On Inversion Of Gradient Magnetic Data for Detection of Multiple Buried Metallic Objectives

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SAGEEP 2004

- **SAGEEP 2003 - we illustrated the use of combining the Euler Deconvolution with inversion for the magnetization vector**
- **Extending to a processing method for multiple objects of different sizes**
- **Synthetic Example**
- **Example over a Test Site**
- **All results and graphics generated in *EMIGMA*©**

Processing Overview

- Euler Depth Estimator

  i) focus on small structural index range – e.g 1.5-2.5

  ii) FFT or simple difference horizontal gradients

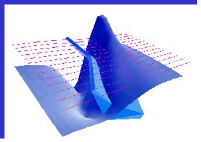
  iii) Measured or FFT Vertical gradients

- Process Euler Solutions

  a) Rodin Algorithm

  b) Statistical Location Processing

- Magnetization Vector Inversion



On Inversion for Detection of Multiple Buried Metallic Objectives

Flow Chart for Implementing Euler Depth Estimator and Vector Inversion

Step 1. Data preparation

Gradients have to be calculated if not measured. Vertical derivative can be computed via FFT. Horizontal derivatives can be computed either by simple difference or FFT.

Step2 Generate Initial Euler solutions

This involves setting appropriate moving window size, structural index indicating the type of anomaly. Any solution which has positive z, or whose distance from its respective moving window is over certain value is discarded.

Step 3. Post-process Euler Solutions by applying Rodin Algorithm

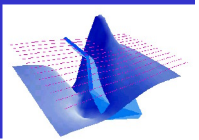
This process selects/eliminates solutions according to the spatial distribution of initial coarse Euler solutions. Only those solution having relatively high geometric concentration will be kept.

Step 4. Determine location of each individual body

Based on the spatial distance to distinguish buried bodies, clusters are split into groups, each of which identifies a body. The location of this body is calculated by means of statistics.

Step 5. Apply Magnetization Vector Inversion

A local search grid is set for each individual body and a subset of measured total data is selected. By performing an automatic iterative target volume modification according to a prescribed volume range of the buried objectives - optimum solutions giving the locations as well as the internal magnetization vectors of buried objects are produced.



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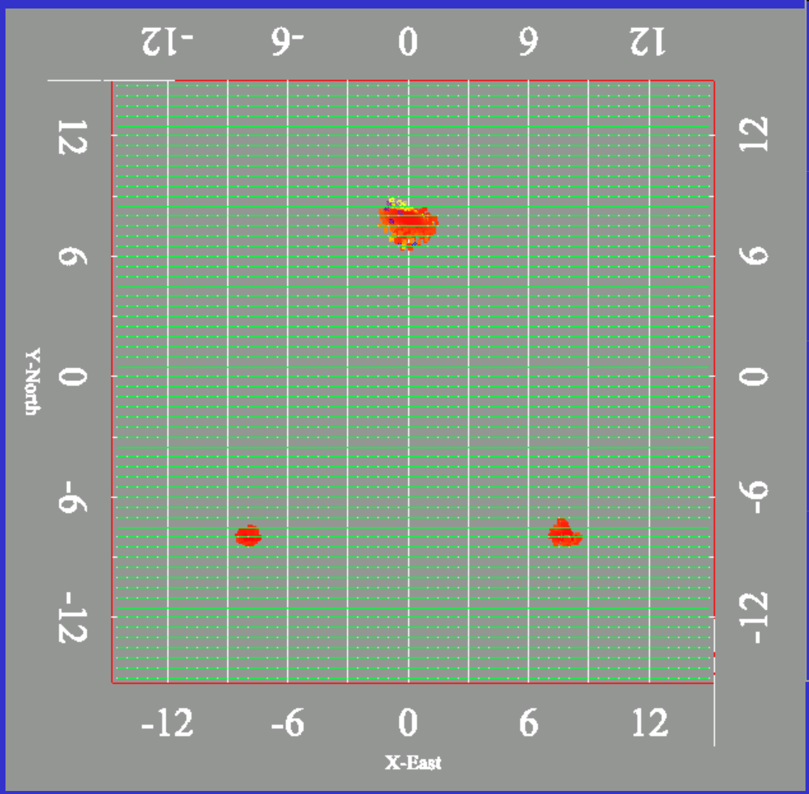
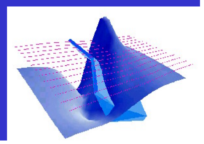
Synthetic Example - .5m x .5m data sampling- Fixed search Grid with a range of SI

Body	X	Y	Z	dip	decl	M	Size
1	0	8	-3	45	45	6	0.008
2	-8	--8	-2.5	80	120	7	0.008
3	8	-8	-2	35	70	7	0.008



	Body	X	Y	Z
Actual locations	1	0	8	-3
	2	-8	--8	-2.5
	3	8	-8	-2
True B and dB	1	0.01	7.87	-3.10
	2	-7.97	-7.97	-2.48
	3	7.98	-7.99	-1.97
noisy B and FFT dB	1	-0.01	7.59	-2.64
	2	-7.82	-7.97	-2.58
	3	7.86	-7.97	-2.18
noisy B and FFT dB/dz simple difference horizontal derivatives	1	-0.13	7.87	-2.51
	2	-7.97	-7.95	-2.52
	3	7.92	-7.80	-2.15

- All results relatively good



On Inversion for Detection of Multiple Buried Metallic Objectives

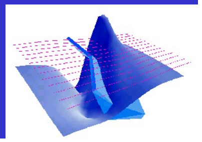
Synthetic Example - Vector Inversion – Course Grid 1m x 1m data sampling

-For the fine grid VI slightly improves the Euler results

-For a course grid the Euler solutions are poorer for noisy data

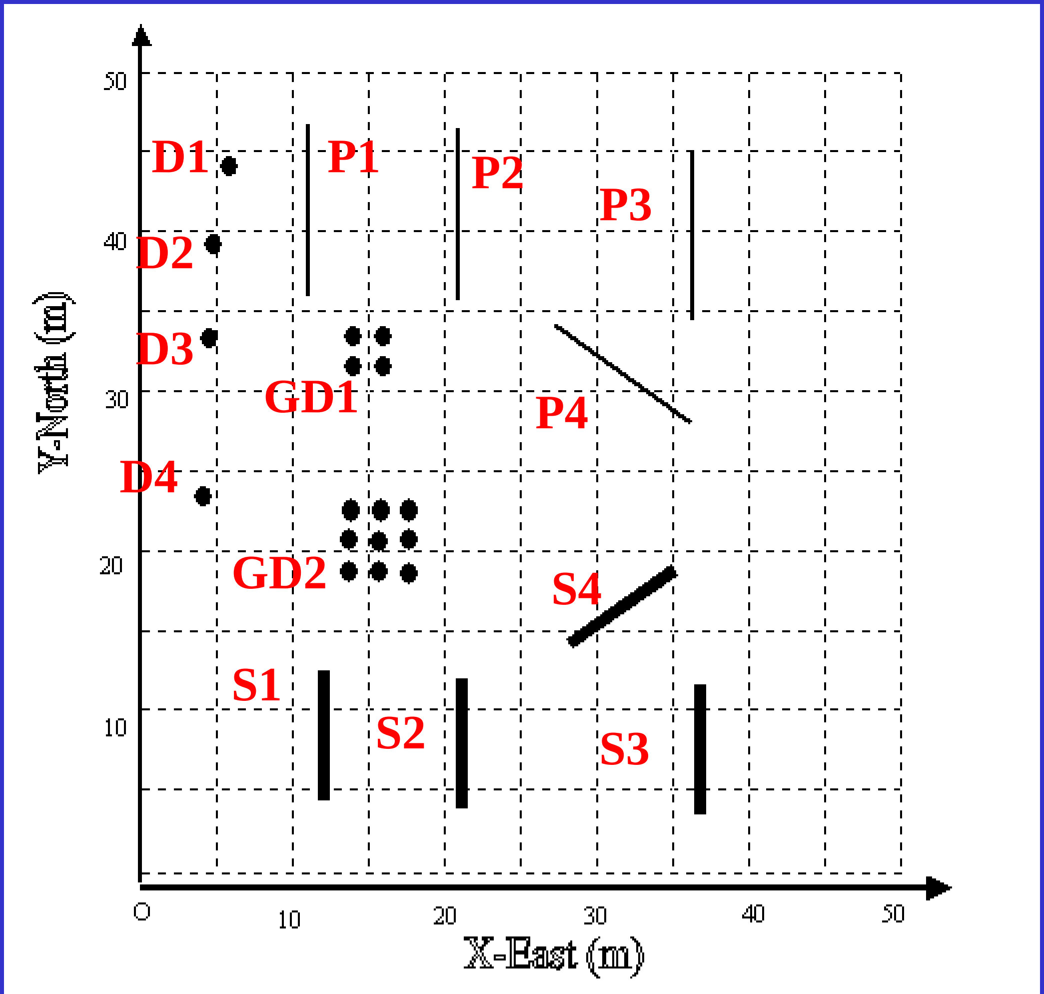
Vector Inversion Results by Processing

	Body	X center	Y center	Z center	dip	decl	M	Cell Size
Actual	1	0	8	-3	45	45	6	0.008
	2	-8	--8	-2.5	80	120	7	0.008
	3	8	-8	-2	35	70	7	0.008
True total field	1	0.02	8.02	-2.95	45.0	44.6	24.6	0.002
	2	-8.0	-8.17	-2.47	73.1	148	17.4	0.003
	3	7.97	-8.02	-1.99	36.5	71.1	17.1	0.003
Noisy total field	1	-0.02	7.66	-3.07	48.2	63.8	28.1	0.002
	2	-8.0	-8.02	-2.47	77.9	132.0	17.4	0.003
	3	7.97	-8.02	-1.84	37.6	70.6	14.8	0.003



On Inversion for Detection of Multiple Buried Metallic Objectives

Layout of Buried Objects, Columbia Test Site, University of Waterloo



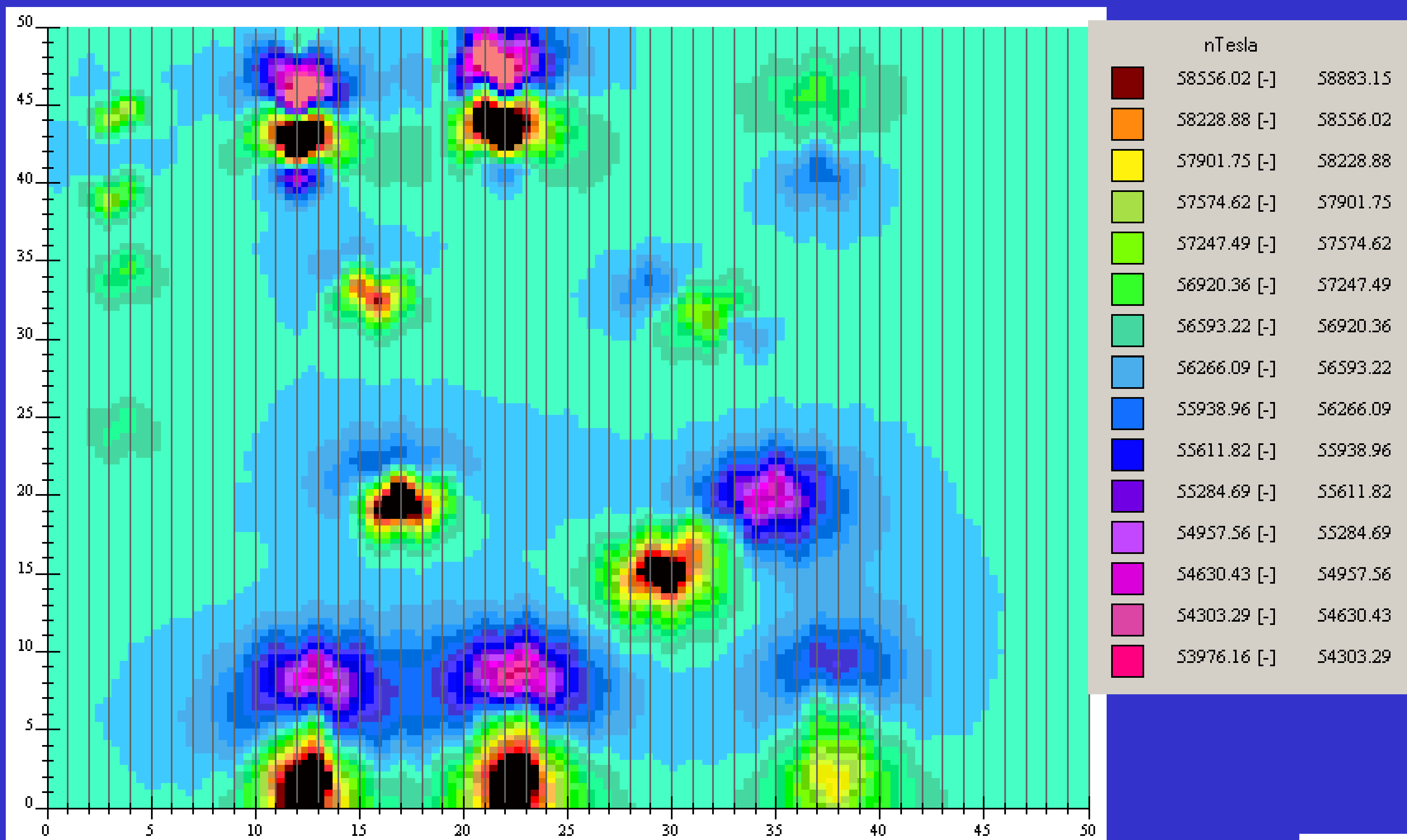
Filled circle
vertical 45 gallon drum
Volume .21m^3 ,height 0.92m

Filled rectangle
vertical sheet
8m by 1m by 0.1m

Segment of line
horizontal pipe
diameter 0.1m

On Inversion for Detection of Multiple Buried Metallic Objectives

Layout of Buried Objects, Columbia Test Site, University of Waterloo



Cesium Magnetometer (SMARTMAG) – 1m x 0.1m data sampling

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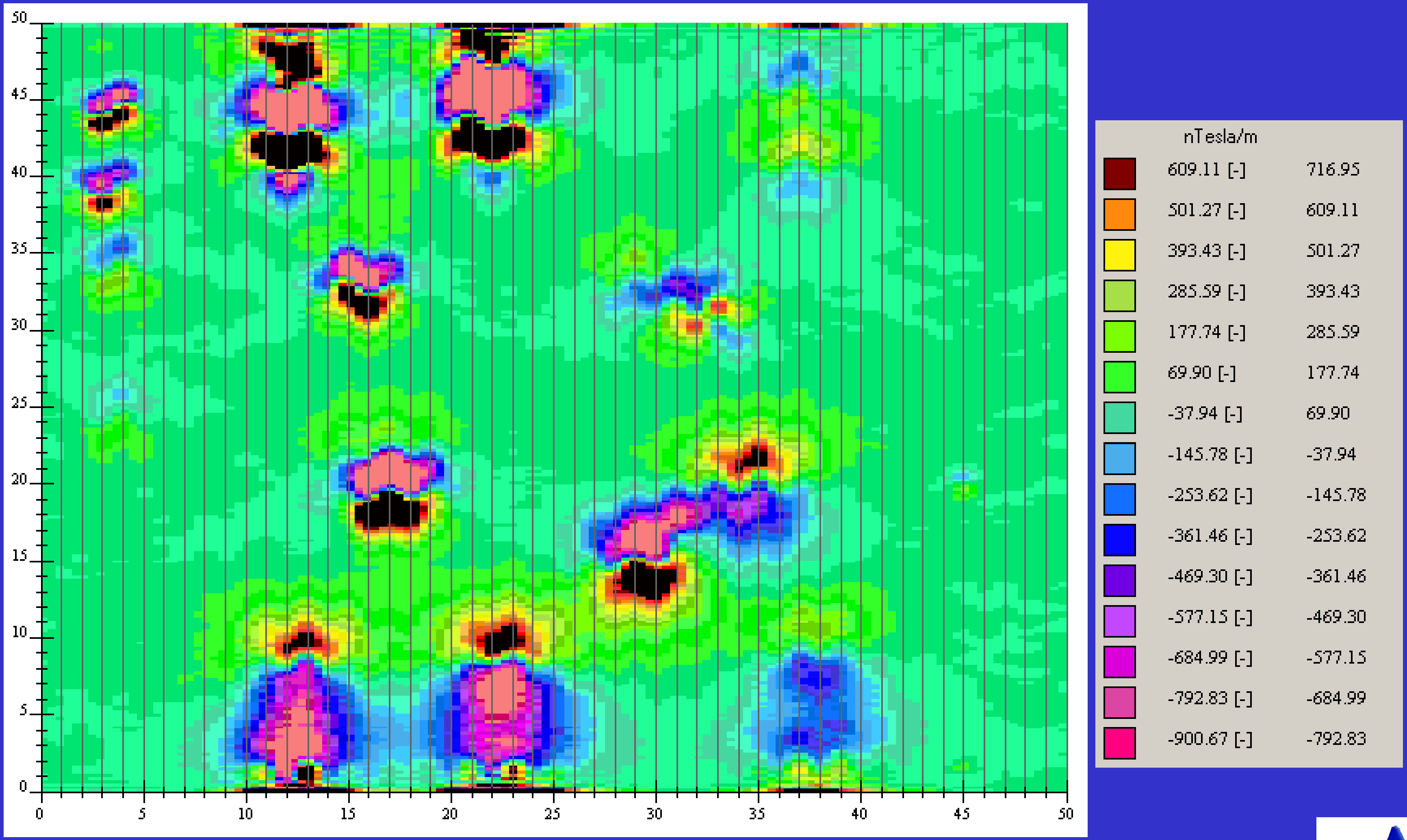
128 by 256 FFT grid with grid cell size 0.4m by 0.2m

Horizontal Derivative (North) from FFT

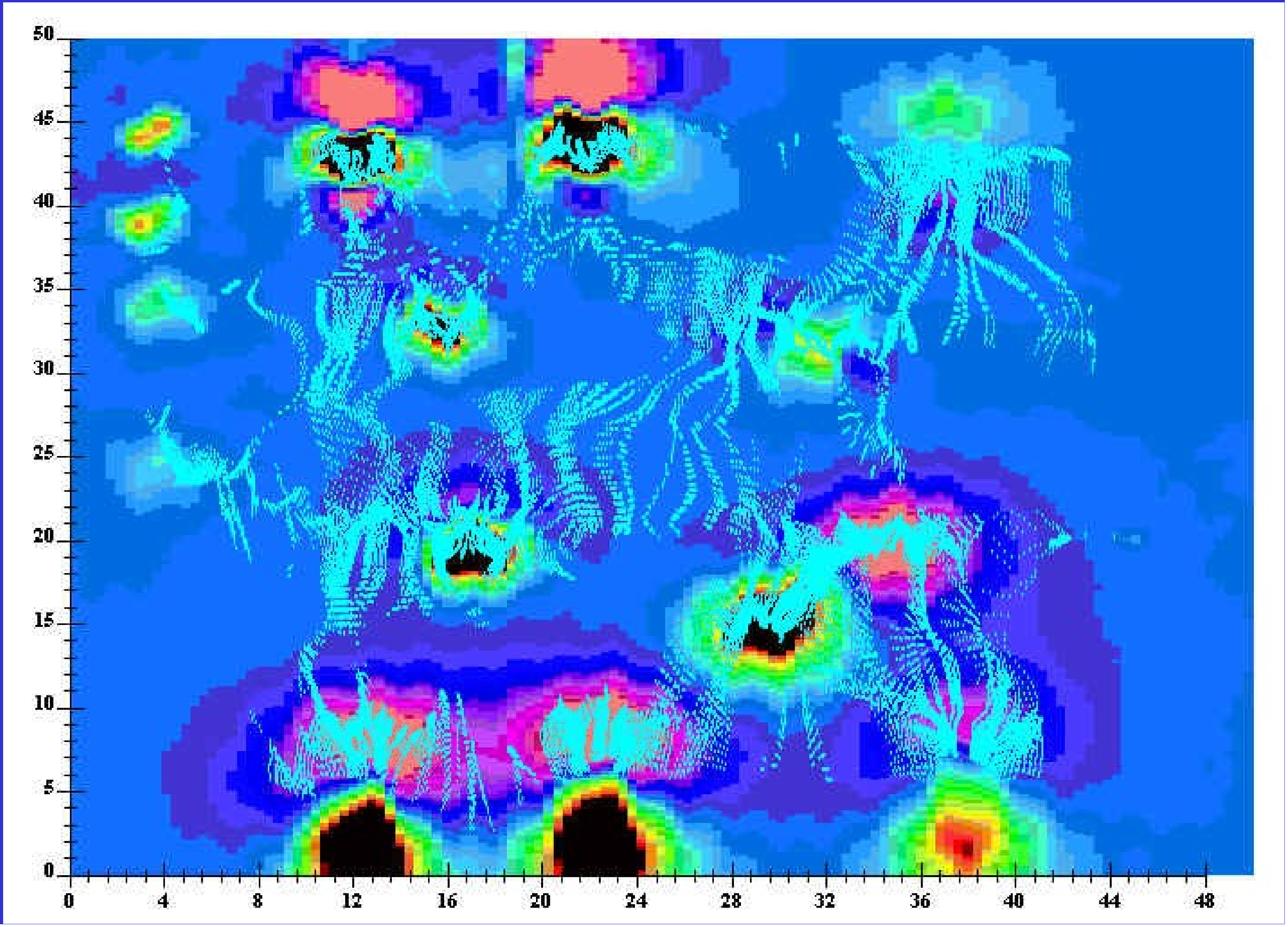


Cesium Magnetometer (SMARTMAG) – 1m x 0.1m data sampling

On Inversion for Detection of Multiple Buried Metallic Objectives

Step2 Generate Initial Euler solutions

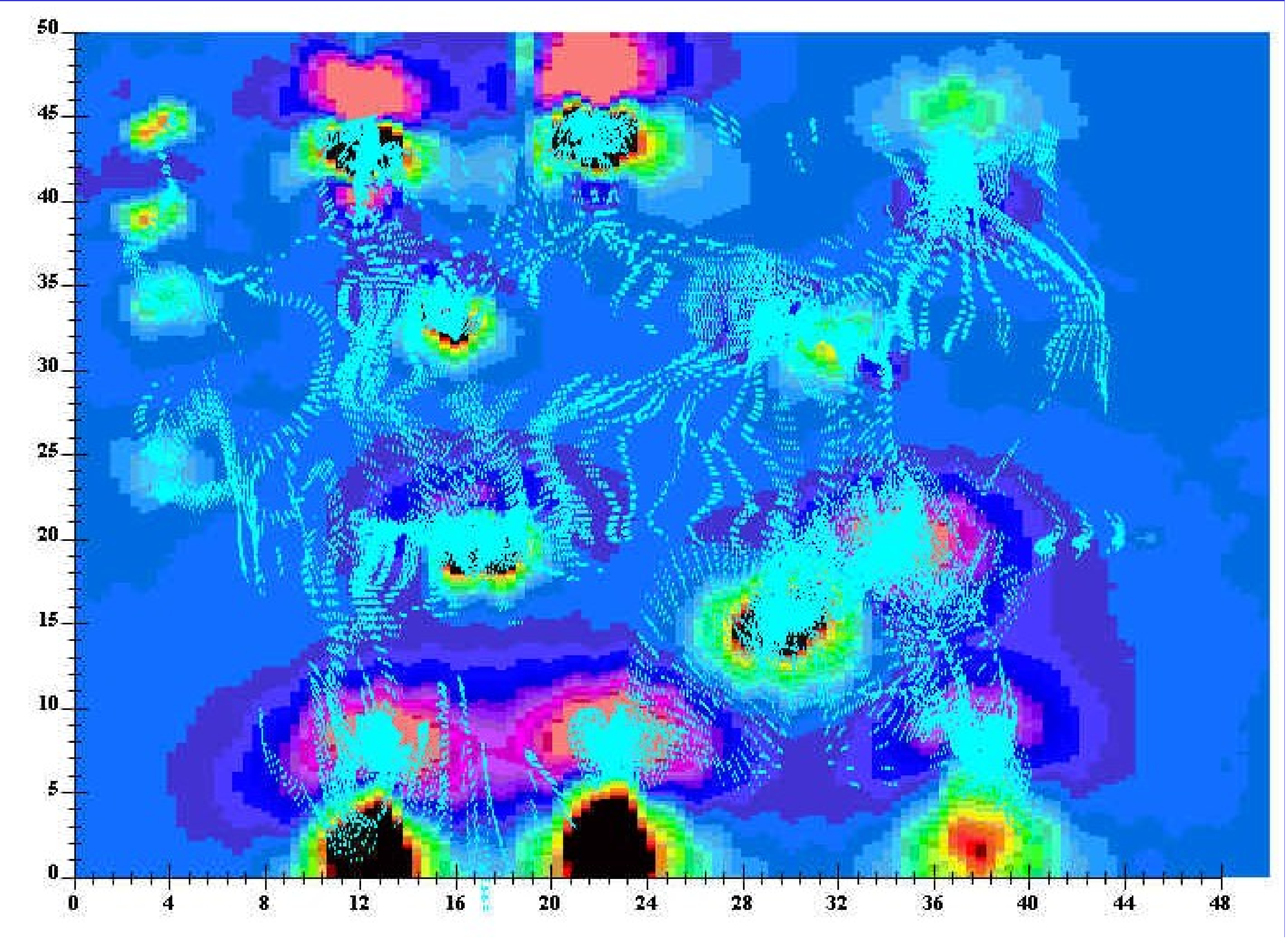
Moving window - 5m by 5m, Structural index - 0.5 to 1.5 by 0.25
55375 solutions



On Inversion for Detection of Multiple Buried Metallic Objectives

Step2 Generate Initial Euler solutions

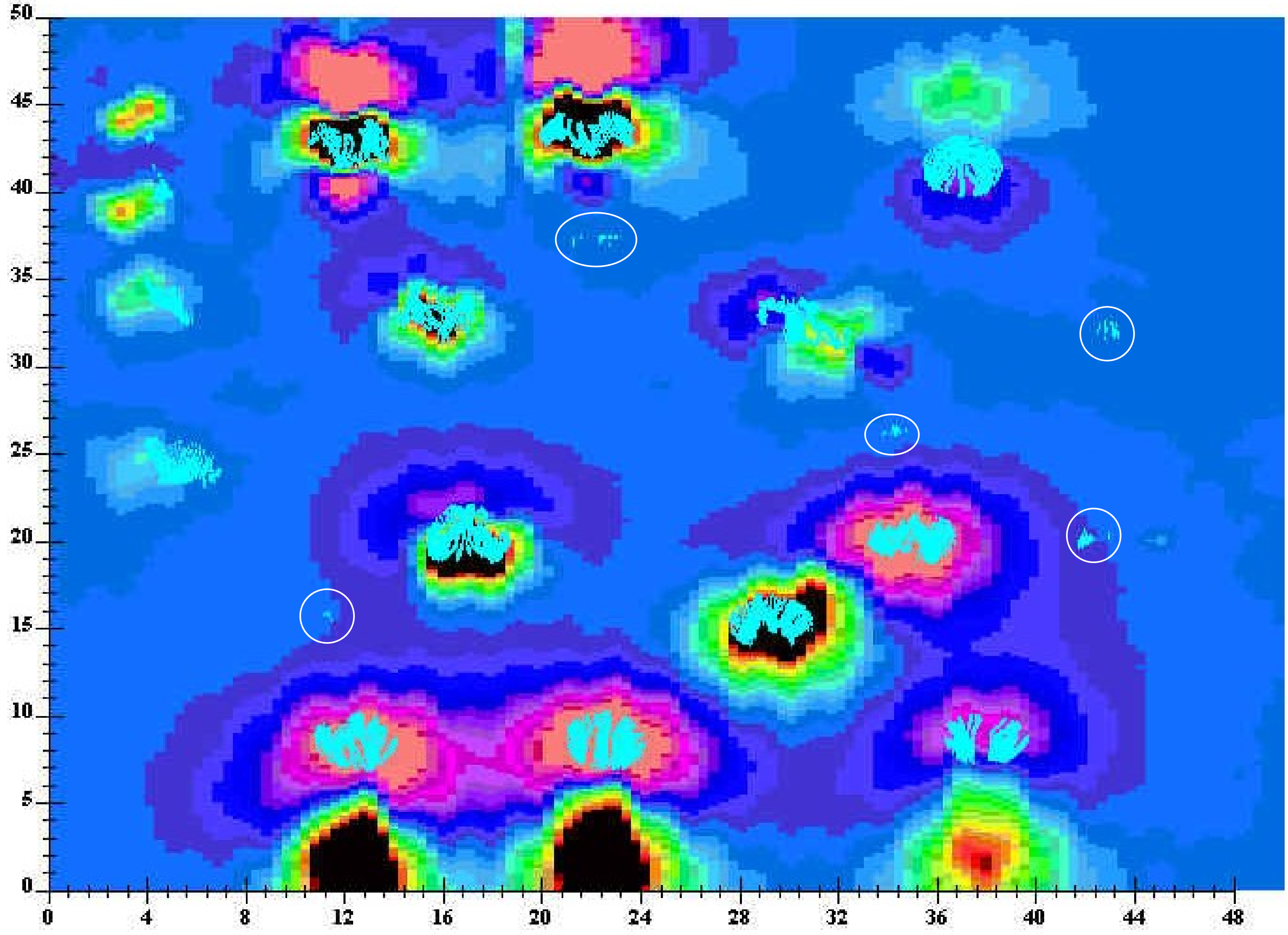
Moving window - 5m by 5m, Structural index - 2.5 to 3.5 by 0.25
74667 solutions



On Inversion for Detection of Multiple Buried Metallic Objectives

Step3 Rodin Processing

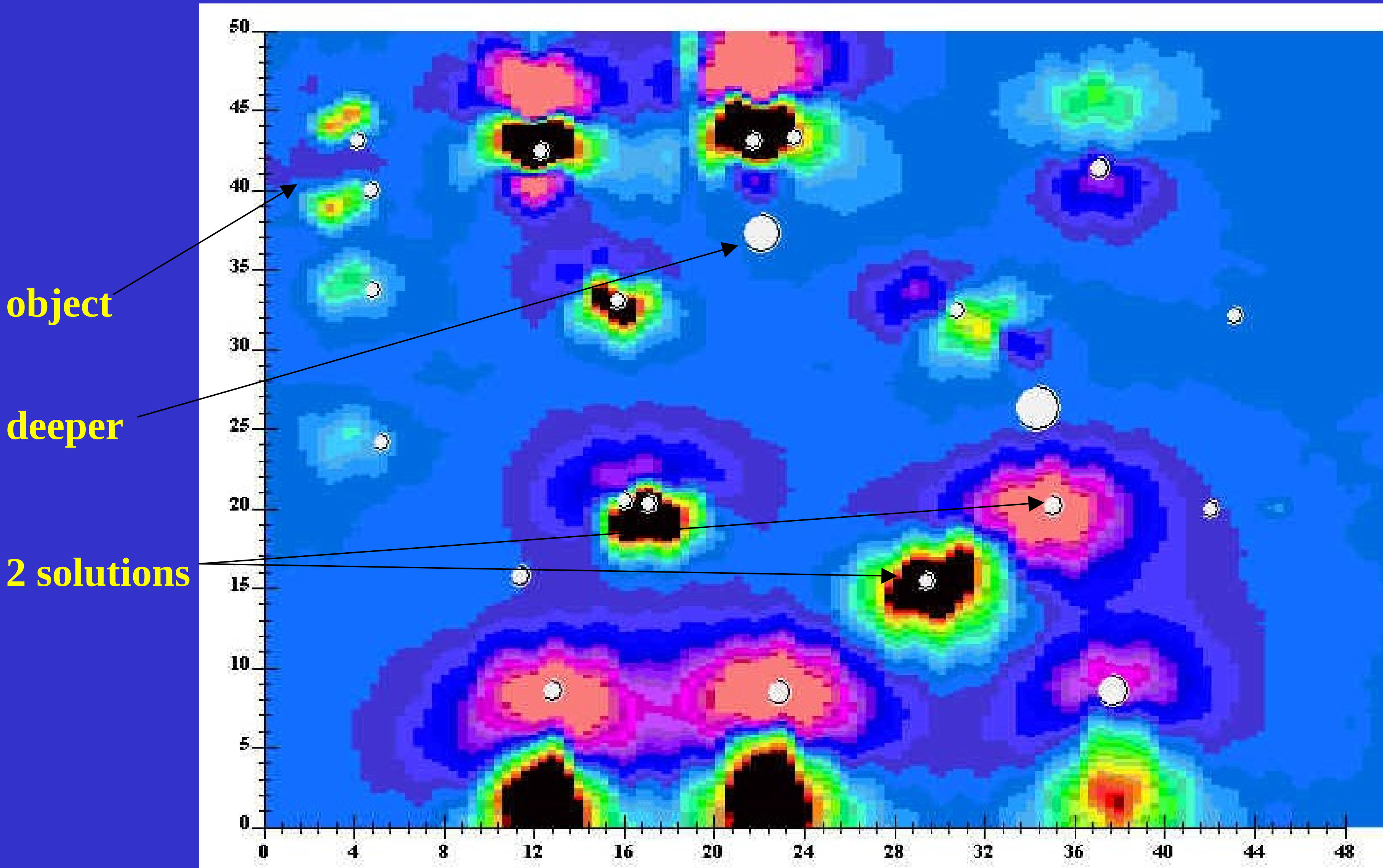
Artifacts?



On Inversion for Detection of Multiple Buried Metallic Objectives

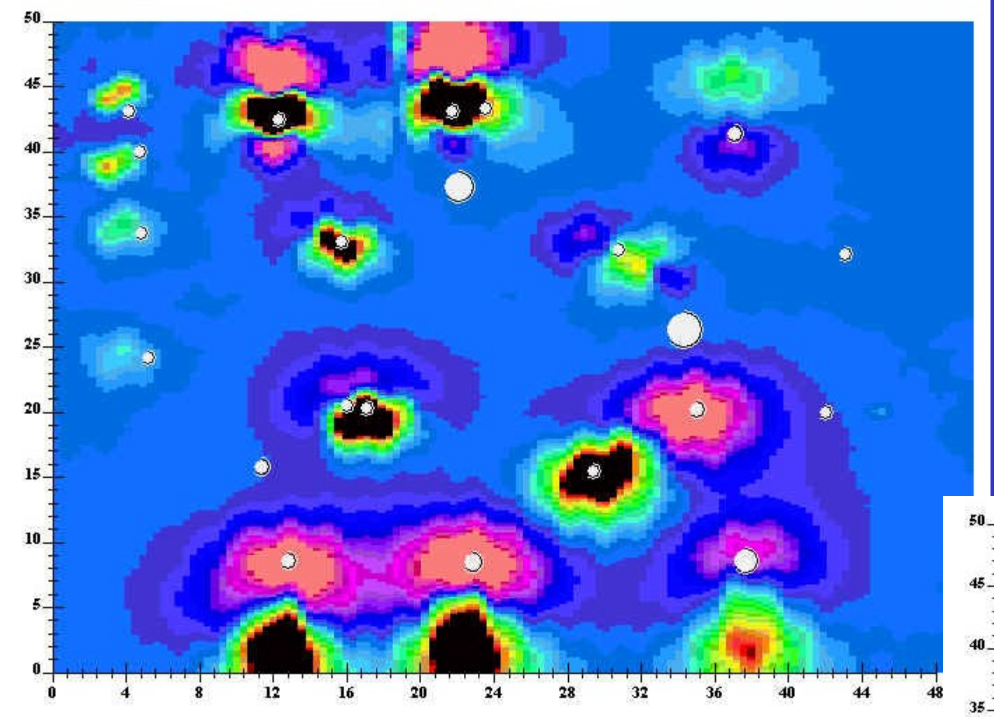
Step4 Statistical Removal Processing

Determine location of each individual body – 1.5m distinguishing distance

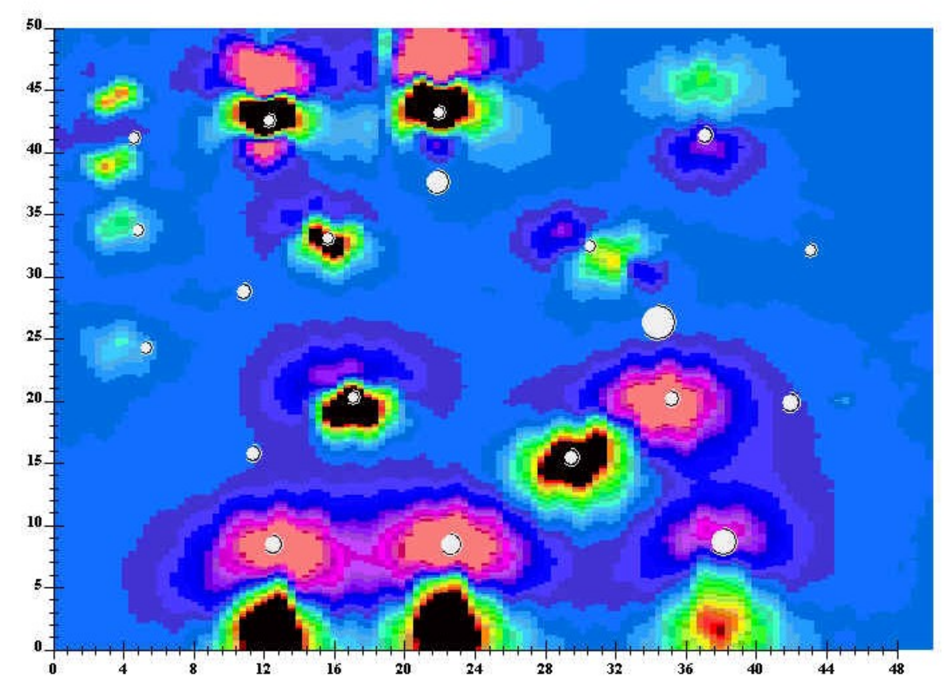


On Inversion for Detection of Multiple Buried Metallic Objectives

Step4 Statistical Removal Processing



1.5m distinguishing distance



2.5m distinguishing distance

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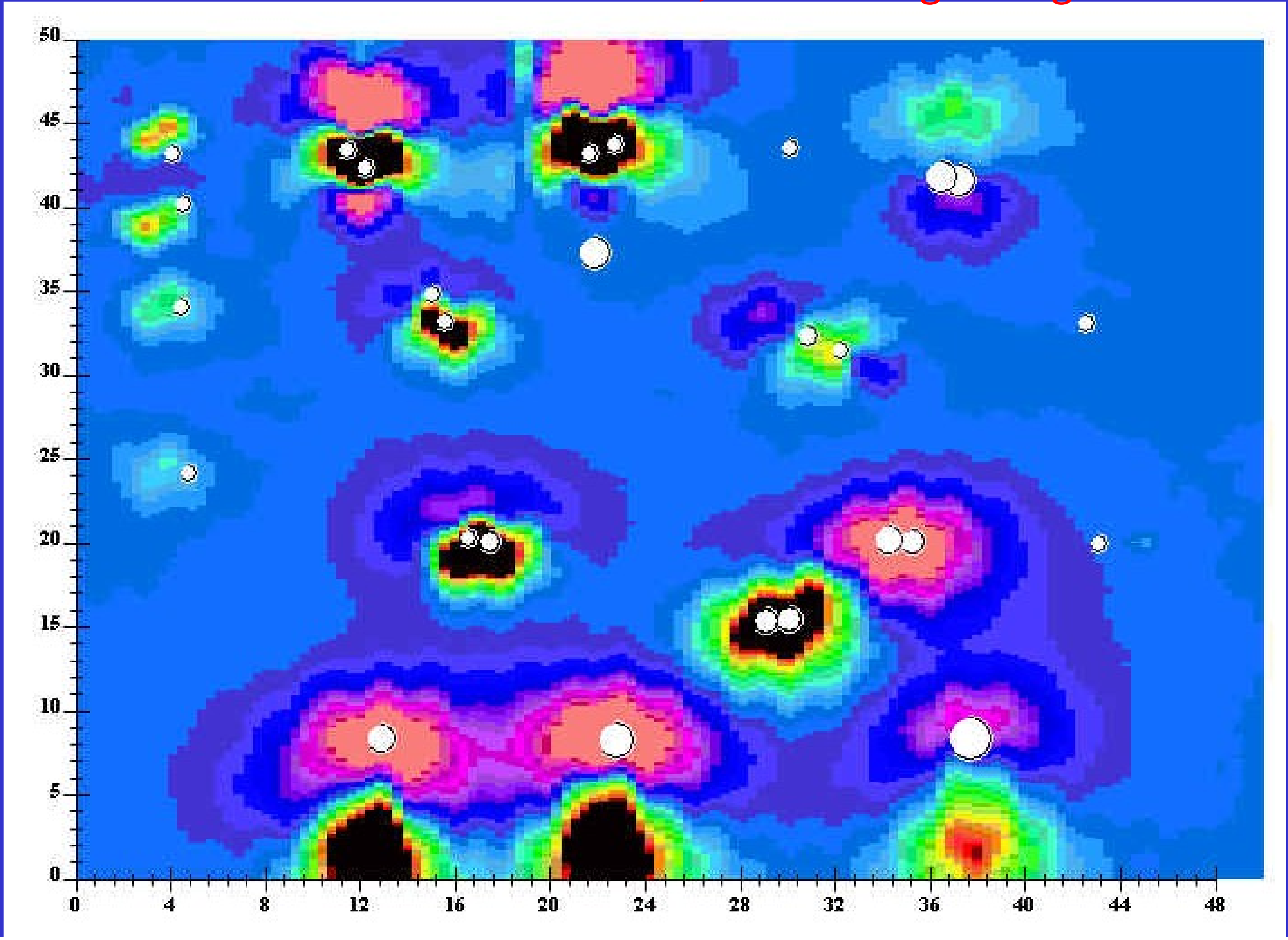
Step4 Statistical Removal Processing

Euler -> Rodin -> Jia **SI – 0.5 –3.25, 1.5m distinguishing distance**

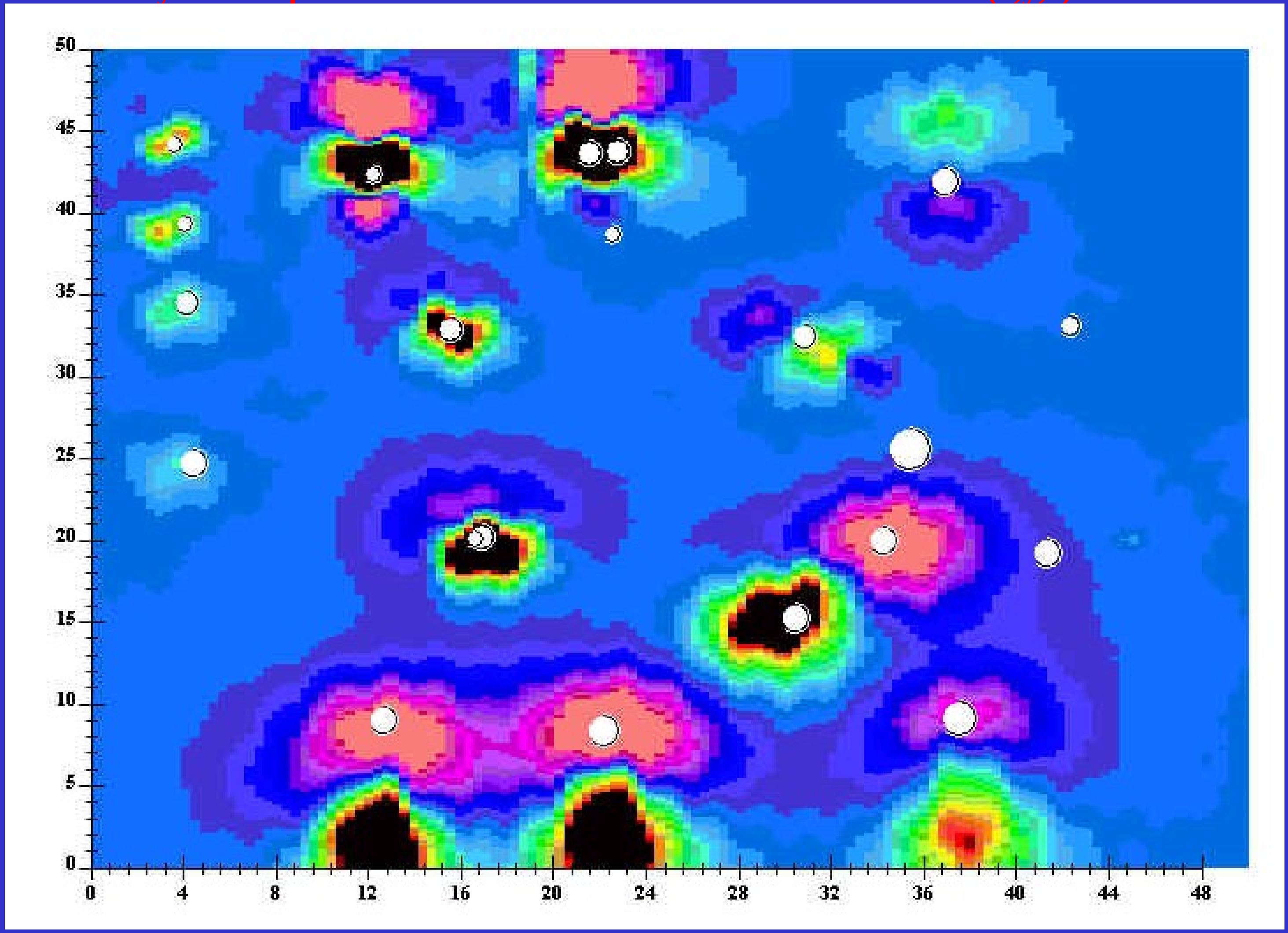


On Inversion for Detection of Multiple Buried Metallic Objectives

Step5   Magnetization Vector Inversion

Locations and Depths

At each individual processed solution, the total field data is automatically retrieved from a 2.5m by 2.5 m square centered on this solution and inverted for M(x,y,z)

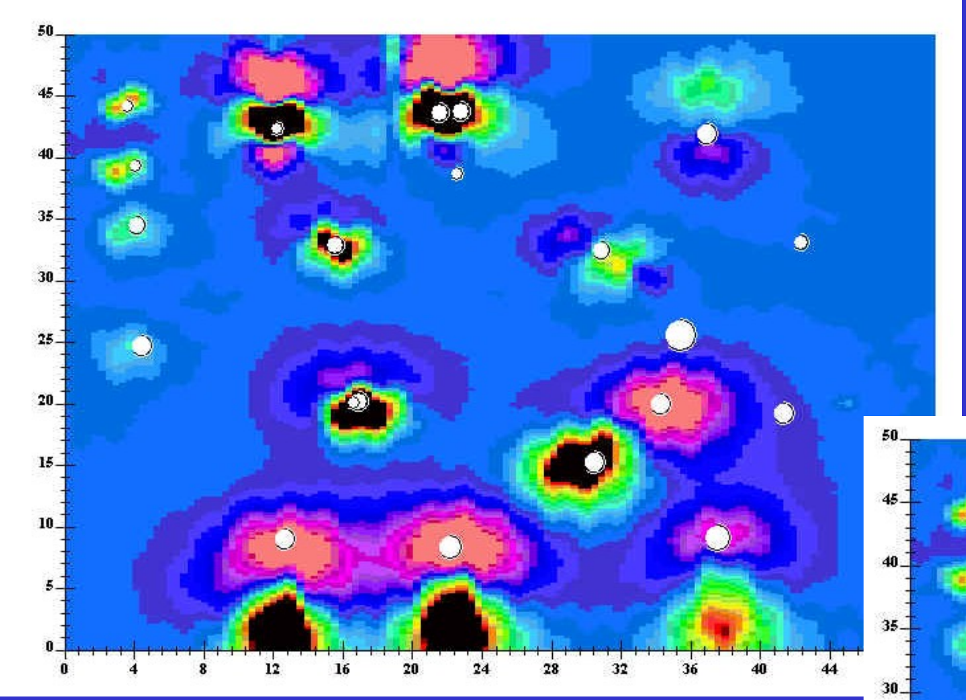


Solutions about 2

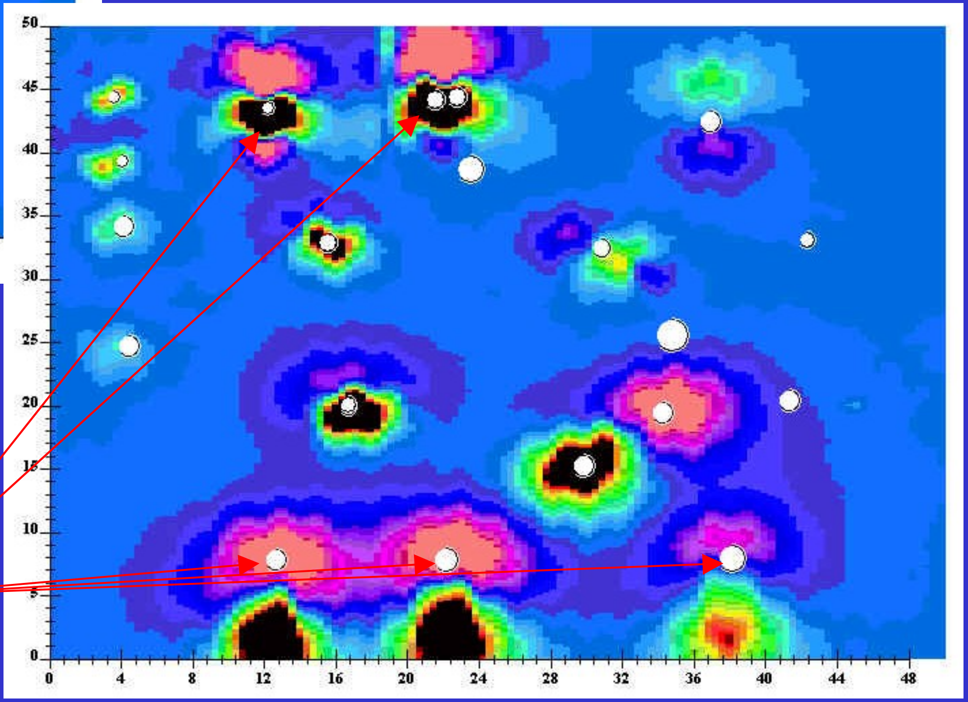
On Inversion for Detection of Multiple Buried Metallic Objectives

Step5   Magnetization Vector Inversion

Locations and Depths – Volume Range (.05,1.9m^3)



2.5m by 2.5 m square

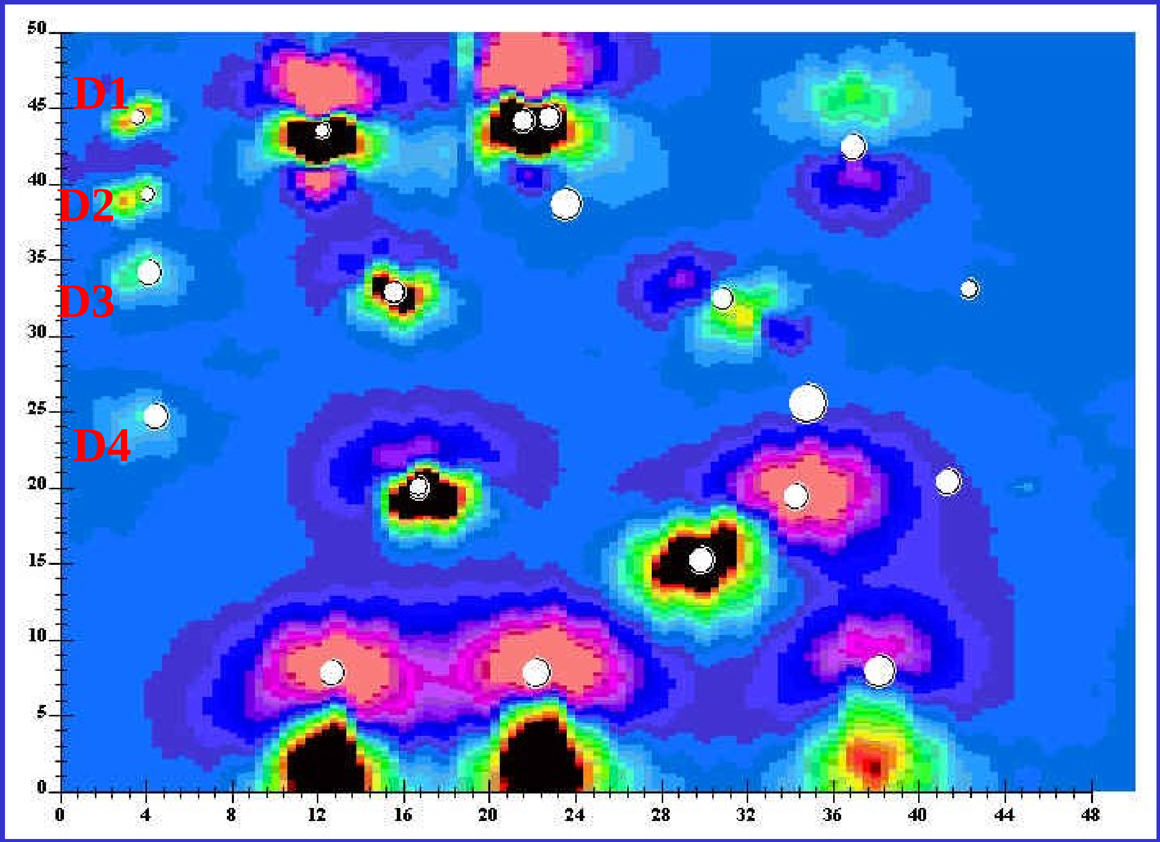


5m by 5m square

closer to centre

Step5 Magnetization Vector Inversion

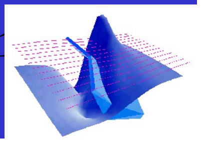
Locations and Depths – Drums = h=.92m



	Jia	VI	Ctr	Top
D1	0.47	0.78	.71	0.25
D2	0.59	1.18	1.21	0.75
D3	0.65	1.77	1.71	1.25
D4	0.74	1.92	2.21	1.75

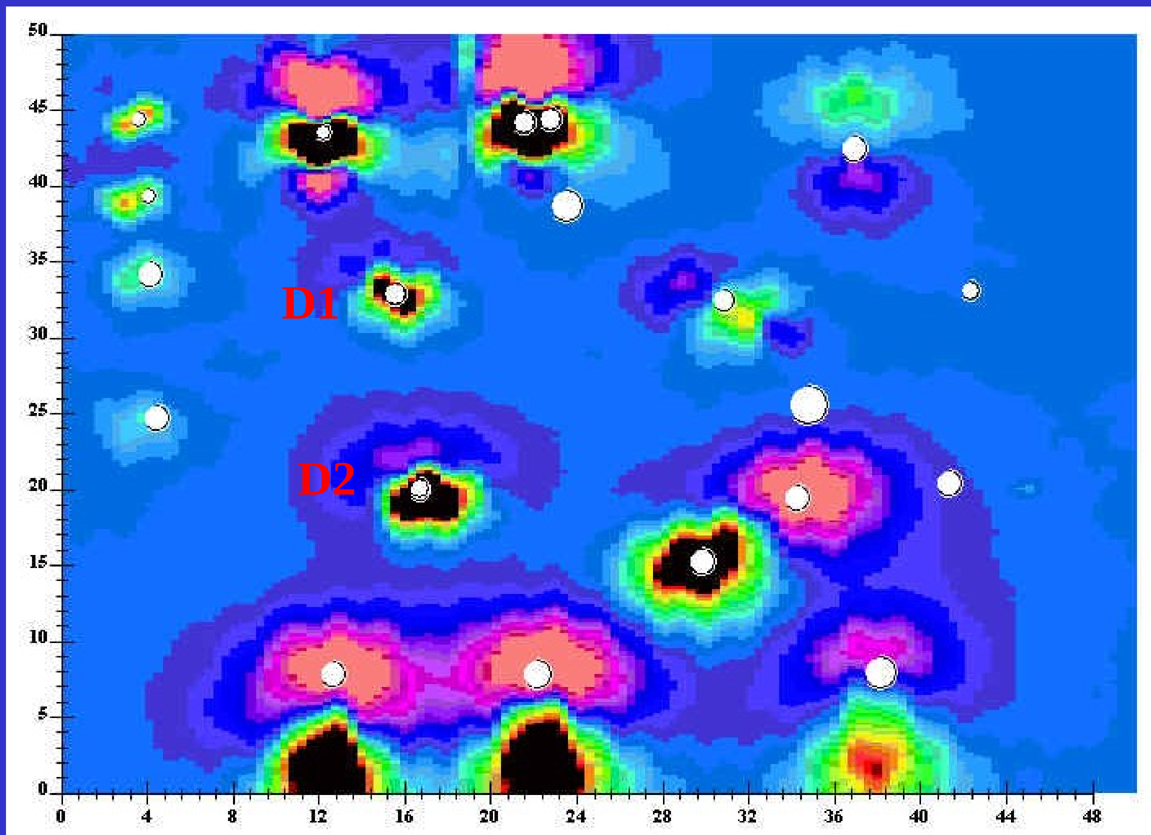
-Jia depth to top good for shallow drums

-VI depth to center good



Step5   Magnetization Vector Inversion

Locations and Depths – Multiple Drums



	Jia	VI	Ctr	Top
GD1	0.53	1.67	1.2	0.75
GD2	0.77	1.48	1.2	0.75

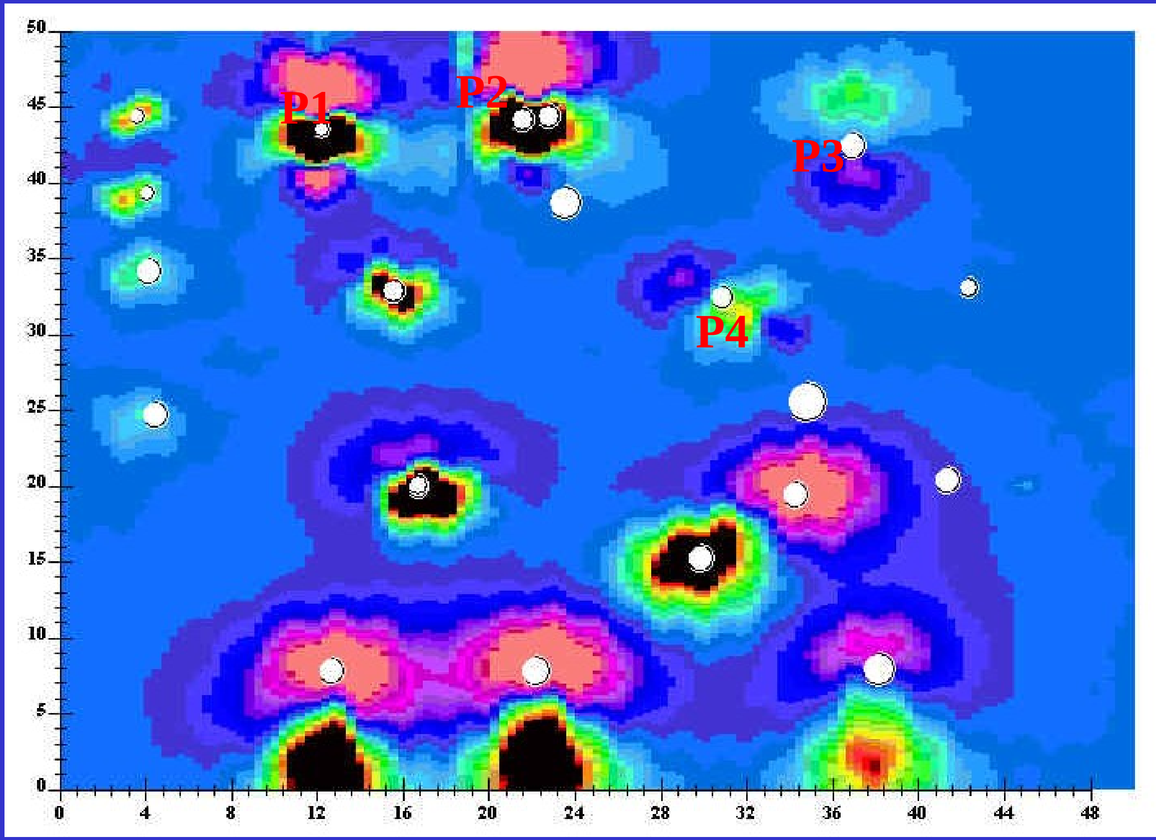
-Jia depth to top good

-VI depth to center good too deep

- multiple M ?, constrain V ?

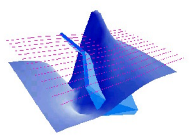
Step5 Magnetization Vector Inversion

Locations and Depths – Pipes – D=.1m



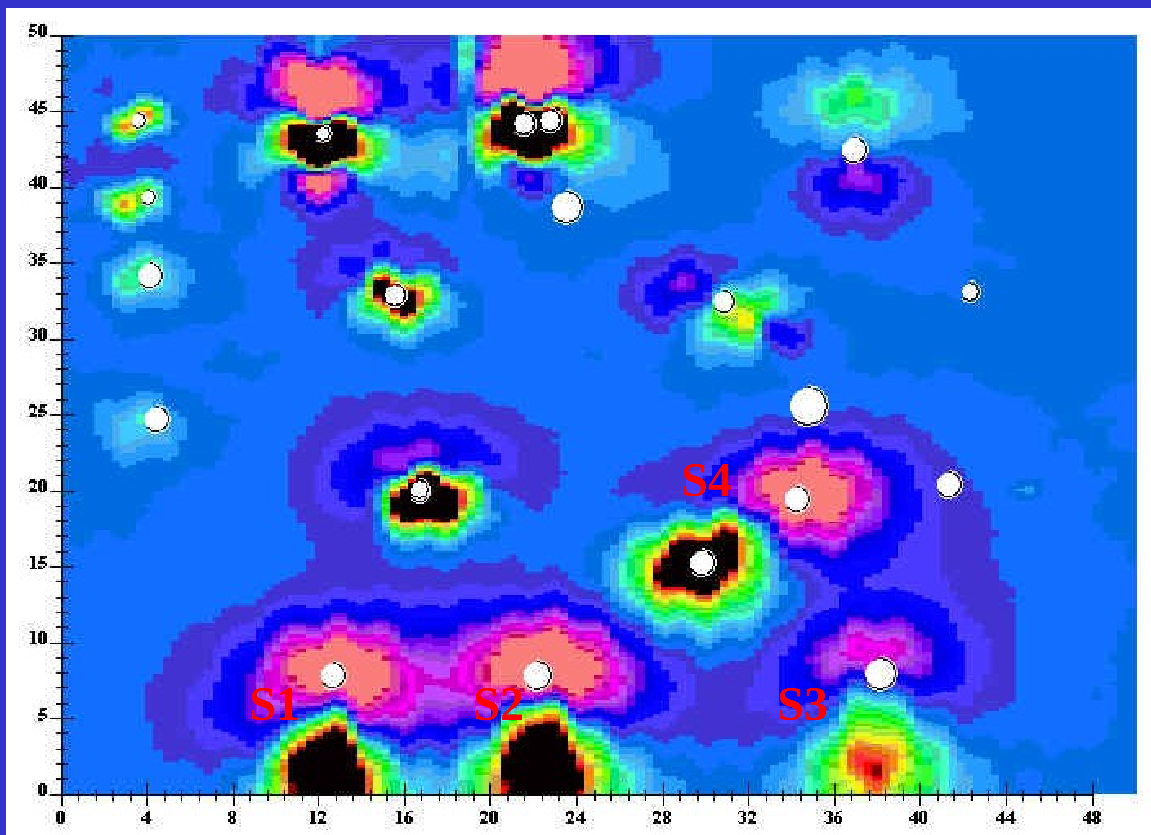
	Jia	VI	Ctr	Top
P1	0.62	1.12	.5	0.5
P2	0.66	1.74	1.0	1.0
P3	1.15	1.99	2	2.0
P4	0.78	1.7	.5-1.5	.5-1.5

-Jia depth to top useful
-VI depth to center good for P3 only
- multiple M’s? constrain V ? Larger grid?



Step5   Magnetization Vector Inversion

Locations and Depths – Sheets – h=1m



	Jia	VI	Ctr	Top
S1	1.0	1.97	1.2	0.75
S2	1.29	2.08	1.71	1.25
S3	1.46	2.22	2.21	1.75
S4	0.94	1.92	1.2	0.75

-Jia depth to top quite good – error about .2m
-VI depth to center good for S3, S1,S4 poor
- multiple M's? constrain V ? Larger grid?

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CONCLUSIONS AND DIRECTIONS

- Preliminary Euler useful
- Correct use of Structural Index for Euler
- Rodin post-processing very helpful
- Statistical grouping gives initial location with good horizontal positioning and approximate depth
- Vector Inversion quick and useful but ….

✓ Use of constrained volumes
✓ Distribution of magnetization
✓ Use of multiple Euler solutions from different SI