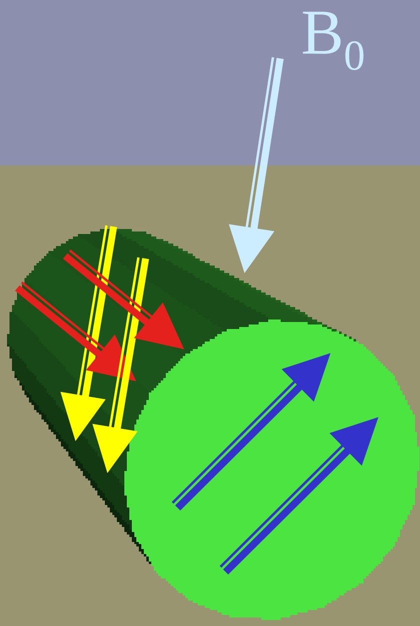
INVERSION OF MAGNETIC AND GRADIENT MAGNETIC DATA FOR DETECTION AND DISCRIMINATION OF METALLIC OBJECTS

- **Forward Simulation of Metallic Objects**
  - ***a) Why? – for what purposes***
  - ***b) How? – methodology , direction***

- **UXO Inversion Objectives**
  - **a)** ***Depth Estimation by*** 3D ***Euler Deconvolution***
  - **b)** ***'Least Squares' Method for Magnetization Vector***

PetRos EiKon Inc

Simulation of the Magnetic Field caused by Metallic Objects



WI - linear or "weak" induced magnetization
SI - non-linear or "strong" induced magnetization
RM – remanent or "permanent" magnetization

- ***how do distributions of WI, SI and RM affect measured B?***
- ***Interactions between permanent and induced***
- ***Total B_T (TMI) versus (Bx,By,Bz),***
- ***nature and use of ($\delta B_T/\delta x$, $\delta B_T/\delta y$, $\delta B_T/\delta z$) plus higher order derivatives ?***

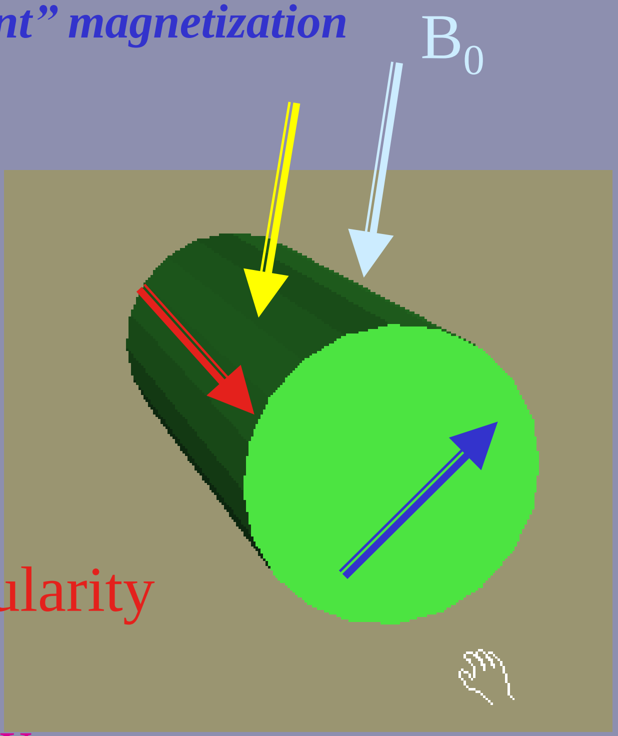
Simulation of the Magnetic Field caused by Metallic Objects

How to Simulate ?

WI - linear or "weak" induced magnetization

SI - non-linear or "strong" induced magnetization

RM – remanent or "permanent" magnetization



$$\underline{B}(r) = \underline{B}_0(r) + \int \delta\mu\, \mathbf{G}(r,r`)\, \Gamma(r`)\, \underline{B}_0(r`)$$

$$+ \int \mathbf{G}(r,r`)\, \underline{M}(r`) + \underline{\text{interactions}}$$

- $\Gamma(r`)$ – analytic integration over singularity
- Derivatives – not by finite difference
- Interactions – multi-body, single body
- *Induced by Permanent ?*

Simulation of the Magnetic Field caused by Metallic Objects

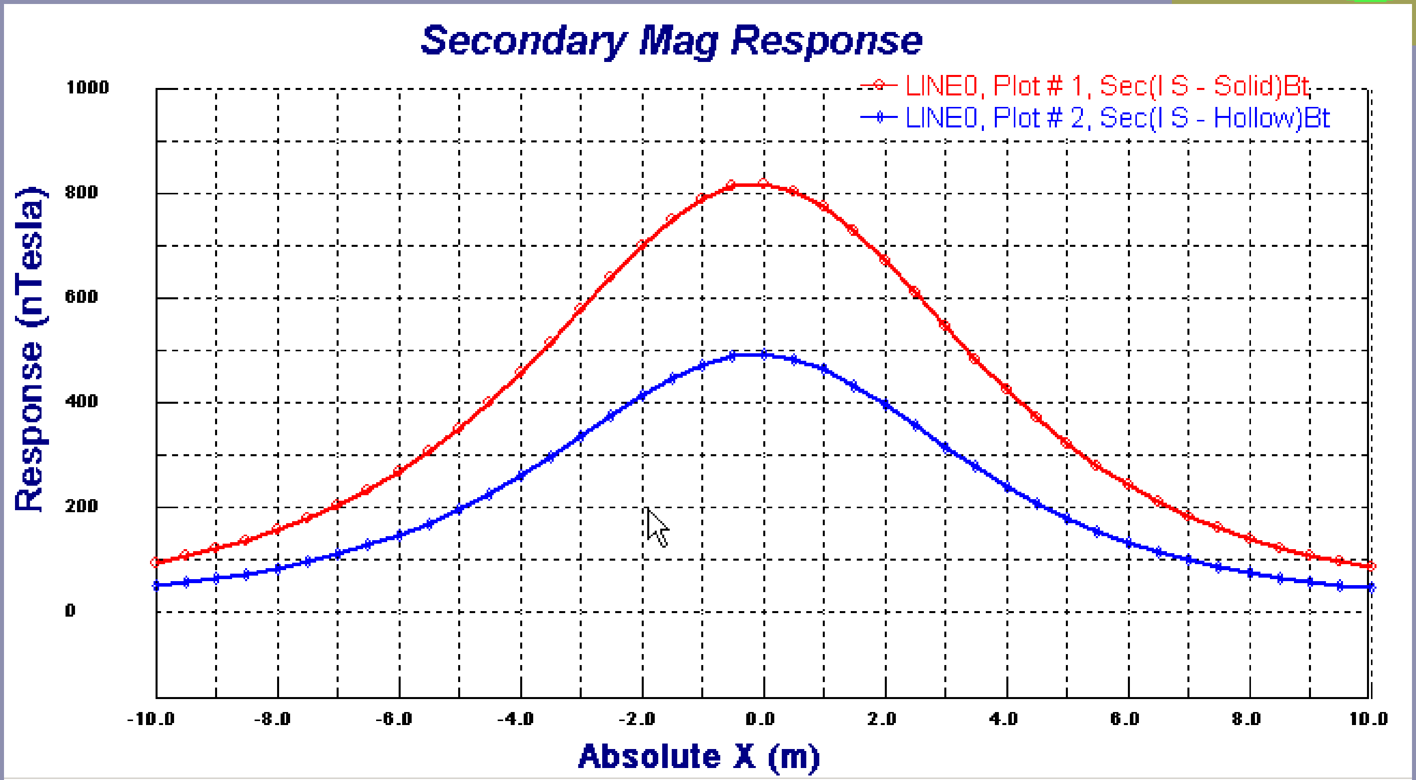
Structural Models ?

Polyhedral grid format which can be used for the different physical models

Simulation of the Magnetic Field caused by Metallic Objects

Structural Models ?

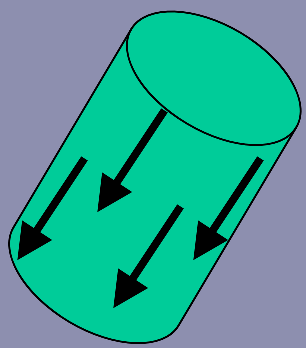
R_ext = 1m, R_int = .8m, L = 5m
Incl = 75º, Declination = 20º



Inversion of the Magnetic Field caused by Metallic Objects

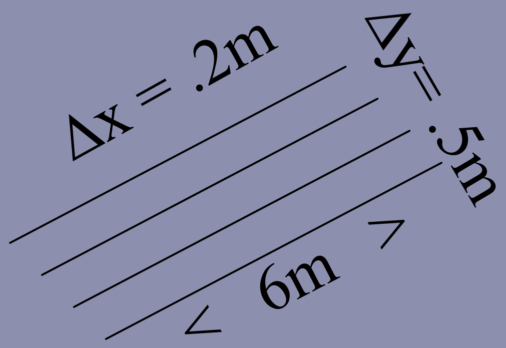
a) 3D Euler Deconvolution –
with statistical analyses of position of magnetization
b) Least Squares Inversion for <u>M</u>

Synthetic Example



R = 56mm
L = 300mm

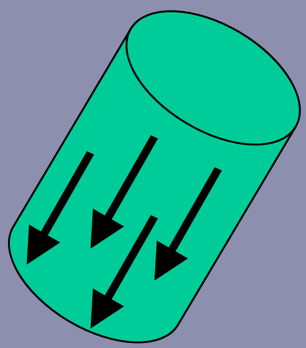
<u>M</u> (incl =75°, decl = 225°,
strength = 2 x B_0)



Inversion of the Magnetic Field caused by Metallic Objects

a) Euler Deconvolution – Zhang et al, Geophysics, 2000

Synthetic Example



R = 56mm
L = 300mm
V = .3m^3

M (incl =75^o, decl = 225^o,
strength = 2 x B_0)

Target	**X**	**Y**	**Z**
Actual	-1	0.25	-1
FFT derivatives	-.625	.245	-.578
True derivatives	-.994	.265	-.994

Inversion of the Magnetic Field caused by Metallic Objects

b) Least Squares – user controlled interactive process

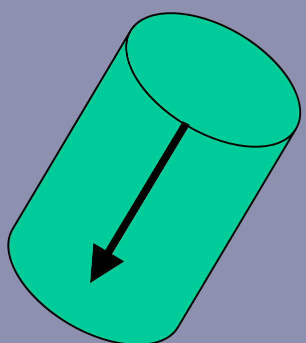
Invert for volume magnetization then divide by volume

1) *Select a search volume – e.g. 4x4x10m*
2) *Select a target volume – e.g. 0.125m^3*
3) *Iterate refining volume with previous positional estimate*

Synthetic Example

Model	X centre	Y centre	Z centre	Dip	Decl	Strength	Cell Size
Actual	-1	0.25	-1	75	225	2	0.003
Inverse I	-1.25	0.75	-0.75	33	-33	0.034	0.125
Inverse II	-1.1	0.3	-0.9	77	264	0.6	0.008
Inverse III	-0.95	0.25	-1	74.9	223	1.49	0.004
Inverse IV	-1.05	0.25	-0.95	76	235	1.8	0.003

M (incl =75^o, decl = 225^o,
strength = 2 x B_0)

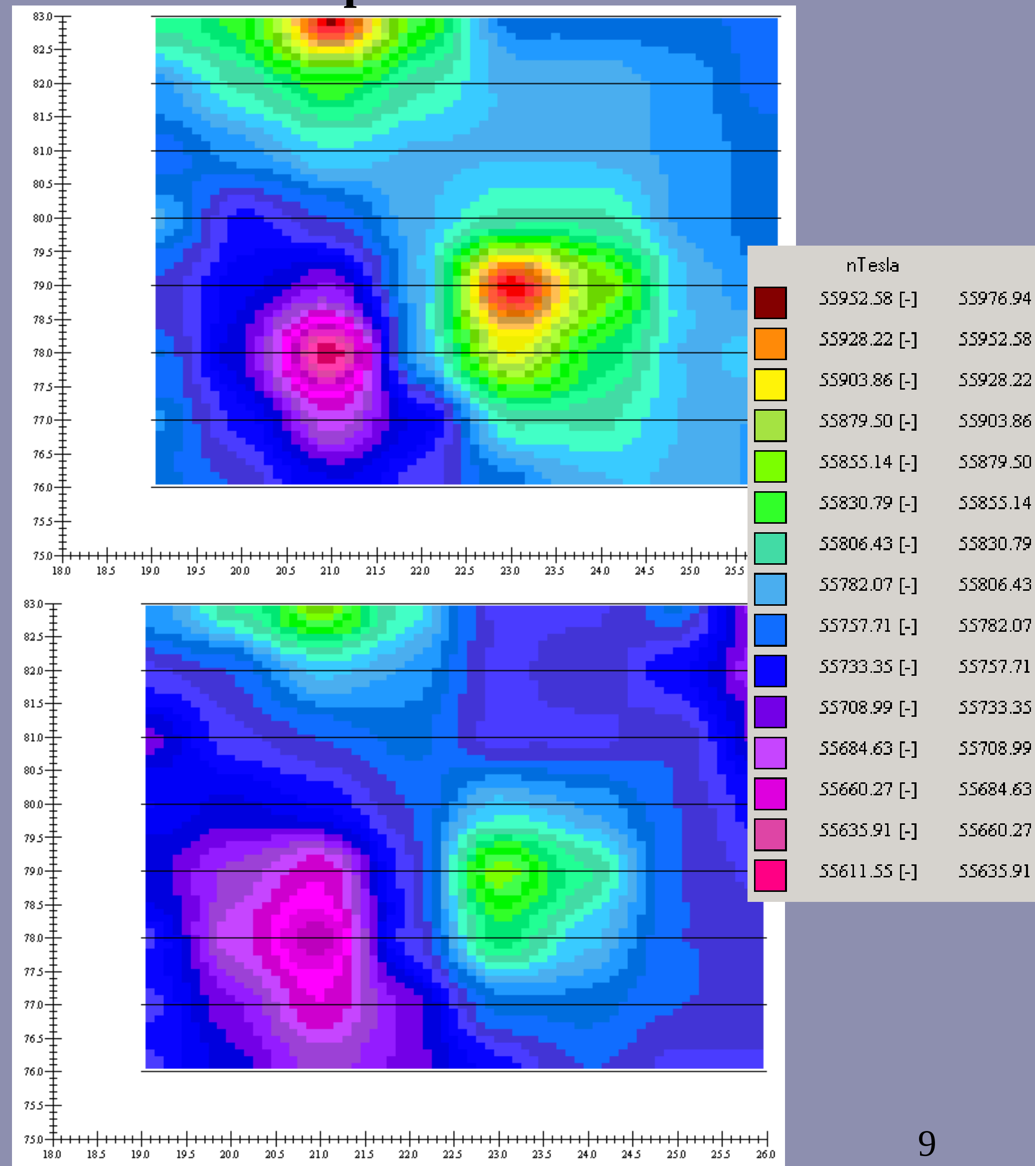


Inversion of the Magnetic Field caused by Metallic Objects

Test Site Example

Artillery Shell B6
depth of burial = 0.5 m
dip 45 degrees
Shell diameter = 10.5 cm,
Length = 46cm
Weight 15 kg
Line Spacing = 1m
Data Spacing = 1m
York University Test Site

Top Sensor – 1m



Bottom Sensor – 0.5m

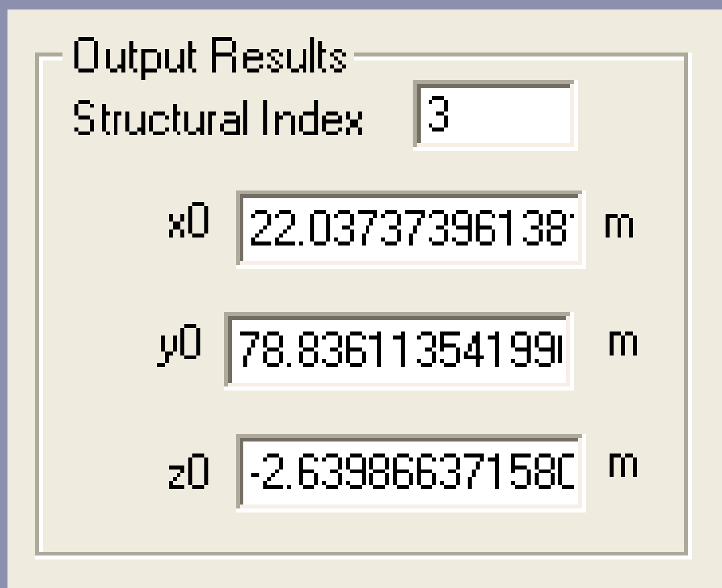
Inversion of the Magnetic Field caused by Metallic Objects

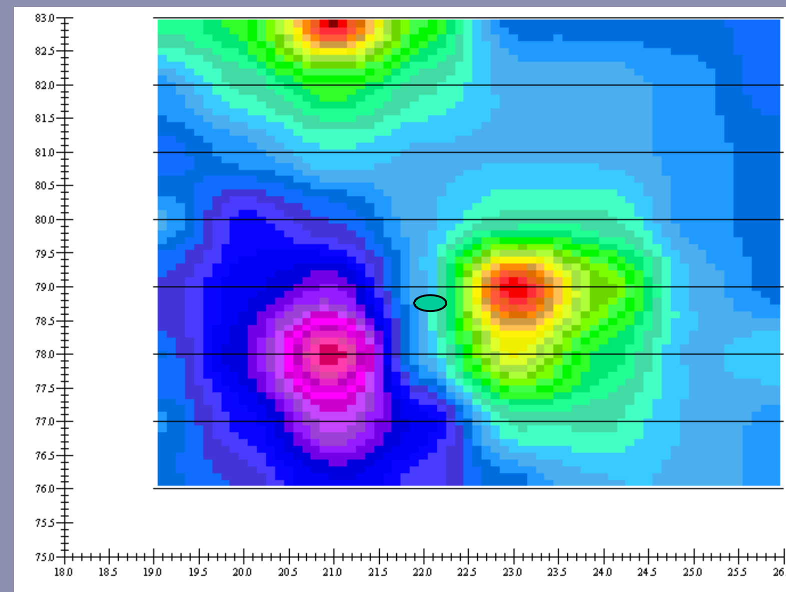
Test Site Example

Euler Deconvolution

- Derivatives by Simple Difference

top-bottom sensor, cross line, inline





depth of burial = 0.5 m

dip 45 degrees

Shell diameter = 10.5 cm,

Length = 46cm

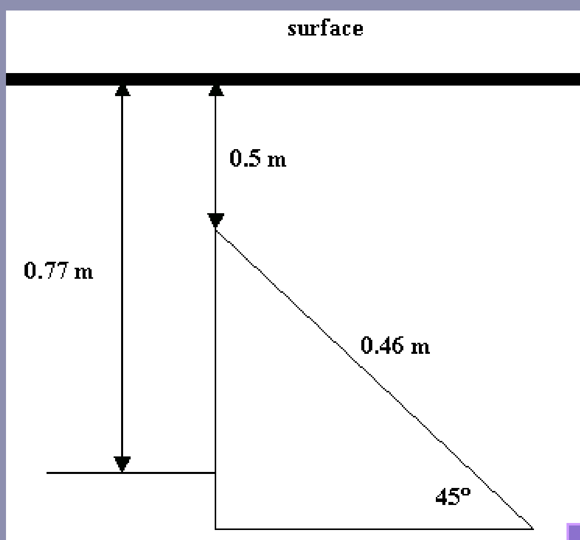
Inversion of the Magnetic Field caused by Metallic Objects

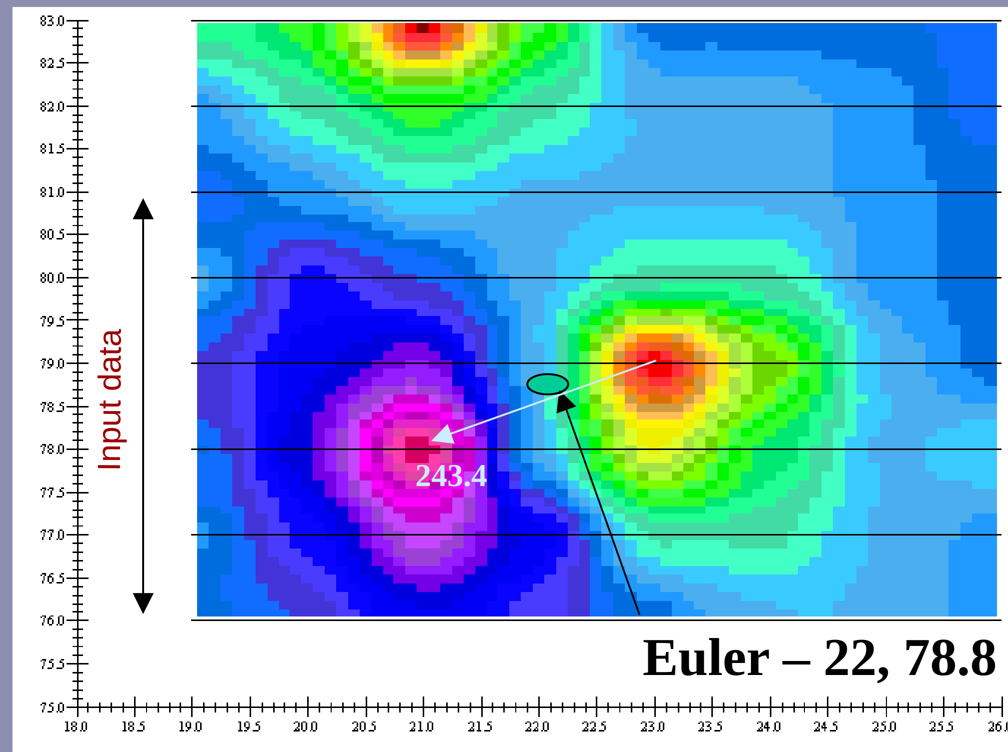
Test Site Example

Least Squares Inversion

$$|\underline{B}| = |\, \underline{B}_o + \underline{B}(\underline{M}) \,|$$

Background
Inclination = 63.3
Declination = 5.1.
55768.5 (nT).
Cubic Volume Used = .004m³

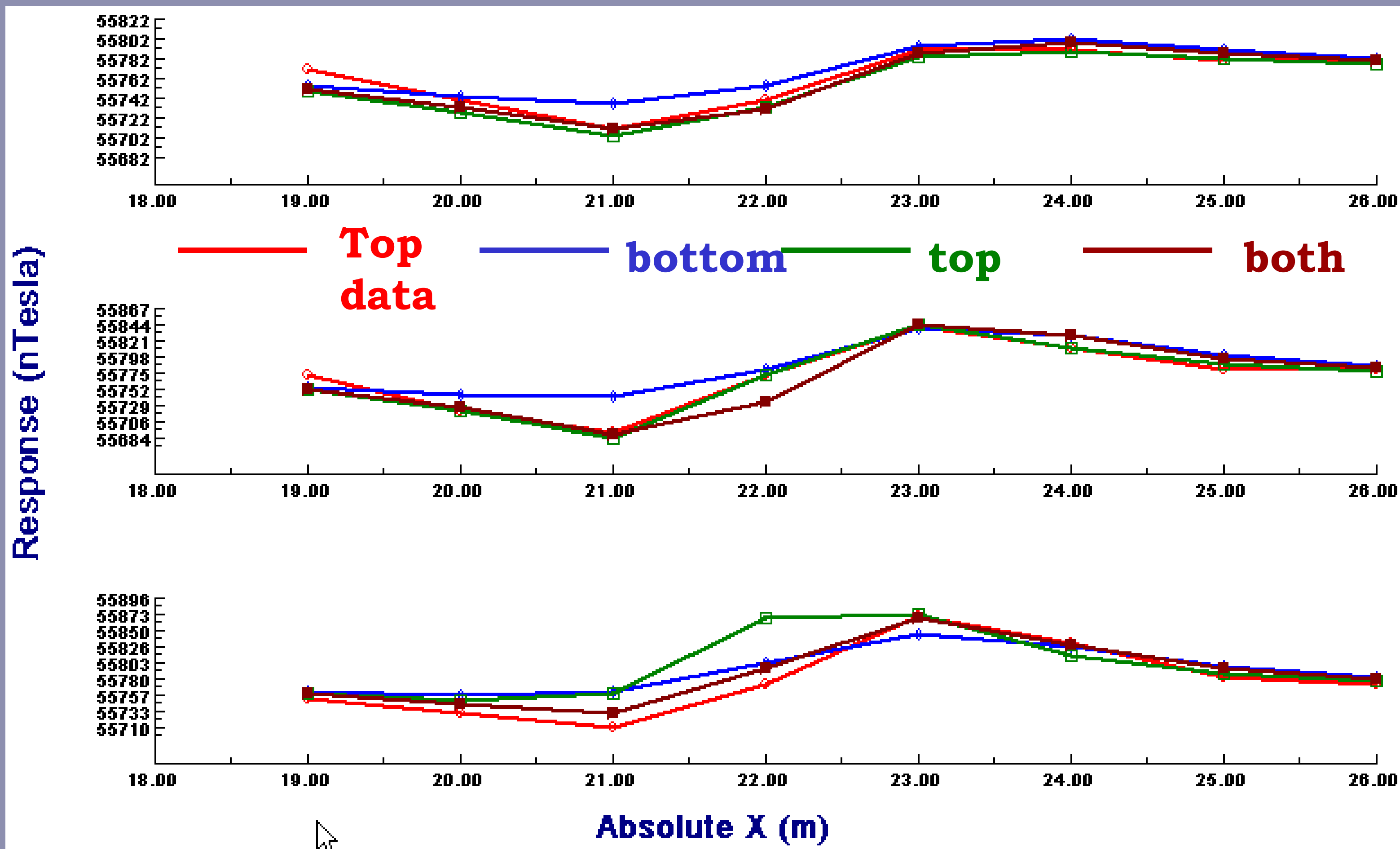




Data	x	y	z	Incl	Decl	Intensity
bottom	22.4	78.4	1.4	16.6	242.0	50.0
top	21.9	78.6	0.8	3.7	234.0	37.4
both	22.2	78.6	0.9	1.4	246.0	41.3

Inversion of the Magnetic Field caused by Metallic Objects

Test Site Example *Least Squares Inversion*



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Forward: Versatile Technique allowing:

- ❖Easy use and development
- ❖Range of physical simulation abilities
- ❖Complex model calculation capability
- ❖Speed

Inversion:

- ❖Quick estimators for position and magnetization

Direction:

- ❖**Comparison with different instruments**
- ❖**Comparison with different data types**
- ❖**Forward modeling for magnetization distribution characterization**