization weight

Occam style model misfit function

$$\phi_m(\mathbf{m}) = \alpha_0 \int w^2(\mathbf{z}) [\mathbf{m}(\mathbf{r}) - \mathbf{m}^0(\mathbf{r})]^2 d\mathbf{v} +$$

$$\int_{i=x,y,z} \alpha_i \int [w(\mathbf{z}) \star_i (\mathbf{m}(\mathbf{r}) - \mathbf{m}^0(\mathbf{r}))]^2 d\mathbf{v}$$

α_i - weighting factors

$w(\mathbf{z})$ - depth weighting

Physical Modes - *Forward Model*

- M via LN
 - ◆ Internal Magnetization vector (M) derived via LN
- H via LN
 - ◆ Internal magnetic vector via LN
- H via Born
 - ◆ Internal H and therefore internal M derived via Born

The forward model or estimated data is derived via an approximation which is either Born or Non-Linear Approximator. For the LN, one can assume that H is derived by LN or M is derived by LN.

Minimization Technique

How to find the minima

■ Quasi-Newton

- ◆ approximate 2nd derivatives for Hessian matrix
- ◆ efficient when Hessian of previous iteration utilized
- ◆ poor results if Hessians from sequential iterations very different

■ Conjugate Gradient

- ◆ gradients used to define search direction
- ◆ minima by line search
- ◆ terminates when gradient reaches a minimum value

Starting Model

Optimization inversion -- Starting model

Get starting model from

Customize A .pev file A permeability distribution (.mag) file

A dataset

File name:

List of starting model settings

#	Center X(m)	Center Y(m)	Center Z(m)	Size X(m)	Size Y(m)
1	0.000000	0.000000	-67.500000	360.000000	270.000000

Edit starting model

of Prisms Modify a prism Add a prism

Geometry and susceptibility

Center (m):	Size (m):	Eular angles (degree):	Susceptibility (X)
x <input type="text" value="0"/>	x <input type="text" value="360"/>	Strike <input type="text" value="45"/>	<input type="text" value="0"/>
y <input type="text" value="0"/>	y <input type="text" value="270"/>	Dip <input type="text" value="0"/>	
z <input type="text" value="-67.5"/>	z <input type="text" value="135"/>	Plunge <input type="text" value="0"/>	

- User defined prisms
- From a forward model
- From a previous inversion

Optimized Inversion Style

Optimization inversion

Mode

M via LN H via LN

H via Born

Minimization technique

Quasi-Newton Constrained Quasi-Newton

Conjugate Gradient Constrained Conjugate Gradient

Weighting function and factors

$w = 1$ $w = (z_0+z)^{-3/2}$ $z_0 =$

$X_0 =$

$A_0 =$ $A_x =$ $A_y =$ $A_z =$

Susceptibility constraints

$\leq X \leq$

Cells with susceptibility value equal to 0 will not be output to permeability distribution (.mag) file.

Data usage: %

Lambda:

Search parameters

Maximum iterations

Gradient tolerance

Susceptibility tolerance

Target misfit

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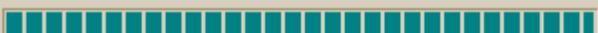
- Physical Mode
 - ◆ internal scattering assumption
- Minimization Technique
 - ◆ mathematical technique for minimizing the functional
- Model weights
 - ◆ regularization weights
- Susceptibility Constraints
- Gradient tolerance
- Susceptibility tolerance
- Target Misfit
- Lambda - data misfit vs model characteristics

Output

General information -- Output

Run status

```
Iteration Number = 4
Misfit = 4.107100579977388E-001
Grad_Misfit = 6.717327263458997
>>>FINAL MISFIT VALUES<<<<
MisFit= 3.798579248706036E-001
RMS Error >> 5.779676024470947
Grad_Misfit = 7.335744286816955
... Terminating Optimization
```

Progress 

Auxiliary files

Input permeability distribution (.mag) file for search area

Input permeability distribution (.mag) file for starting model

Output permeability distribution (.mag) file

Output Meshviewer (.grd) file

Output to database

Project name:

Survey name: Data set name:

Action

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- Misfit parameter progress

Meshviewer

