High-Precision Mapping of Submerged Objects Using the Full-Gradient Overhauser Magnetometer System

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Abstract. We tested the full-gradient magnetometer's system of two ortho oriented Overhauser with a GPS receiver in shallow water. Our investigations show that this is a promising layout prototype of magnetometer measuring complex, designed for high-precision 3D detecting and studying of underwater man-made objects. With such a system, and the existing set of techniques and software we can be able to reliably map and identify anomalies created by such objects, solving the problem of their locations within a small part of meter.

INTRODUCTION

In August 2015 Institute if oceanology RAS , Ural Federal university and State Oceanographic Institute conducted experimental and methodological works for definition the possibilities of magnetometric method of high-precision 3D mapping of submerged objects on board of research vessel «Victor Buynitskiy». The purpose of our research is a development of methodical requirements for hardware – software system of magnetometric method and for technology of 3D mapping. This method based on a multichannel (multisensory) system which allows to make one measurement of a geomagnetic field in different 3D points, was bused as a main technology of magnetometer survey.

RESULTS AND DISCUSSION

The multichannel system consists of two absolute Overhauser gradiometers such as geological survey land-based gradiometer MMPOS-2 and deep-towed gradiometer SeaPOS-2 which are hard fixed on the low-magnetic warp platform (rubber boat) used for geomagnetic field's measurement. Magnetometers (POS-Proton Overhauser Sensor Series) registered by number 44807-10 in the State Register of measuring instruments and allowed for using in Russian Federation as measuring instruments of magnetic field's induction (pattern approval certificate RU.C.34.005.A No. 40335, specification 4314-001-020692208-2007) were developed and have been producing now at Ural Federal university's research laboratory of quantum magnetometry.

A warp system consists of two ortho-directed and height-separated gradiometers which are hard-fixed with each other and with GPS-receiver worked at differential mode was used as main measuring instrument at the surface position. This construction makes possible to register at 4D (time + space axes) three ortho gradient of magnetic field at the moving coordinate system with high-quality accuracy. It can compute a full-gradient module of Earth's magnetic field continuously named analytical signal which is invariant relative to rotation axes of coordinates and which is a good mapping function despite of current sensor's position in space. A high instrument accuracy of survey (Fig. 1) was adding by exclusion essential daily variation from results of field's measuring (variation station

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based on gradiometer MMPOS-2 was placing by the time of works on the shore and by computing and accounting of deviation correction of all sensors.

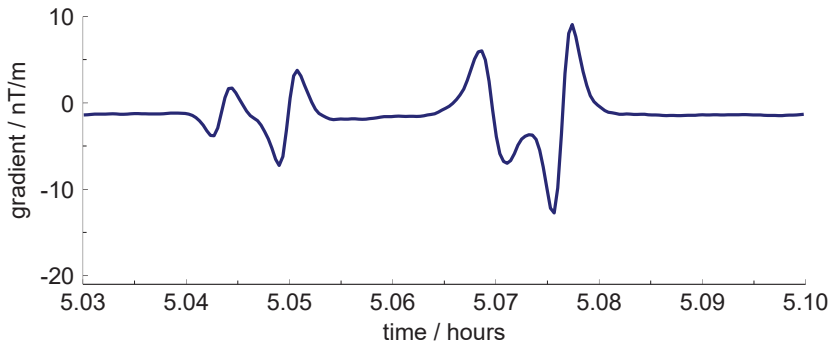

FIGURE 1. Example of the record of transverse gradient by pair MMPOS-2

A technology developed at the Institute of oceanology RAS was applied for a primary data of module of an Earth's magnetic field processing. This technology consists of some methods and software application that accept to transform an input stream of magnetic and navigational initial conditions at usable data of quantitative interpretation operatively and quality. There is a possibility to learn qualities of sources of anomaly and to choose a correct model after getting detailed maps of magnetic anomaly for different objects. So, we use laboratory's of geophysics field of the Institute of oceanology RAS algorithms "Linvers 2" and "Magdepth 3D". Statistic by field spectrum and deterministic (an algorithm of Euler's deconvolution) methods were consummated for estimation depths to the center of magnetic mass and for top and bottom border of anomaly's source. Software implements solution of our original estimation of geometric characteristic of simple simulation sources in modulus of anomaly's analytical signal (Fig. 2 and Fig. 3).

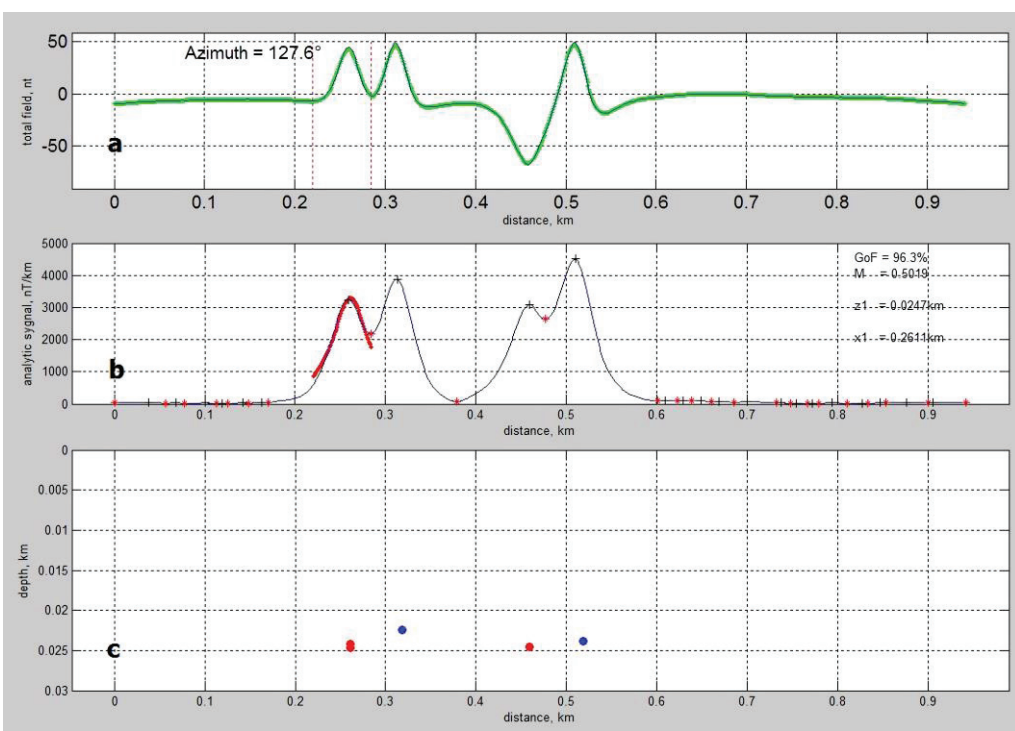

FIGURE 2. 2D interpretation of local magnetic anomaly of objects (a), their analytical signal (b) and states computed at «Linverse 2D» system (c); monopole, dipole, monopole, dipole

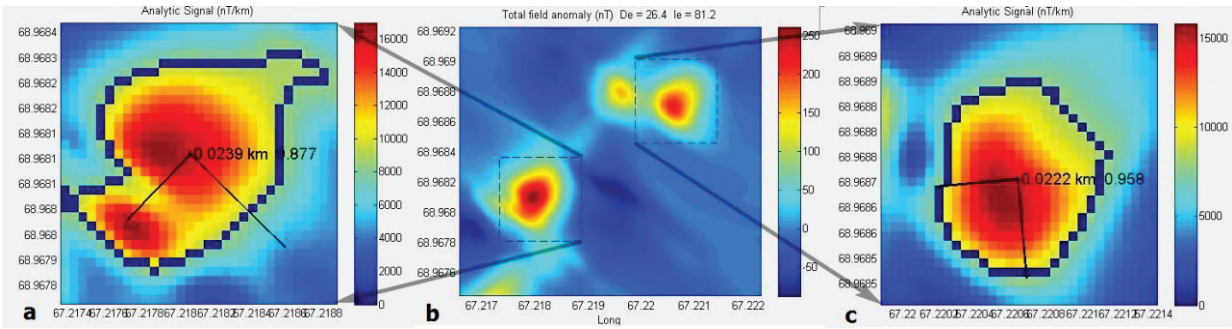

FIGURE 3. 3D interpretation of local magnetic anomaly of objects (a), their analytical signal (a, c) and states computes at «MagDepth 3D» system (c); "a" and "c" are monopole

One of the main advantages of using survey method based on full-gradient system is a possibility to generate maps of anomalous field without complex procedure of profile field's reconstruction according to the gradient. Actually, ortho pair of gradiometers can register in the plane of survey two ortho-horizontal field's gradient, but a high-accuracy navigation can fix current position and direction of gradiometer's axis. After simple procedure's realization of transformation of course and transversal gradient with ortho-fixed direction, for example S-N, W-E (x and y), we synthesize maps (grids) of this gradient. Now all conditions for free of variations anomalous field's reconstruction are executed over the area of survey using 2D Hilbert transform (Nelson method). The results of area's research are performed in Fig. 4.

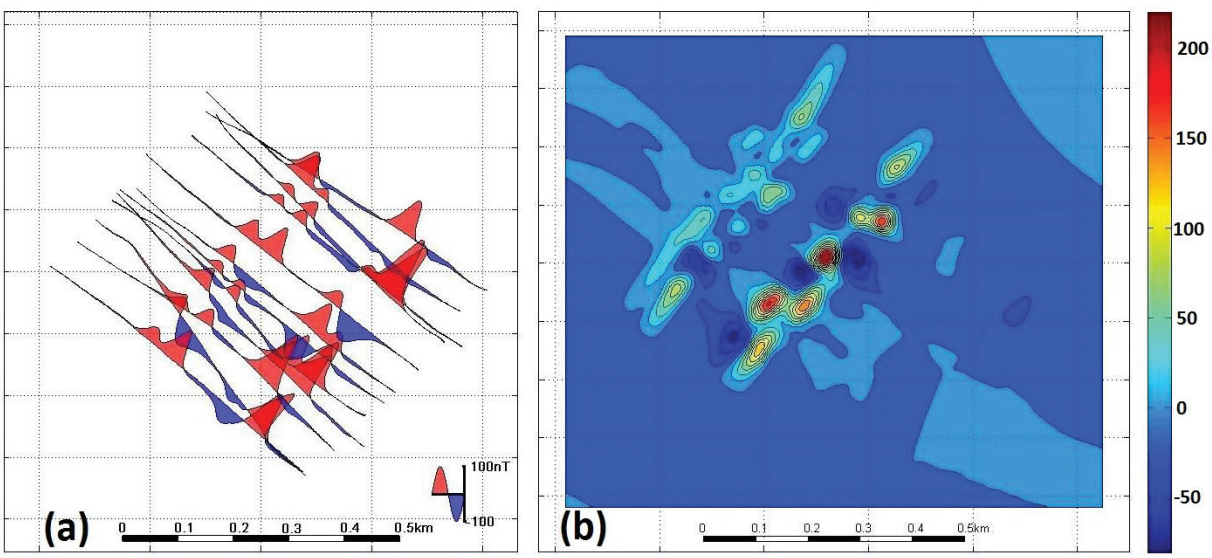

FIGURE 4. The result of area's research on the objects: a – Chart of magnetic field's anomaly, b – map of isodynamic lines of magnetic field's anomaly

Chosen local anomalies and synthesized on them grid with permission 5 and 2 m became the basis of statistical and inverse estimations according to 3D position of the sources of anomalies.

Detailed local anomalies and synthesized by them grids with resolution of 5 and 2 m. lay the foundation for static and inverse characterization of 3D position of anomaly's sources. We use estimation by spectrum for averaged characteristic of several interfering sources. Euler's deconvolution was used for solution's control dominantly. Dispersions of object position's estimation amount of 15–20 determinations were 0.3 to 0.5 m or less. It is a great result of mass source position detection for typical anomaly.

Traditional approach of modern marine geomagnetic survey is a towing by ship for sufficient distance (3–4 a ship length) a low depth of several registration's sensor of scalar of Earth's magnetic field vector and/or the component of it. This approach is well worked out in detail, enough economical and reliable as a decision of scientific applications including exploratory applications. However the main disadvantage is low accuracy of space

positioning of sensors and their relative position cause of time's variables unregistered geometrical vibrations of measuring system during towing by flexible cable. Consequently it obstructs using of differential-magnetic survey having essential advantages compared with traditional approach by accuracy and resolution.

CONCLUSIONS

Full-gradient magnetometer survey consists of two ortho Overhauser gradiometers with GPS receiver and proves one's worth as a perspective prototype of magnetometric measuring complex for high-accuracy 3D mapping of submerged technogenic objects. It is possible to map, to identify and to interpret anomalies which are generated by these objects as a result of solving a problem of identification and localization accurate of meter's fraction using this system and a set of software.

REFERENCES

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