



GRAV-MAG SUITE: An open source MATLAB-based program for processing potential field data

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Abstract

GRAV-MAG SUITE is a MATLAB-based program that has been developed for processing potential field data. The program is composed by several tools, which involve miscellaneous field transformations and enhancing filters, semiquantitative methods, and simple shape forward modeling algorithms. GRAV-MAG SUITE provides a graphical user interface (GUI) that facilitates the user's interaction with the program. In order to illustrate the program functionalities, a set of tools will be applied on a synthetic data composed by six prisms representing the most typical geological structures.

Introduction

Airborne potential field data has been a cornerstone of the mineral industry through the last decades. The use of gravity and magnetic data plays an important role in identify subtle features related to sources with economic value. However, potential field data has a frequency content that may evidence details regarding both shallow and deep causative sources, and the extraction of information related to specific frequency bands depends on the enhancement technique applied to data. In this context a set of qualitative and semiquantitative techniques has been developed (Nabighian 1972; Roest et al. 1992; Cordell and Grauch 1985; Miller and Singh 1994; Cooper and Cowan 2006; Ferreira et al. 2013; Thompson 1982; Salem et al. 2007; Cooper 2015).

Currently, the processing of potential field data is carried out mostly by commercial software packages. However, another strand, encompassing open source software has been taken strength since new technologies have made its development possible (Mendonça and Meguid 2008; Arisoy and Dikmen 2011). In this scenario we present a MATLAB-based open source software for processing both gravity and magnetic data.

Several program functionalities will be tested on synthetic data composed by prismatic sources whose dimensions simulate common geologic features. In order to validate the implemented methods, the source parameters estimated by the qualitative and semiquantitative methods will be compared to the exact parameters used to generate the synthetic model.

Program interface

GRAV-MAG SUITE is composed by a set of MATLAB functions. The program functions are categorized into two types: GUI functions, and processing functions. The first type are functions responsible to generate the program graphical user interfaces, and the second type are functions which perform some processing task.

Among the GUI functions there is a main function which generates the core interface. This graphical interface is composed by two fields. The first field is the menu field, which links the core interface with all other program GUIs. The second field presents the current data the user is processing and has some GUI components to customize the data visualization (Fig. 1).

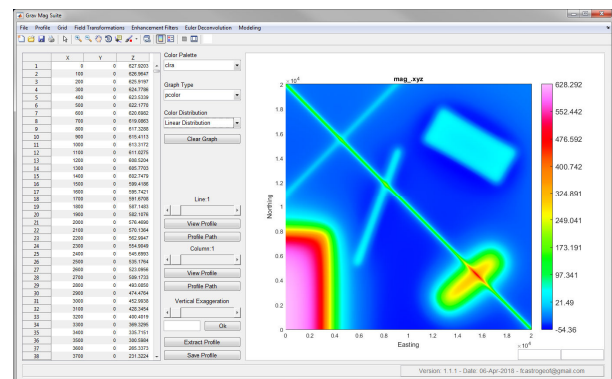


Figure 1 – Main GRAV-MAG SUITE graphical user interface with the synthetic data loaded.

In the *File* menu, the user can find options to open a dataset disposed on xyz column format or in a matrix form, view the data statistics, and export the data in a common figure formats. The *Profile* menu provides a set of options to process a profile data, for instance, to perform numerical differentiation and apply some enhancement filters, and to extract profiles from gridded datasets. The *Grid* menu provides some grid operations like interpolation, windowing, regrid, and trend removal.

In the *Field Transformations* menu there is a set of linear Fourier filters, for example, derivative filter on 3D orthogonal directions, upward/downward continuation, vertical integration, reduction to the magnetic pole and equator, directional cosine filter, anisotropic diffusion filter, among others.

The *Enhancement Filters* menu is divided into two categories. The first category groups qualitative filters commonly used to enhance or suppress some data frequency bands of gridded datasets. The second one gathers the semiquantitative methods to estimate some

source parameters like horizontal location, depth to the top and bottom, physical property contrast, and dip, etc.

Program functionalities

In order to illustrate the program functionalities, a synthetic model with six prisms was generated to simulate interfering dike-like bodies, contacts, and prismatic bodies with different strike directions, and depths to the top (Fig. 2).

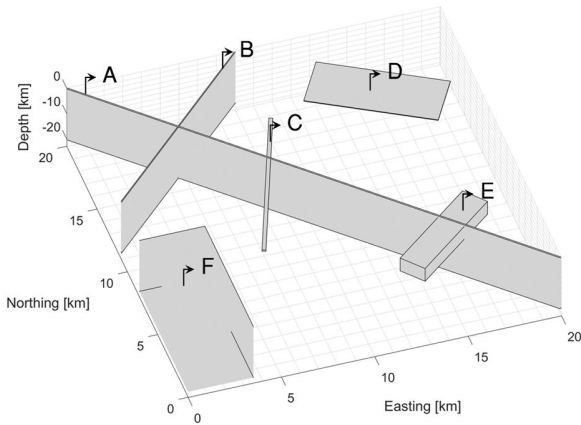


Figure 2 – 3D representation of synthetic model.

The model parameters are shown in Table 1. The strength, declination, and inclination of the induced field vector are 57000 nT, 0, and 90 degrees, respectively, and no remanent magnetization was considered. The magnetic anomaly was computed in grid with mesh ranging from 0 to 20 km in both x and y directions, with a squared grid cell of dimension 100x100 meters.

Table 1 - Spatial and physical parameters of the synthetic model. X, and Y are the coordinates of the prisms, and Z are the prisms depth to top.

Prism	X (km)	Y (km)	Z (km)	Length (km)	Width (km)	Thickness (km)	Strike direction (degrees)
A	10	10	0.1	50	0.1	20	-45
B	4	15	0.3	50	0.05	20	45
C	7.5	10	0.4	10	0.2	0.5	20
D	15	15	0.5	7	3	0.2	120
E	15	4	0.8	6	1.5	5	50
F	-1.5	-17	0.7	50	10	20	0

Figure 3 shows the total magnetic intensity (TMI) computed using the model of Figure 2. Prisms representing the bodies A and B have dimensions which characterize dike-like bodies, while prisms C, D, and E characterize a duct,

horizontal thin slab, and a culvert, and prism F represents a contact model.

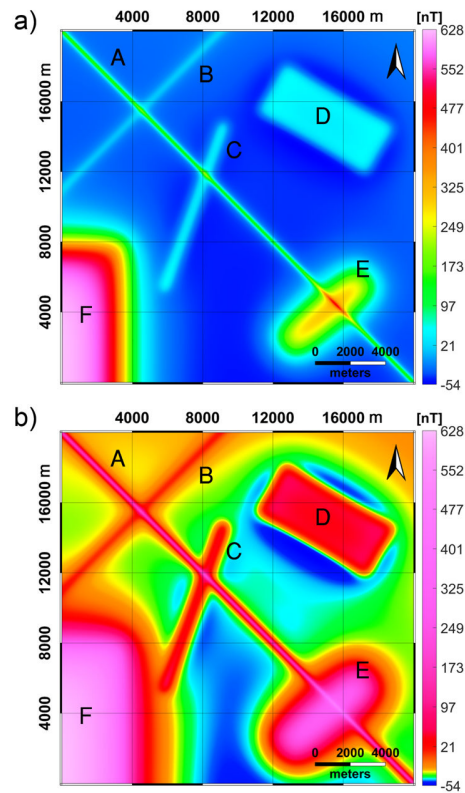


Figure 3 – Total magnetic intensity of synthetic data. a) Linear color distribution (MATLAB's default). b) Histogram color distribution.

The magnetic anomaly shown in Fig. 3 was generated using GRAV MAG PRISM, a MATLAB-based forward modeling program for both magnetic and gravity fields generated by prismatic bodies (Bongiorno et al. 2013). GRAV MAG SUITE offers a GUI function that calls the original GRAV MAG PRISM scripts. (Fig. 4). GRAV MAG PRISM GUI has entry components for both field and source parameters, needed for the computation of the gravity and magnetic anomaly fields.

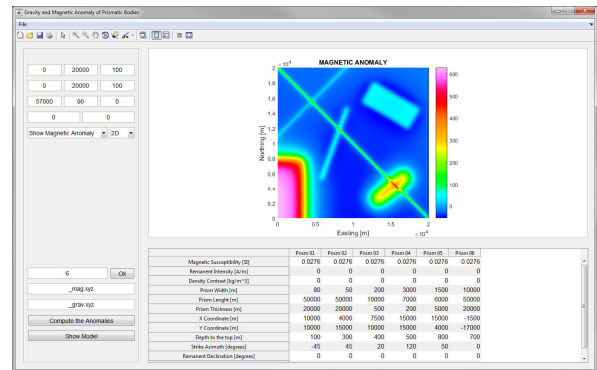


Figure 4 – Graphical user interface of Grav Mag Prism.

GRAV MAG SUITE performs forward modeling of two-dimensional bodies with simple shapes, for example, dike-like, spherical, and cylindrical bodies using closed formula (Telford et al. 1990), and irregular cross-section bodies using the line integral approach (Hubbert 1948; Talwani et al. 1959; Won and Bevis 1987) (Fig. 5).

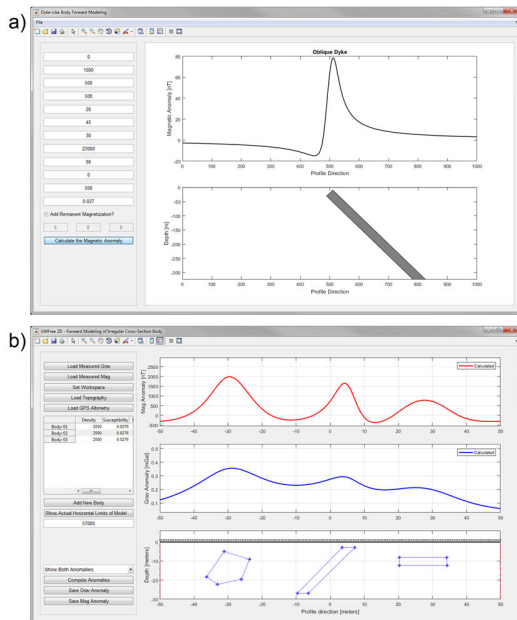


Figure 5 – Other forward modeling GUIs. a) Dike-like body forward modeling GUI with magnetic anomaly caused by a 45 degrees dipping dike. b) Irregular shaped body forward modeling GUI with both gravity and magnetic anomalies caused by three irregular cross-section bodies.

To grid scattered data the program offers traditional interpolation methods like bilinear, bicubic, nearest neighbor, and natural neighbor (Verbyla 2003). When an anisotropic sampling rate is verified, as in airborne surveys, these interpolate methods generate spatial aliasing of short-wavelength features, like boudinage effects. This issue can be overcome by using an anisotropic diffusion filter (Smith and O’Connell, 2005) (Fig. 6).

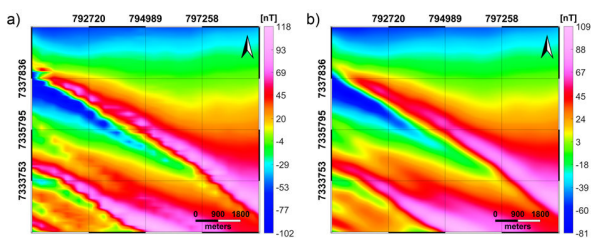


Figure 6 – Aeromagnetic data of southeast São Paulo State. a) Survey gridded by bilinear interpolation method. b) Same survey after applying anisotropic diffusion filter.

Once the anomaly maps are generated, a set of processing tools can be applied, for instance, a profile extraction (Fig. 7), windowing some anomaly map (Fig. 8), derivative filters (Fig. 9), and field continuation filters (Fig. 10).

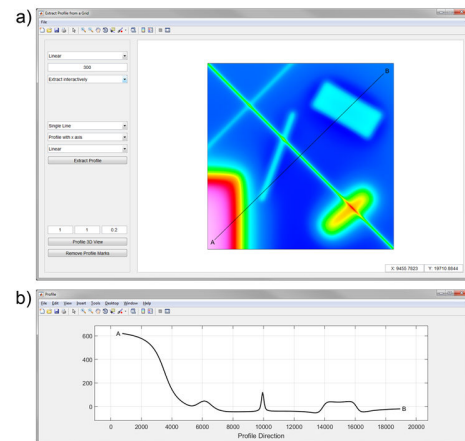


Figure 7 – Profile extraction GUI. a) Main profile extraction interface. b) Extracted profile.

Figure 7 illustrates the profile extraction tool present in the Profile menu of GRAV-MAG SUITE. This tool allows the user to extract profiles in any direction of the anomaly map, and the profile can be a single line or a polyline, which comprises a multiple line segments profile.

To select a region rather than a profile, one can use the Window Grid GUI present in the Grid menu. This tool provides some options that allow the user to apply a window to a gridded dataset. This window can be rectangular, polygonal, or irregularly shaped (Fig. 8).

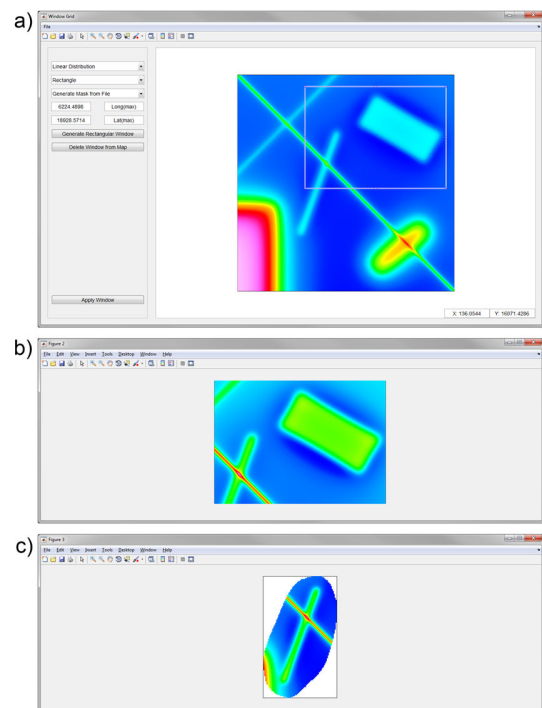


Figure 8 – Window grid GUI. a) Main window grid graphical user interface. b) Anomaly map windowed by a rectangular window (white line rectangle in a). c) Anomaly map windowed by an irregular window.

GRAV MAG SUITE has support for different derivative algorithms. It is possible to take the derivative in the three orthogonal directions, products necessary for computing several enhancement techniques (Fig. 9). All filters implemented on GRAV-MAG SUITE prepare the input grid by expanding, filling NaN/dummy values, and tapering, to prevent edge noise introduced by Fourier operations.

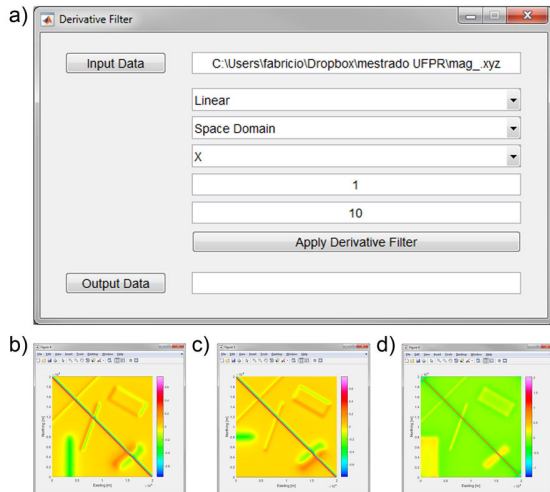


Figure 9 – Derivative filter. a) Graphical user interface of derivative filter. b) First order derivative in x direction. c) First order derivative in y direction. d) First order derivative in z direction.

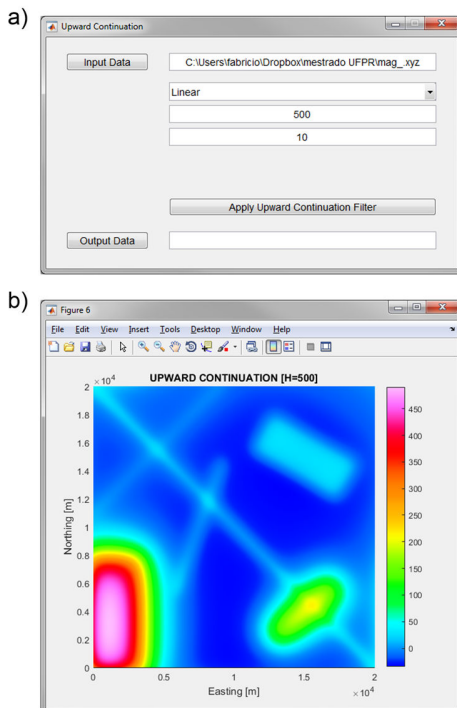


Figure 10 – Field continuation filter. a) Field continuation GUI. b) Anomaly of Figure 3 upward continued by a height of 500 meters.

Several enhancement filters or qualitative methods are implemented in GRAV-MAG SUITE. Figure 12 illustrates some of these filters: ASA (Nabighian 1972; Roest et al. 1992), THDR (Cordell and Grauch 1985), TDR (Miller and Singh 1994), TDX (Cooper and Cowan 2006), and TAHG (Ferreira et al. 2013).

Furthermore, a set of semiquantitative methods are also implemented in GRAV-MAG SUITE, such as, Euler deconvolution (Thompson 1982), tilt-depth (Salem et al. 2007), source distance (Cooper 2015), and Signum transform (de Souza and Ferreira 2015; Oliveira et al. 2017).

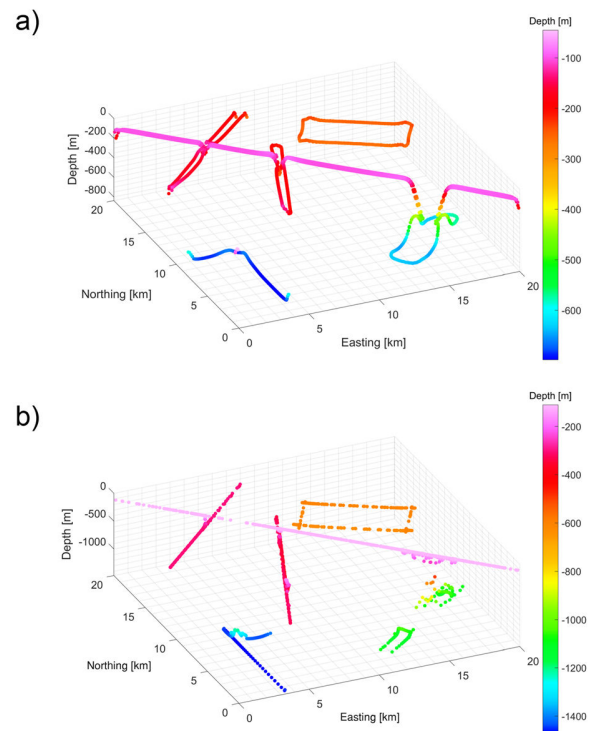


Figure 11 – Depth solutions estimated by semiquantitative methods. a) Tilt-depth solutions. b) Euler deconvolution depth solutions for a structural index of 1 and window size of 10x10 grid points (1000x1000 meters).

Figure 11 shows the depth estimates of two semiquantitative methods. Although Tilt-depth method (Salem et al. 2007), represented in Figure 10a is recommended only to approximate the depth of contact models, a good depth estimation of the other sources was verified. The same was verified in Euler deconvolution depth solutions except for the contact model whose depth was overestimated.

Conclusions

A set of processing tools, usually restricted to commercial software, has been implemented for use in MATLAB in the form of an integrated system with a graphical user-friendly interface.

By enabling the access of commercial software algorithms to the community, we facilitate the reproduction of academic works for validation purposes, as well as its application and improvements in new researches.

Semiquantitative methods implemented on GRAV-MAG SUITE have estimated the sources parameters with acceptable error, even when the methods have intrinsic limitations on situations whose source's shape leads to poor estimates.

The program should be available by April 2019, upon completion of the related master's degree research. Until the final release, more functionalities are planned to be included, such as more interpolation methods like minimum curvature (Briggs, 1974), improvements of source distance method (Cooper, 2015), among others.

Acknowledgments

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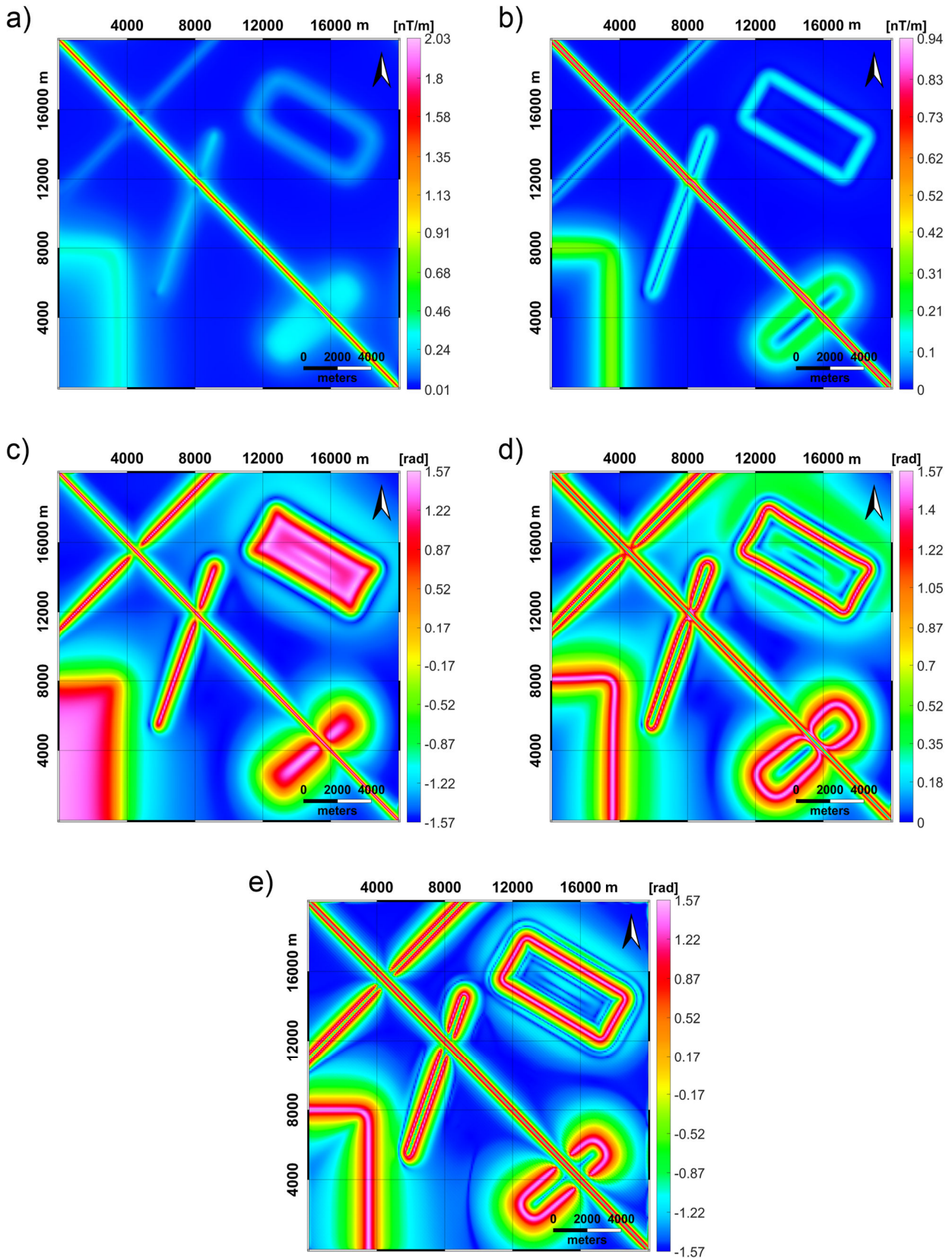


Figure 12 – Qualitative enhancement filters. a) ASA; b) THDR; c) TDR; d) TDX; e) TAHG.