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SENSYS® Magnetometers & Survey Solutions

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Diese Maßnahme wird mitfinanziert durch Steuermittel auf der Grundlage des von den Abgeordneten des Sächsischen Landtags beschlossenen Haushaltes.

DGG

Application of Phase-Based Edge Detectors to Magnetic Data for Explosive Ordnance Detection

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PROBLEM

Geophysical sensing methods deployed to investigate sites contaminated by unexploded ordnances (UXO) are not able to distinguish types of anomaly-causing objects. However, for explosive ordnance disposal (EOD), it is desirable to be able to exclude false positives in order to reduce time and cost of remediation.

GOAL

Highlighting parameter contrasts in 2-d magnetic anomaly data allows to estimate positional information of buried objects. We aim for an opportunity to also deduce depth and geometry information by means of filter techniques and image processing approaches to possibly decide whether we deal with ammunition or scrap metal.

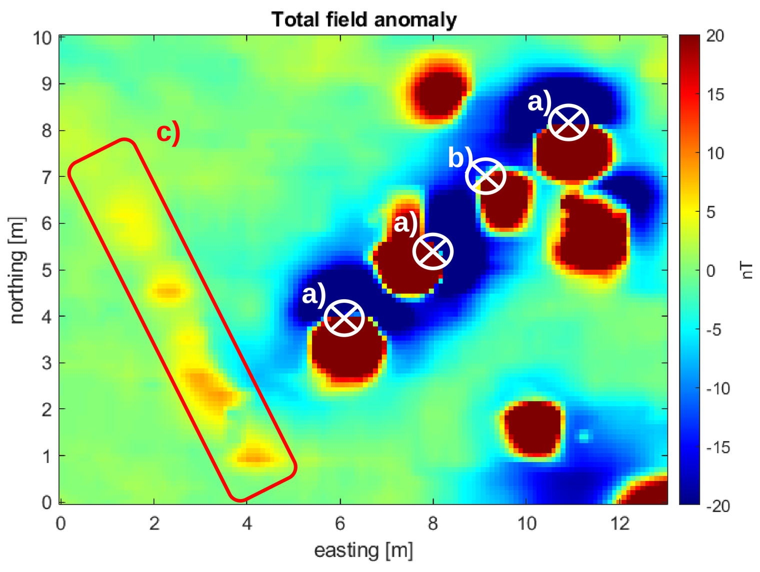


Fig. 1: Section of a magnetic anomaly map acquired at the test site of SENSYS GmbH in Bad Saarow

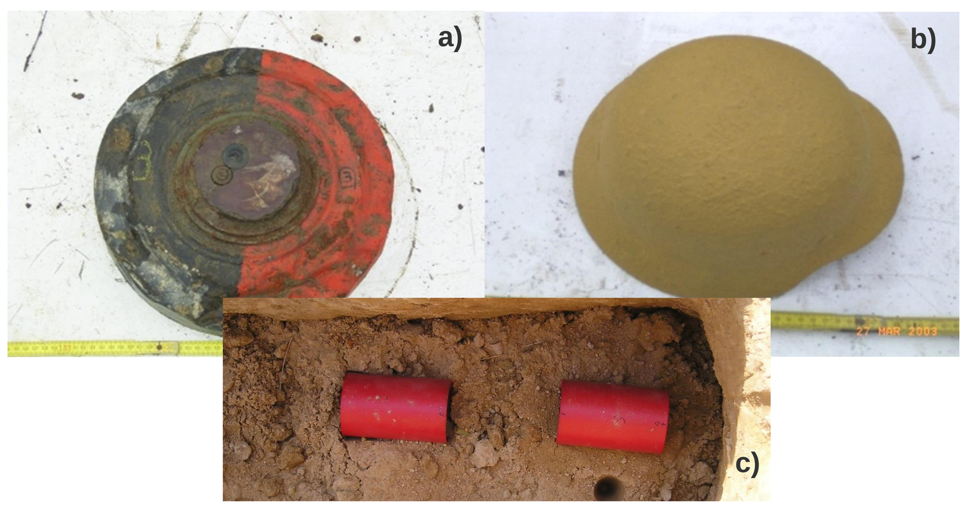


Fig. 2:, **a)** Tank mine (RU: TM 62 M), Depth: 0.3 m, 9.4 kg, 310/101 mm, **b)** Steel helmet (GER: WWII), Depth: 0.2 m, 1.2 kg, 320/160 mm, **c)** Resolution line (pipe segments at various depths)

METHODOLOGY

- Analyzing anomaly signatures by applying phase-based edge filters
- Horizontal and vertical derivatives can emphasize magnetization contrasts as boundaries

1. Upward continuation

Smooth data and reduce effect of near-surface high-frequency structures

2. Reduction to the pole

Eliminate induced magnetization to achieve more accurate positioning

3. Edge detection filters

Perform a structural analysis on 2-d anomaly data

SYNTHETIC DATA

κ	0,126	Depth [m]	20
hx [m]	20	Azimuth [°]	30
hy, hz [m]	10	Noise [nT]	Gaussian N(0, 1)

Total horizontal gradient (THD)

$$\sqrt{\left(\frac{\partial F}{\partial x}\right)^2 + \left(\frac{\partial F}{\partial y}\right)^2}$$

Analytical signal (|AS|)

$$\sqrt{\left(\frac{\partial F}{\partial x}\right)^2 + \left(\frac{\partial F}{\partial y}\right)^2 + \left(\frac{\partial F}{\partial z}\right)^2}$$

Tilt angle derivative (TDR)

$$\operatorname{atan}\left(\frac{\frac{\partial F}{\partial z}}{\sqrt{\left(\frac{\partial F}{\partial x}\right)^2 + \left(\frac{\partial F}{\partial y}\right)^2}}\right)$$

Improved analytical signal (IAS)

$$\operatorname{asin}\left(\frac{\frac{\partial AS}{\partial z}}{\sqrt{\left(\frac{\partial AS}{\partial x}\right)^2 + \left(\frac{\partial AS}{\partial y}\right)^2 + \left(\frac{\partial AS}{\partial z}\right)^2}}\right)$$

→ F - measured potential field

→ All derivatives evaluated in wavenumber domain, all operations applied pointwise, i.e., dF/dx = dF/dx(x,y)

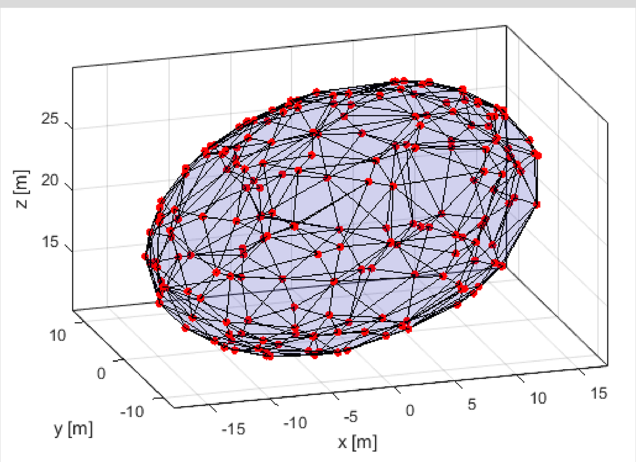


Fig. 3: Magnetized ellipsoid located beneath the observation plane

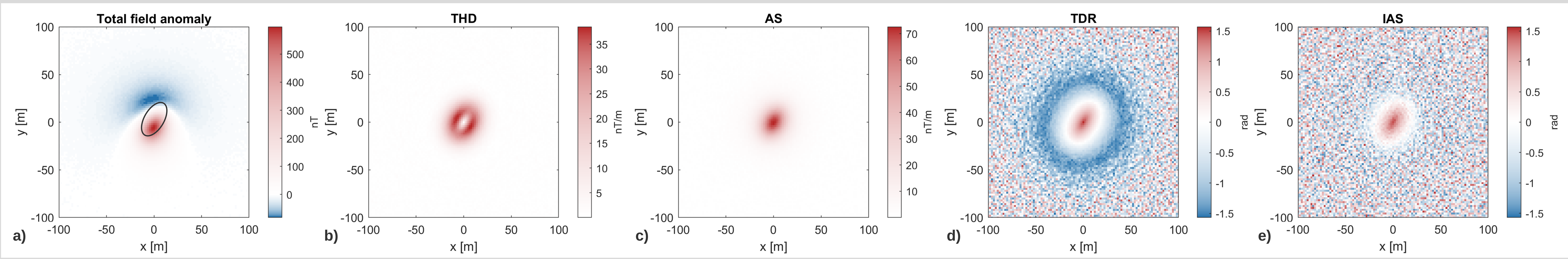


Fig. 4: Synthetic data application of selected egde detectors for a single magnetized ellipsoid: **a)** Total field anomaly, **b)** Total horizontal derivative, **c)** Analytical signal, **d)** Tilt angle derivative, **e)** Improved analytical signal

REAL DATA

In order to test the practical applicability for UXO detection, we apply several detector algorithms to selected magnetic field data sets from the SENSYS test site in Bad Saarow.

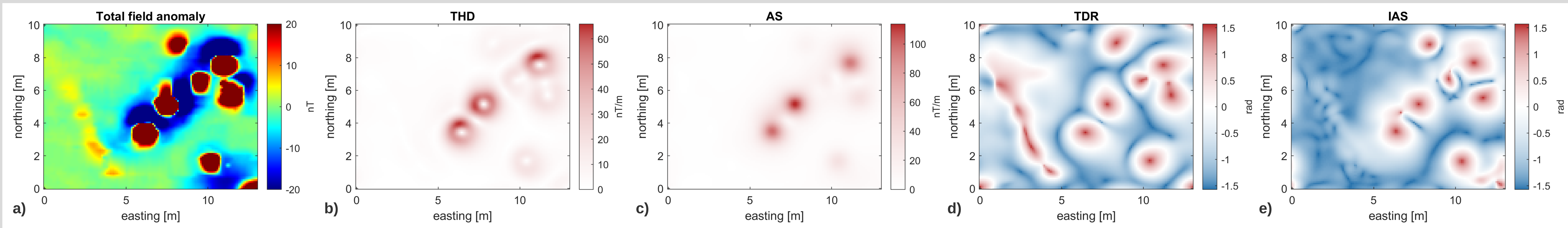


Fig. 5: Application of selected edge detectors to the total field anomaly caused by a magnetized ellipsoid: **a)** Total field anomaly, **b)** Total horizontal derivative, **c)** Analytical signal, **d)** Tilt angle derivative, **e)** Improved analytical signal

Analysis of constrained dynamic range

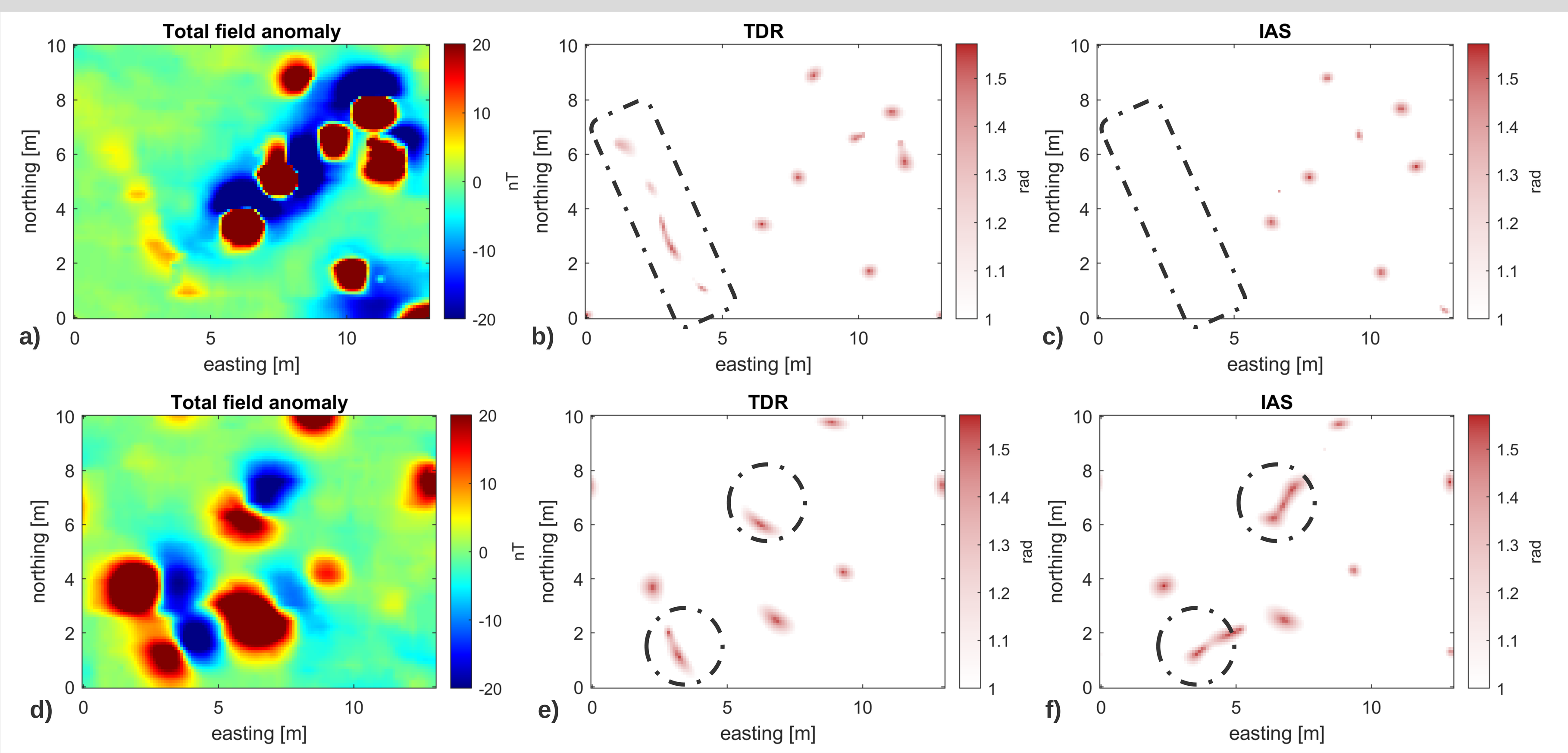
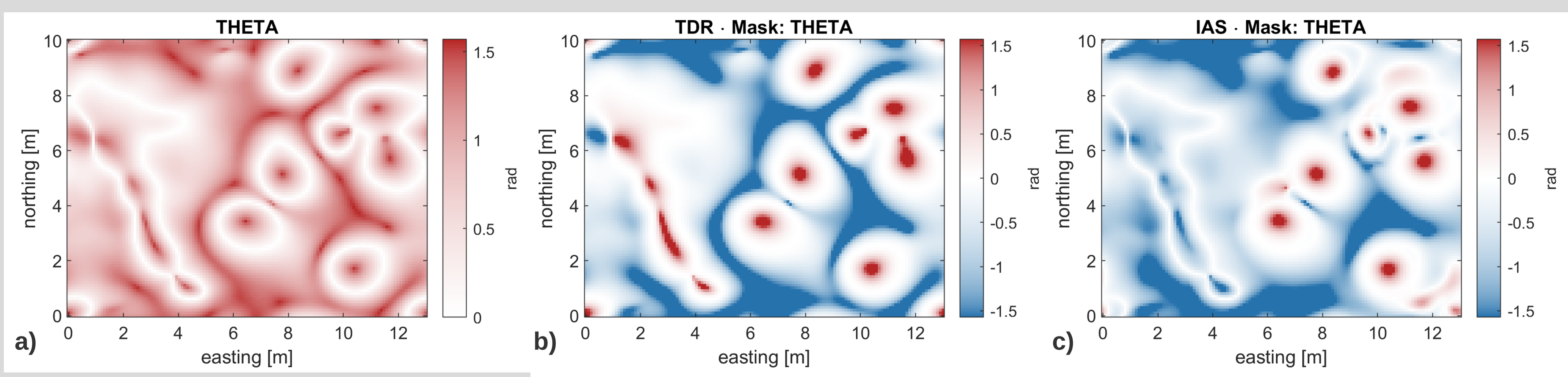


Fig. 6: Constrained amplitude range for two selected test site sections: **a)** Total field anomaly of section 1, **b)** Tilt angle derivative (S1), **c)** Improved analytical signal (S1), **d)** Total field anomaly of section 2, **e)** Tilt angle derivative (S2), **f)** Improved analytical signal (S2)

New Approach: Combined application of detectors with pre-defined mask



Mask: THETA

$$\mathrm{THETA} = acos\left(\frac{THD}{AS}\right)$$

Mask: AS

$$Mask(AS < tsh) = 0$$

$$threshold: ths = 10\,\frac{nT}{m}$$

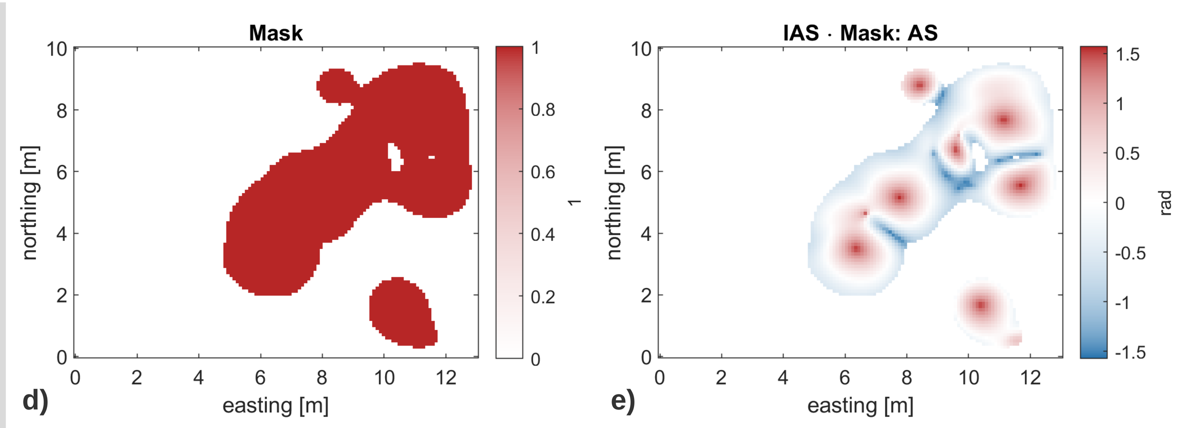


Fig. 7: a) Mask: Theta Map **b)** Tilt angle derivative using THETA-Mask, **c)** Improved analytical signal using THETA-Mask, **d)** Mask: Analytical signal **c)** Improved analytical signal using AS-Mask

CONCLUSION

Challenges

- Trade-off between resolution and reliability
- Edge detectors with the highest resolution suffer from noise amplification
- Disappearing structures due to an extensive dynamic range of the data
- Exact positioning is made difficult by remanent part of the magnetization

Potentials

- Recognition of the horizontal location and extent of sources
- Combined evaluation of different methods to increase reliability and improve interpretability despite effects through remanence, tilt, interference and depth expansion
- Additional usage of location- or value-dependent masks to stress out important features or eliminate interfering areas

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References

[1] Ibraheem et al. (2021). IAS: A New Novel Phase-Based Filter for Detection of Unexploded Ordnances. Remote Sensing. 13. 4345. 10.3390/rs13214345.

[2] Pham et al. (2021). Mapping subsurface structural lineaments using the edge filters of gravity data. Journal of King Saud University - Science. 33. 10.1016/j.jksus.2021.101594.