ASSESSMENT OF THE IMPACT OF UNMANNED AERIAL VEHICLES WITH DIFFERENT ENGINE TYPES ON THE MMPOS-1 MAGNETOMETER

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ABSTRACT

Active development of unmanned aerial vehicles has led to their widespread use for various purposes, and magnetic prospecting is no exception. UAVs in various modifications are used in aeromagnetic surveys intended for magnetic mapping of the subsurface. This allows to solve the problems of not only aeromagnetic prospecting (identification of ore deposits, petroleum prospecting, etc.), but also of geological engineering and archeology.

The advantage of using UAV lies in the cheapness and safety of the survey. Magnetic prospecting in this case is carried out with minimal financial and time costs, while the study area is limited only by the time of flight. As a rule, UAV flight time varies from 1 to 1.5 hours. This problem is due to the limitation of the energy source of the UAV. In addition, most UAVs are made from light materials such as carbon composite and aluminum, which has a positive effect on their use in aeromagnetic prospecting.

However, there is little research on the impact of UAVs on magnetometers. Most of the work is devoted directly to the processing and interpretation of the results.

This paper analyzes the influence of a quadcopter, an octocopter and a two-stroke combustion engine on the readings of the quantum magnetometer MMPOS-1. The impact of electric motors and a combustion engine is shown. A comparative analysis was carried out aimed at revealing the most optimal distance for a magnetometer sensor. The impact of various types of UAV is estimated, depending on their design features.

Keywords: magnetic, UAV, geophysics, aeromagnetic.

INTRODUCTION

Today, there are a number of UAVs designed specifically for magnetic prospecting. As an example, two UAVs – the Geoscan 401 Geophysics (Russia) [1] and the GEM Hawk (Canada) [2] – should be mentioned. The Geoscan 401 is a UAV quadcopter, and the GEM Hawk is a UAV helicopter. The main technical characteristics of these vehicles are presented in Table 1.

https://doi.org/10.5593/sgem2020/1.2/s05.061

Table 1: UAV Specifications [1, 2]

UAV Specifications	Geoscan 401 Geophysics (Russia)	GEM Hawk (Canada)
Type UAV	quadcopter	helicopter
Usable payload	2.5 kg	1 – 4 kg
Operational weight	-	12.4 kg
Maximum Take-Off weight	9.3 kg	16.4 kg
Cruise speed	1 –50 km/h	1 – 50 km/h
Cruise endurance	60 mins	50 mins
Wind limit	Up to 12 m/s	-
Operation Temperature	-20 °C to +40 °C -20 °C to +40 °C (with the battery Arctic)	-10 ºC to +40 ºC
Batteries	37 V LiPo	22.2 V 22 Ah GS LI-PO

The Geoscan 401 Geophysics comes with the Geoscan QM-Rb-1 Rubidium magnetometer. The GEM Hawk utilizes the GSMP35U Potassium magnetometer. The sensitivity of these magnetometers is 0.1 nT. The magnetometer sensors are towed on non-magnetic cables. The Geoscan 401 cables are 20 m in length, the GEM Hawk cables are 10 m long.

Today, the standard technique described in the Instructions for Magnetic Exploration [3] is used to eliminate the influence of the UAV on the sensor and to choose the towing method. However, these instructions were developed in 1981 and do not take account of new technological developments.

In 2015, a group of scientists from Moscow State University studied the magnetic field around the Geoscan 201 (plane type) and the effects of the electromagnetic noise from its power and navigation systems. Two magnetometers – Geometrics G858 Cesium magnetometer and MMPOS-1 Overhauser magnetometer – were used to record the magnetic field. As a result, it was agreed that the magnetometer should be located at the maximum possible distance from the nose and the tail end. It was also recommended that the electromagnetic motors should be replaced with a combustion engine [4].

However, the number of such studies is quite small. There were several studies carried out by Chinese scientists who analyzed the influence of electric motors on the readings of the magnetometer. To compensate for the influence of the UAV (quadcopter) systems on the magnetometer, the correction factors were calculated for each position of the magnetometer sensor (i.e. magnetic deviation caused by the UAV was evaluated and compensated). However, the influence of a combustion engine was not assessed in these works [5, 6, 7].

MATERIALS AND METHODS

A 20x20 m site with minimum magnetic fluctuations was arranged to evaluate the magnetic field from the electric motors and the combustion engine. The site was divided into profiles, and stakes were set every 2 m (Figure 1).

The UAVs used were quadcopter and octocopter, and the engine was a two-stroke combustion engine from a bush cutter. The technical characteristics are shown in Table 2. The quadcopter is made of non-magnetic materials: the main elements are made of carbon fiber; some of the elements are made of aluminum. The octocopter is assembled similarly to the quadcopter (from carbon fiber), though its frame is made out of iron-containing materials.

Two MMPOS-1 quantum magnetometers were used in this project: one of them was for the magnetic survey and the other one acted as a base magnetic station.

The survey was carried out in several stages in order to determine the influence of the engines on the magnetometer. First, the background magnetic field was measured (Figure 2). The influence of the UAV (the motors and the material) and the combustion engine was evaluated by measuring the magnetic field first with the engines turned on and then with the engines turned off. To that end, one of the UAVs or the combustion engine was placed in the center of the site (Profile #6, Stake #6). As a result, six magnetic field maps were obtained.

Magnetic deviation was not addressed in this work, since this phenomenon is well studied and is described in details in the Instructions for Magnetic Exploration [3].

Table 2: UAV Specifications

UAV Specifications	Quadcopter	Octocopter
Usable payload	0.5 kg	5 kg
Maximum Take-Off weight	6 kg	30 kg
Cruise speed	1 –50 km/h	1 – 50 km/h
Cruise endurance	25 min	50 min
Operation Temperature	-10 °C to +40 °C	-10 ºC to +40 ºC
Batteries	22.2 V 22 Ah GS LI-PO	22.2 V 22 Ah GS LI-PO

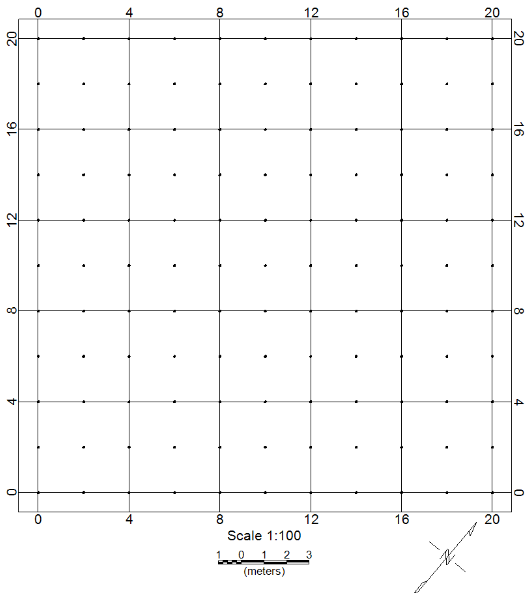

Figure 1 – Sketch map of profiles and stakes.

https://doi.org/10.5593/sgem2020/1.2/s05.061

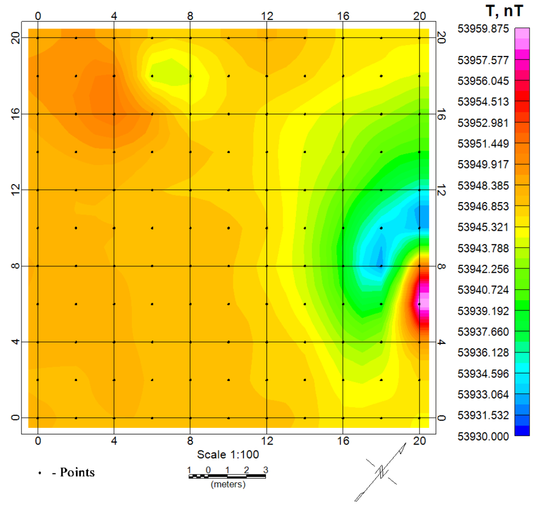

Figure 2 – Map of background magnetic field.

ANALYSIS OF THE MAGNETIC FIELD AND EVALUATION OF ITS INFLUENCE ON THE MAGNETOMETER

The analysis of the magnetic field was performed in Geosoft Oasis Montaj. The correction for magnetic field variations was carried out using the standard Oasis Montaj procedure. Then, the regional magnetic field was subtracted from the observed magnetic field using standard Oasis Montaj procedures. As a result, seven maps were obtained: map of the background local magnetic field (Figure 3); map of the local magnetic field with the quadcopter turned off (Figure 4a) and on (Figure 4b); map of the local magnetic field with the octocopter turned off (Figure 5a) and on (Figure 5b); map of the local magnetic field with the combustion engine turned off (Figure 6a) and on (Figure 6b).

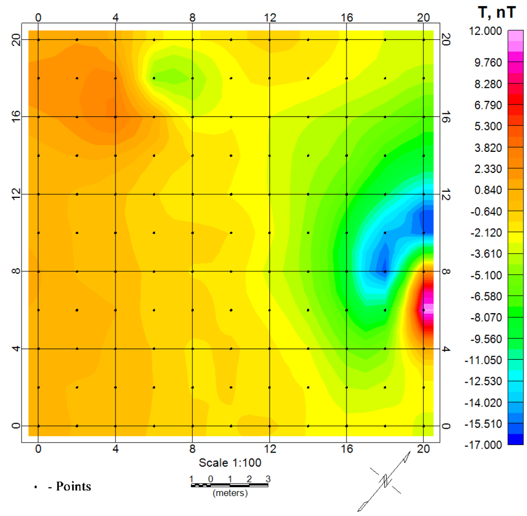

Figure 3 – Map of the background local magnetic field.

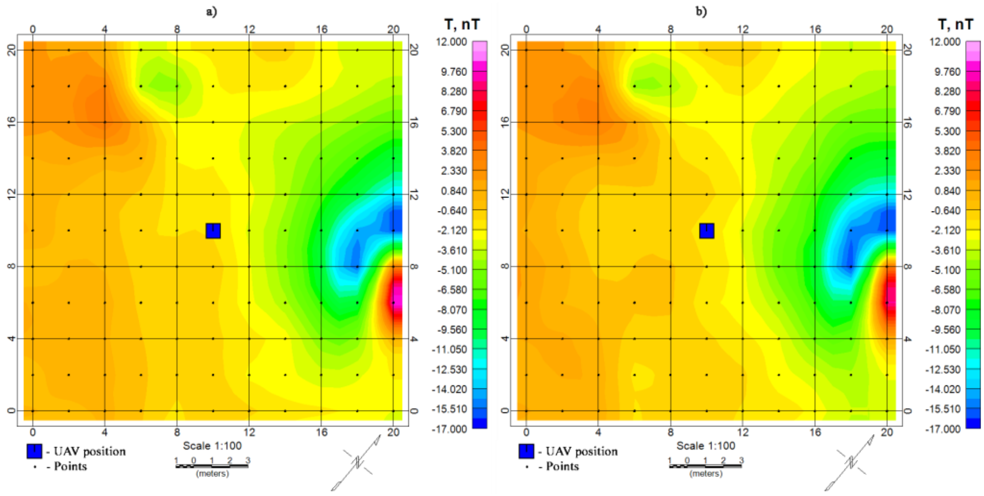

Figure 4 – Map of the local magnetic field with the quadcopter turned on (a) and off (b).

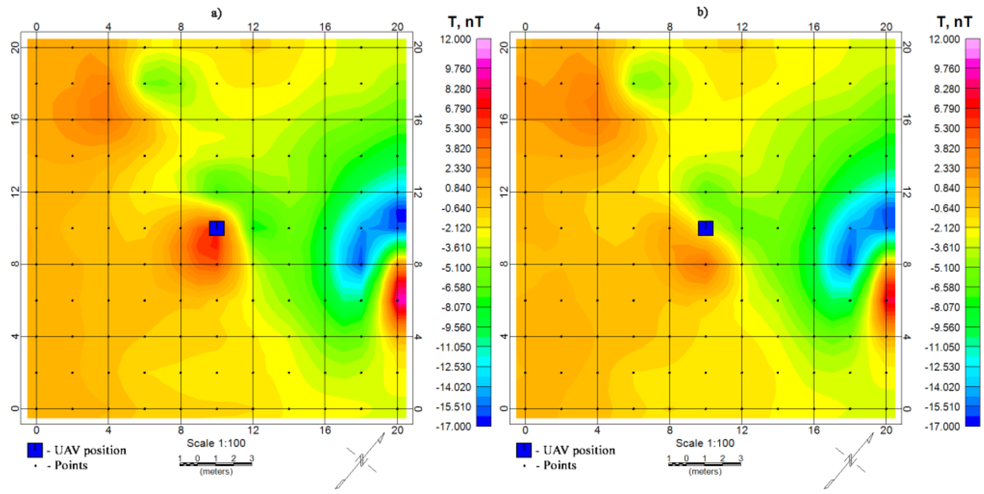

Figure 5 – Map of the local magnetic field with the octocopter turned on (a) and off (b).

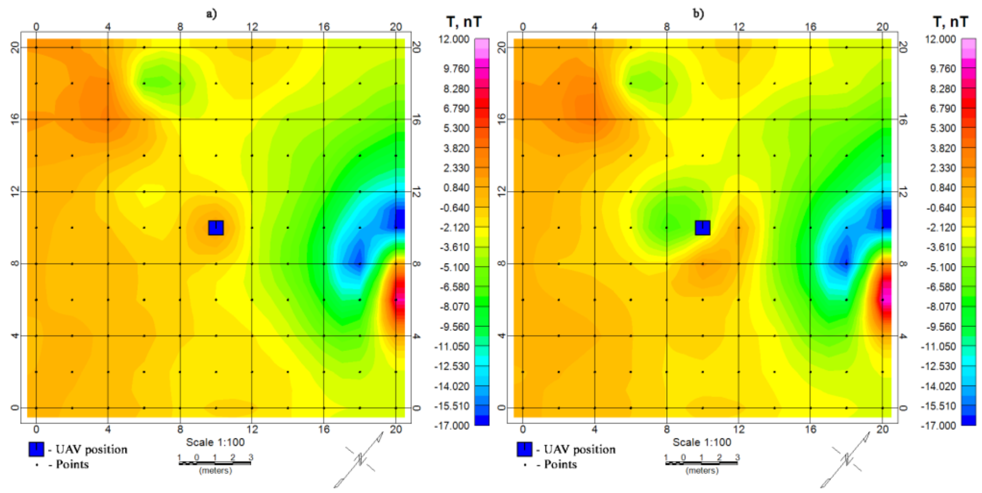

Figure 6 – Map of the local magnetic field with the combustion engine turned on (a) and off (b).

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The obtained maps were used to evaluate the influence of the UAV motors and the combustion engine on the magnetometer. To that end, the background local magnetic field was subtracted from the local magnetic field. As a result, six maps of the magnetic field were obtained: with the quadcopter (Figure 7), the octocopter (Figure 8) and the combustion engine (Figure 9) turned on and off.

Analysis of the magnetic field around the quadcopter showed that it does not influence the magnetometer measurements.

The magnetic field around the octocopter is shaped as a dipole extending in an south-to-north direction. The dimensions of this anomaly are 8x10 m; the maximum amplitudes with the engine turned off and on are 9 nT and 12 nT, respectively.

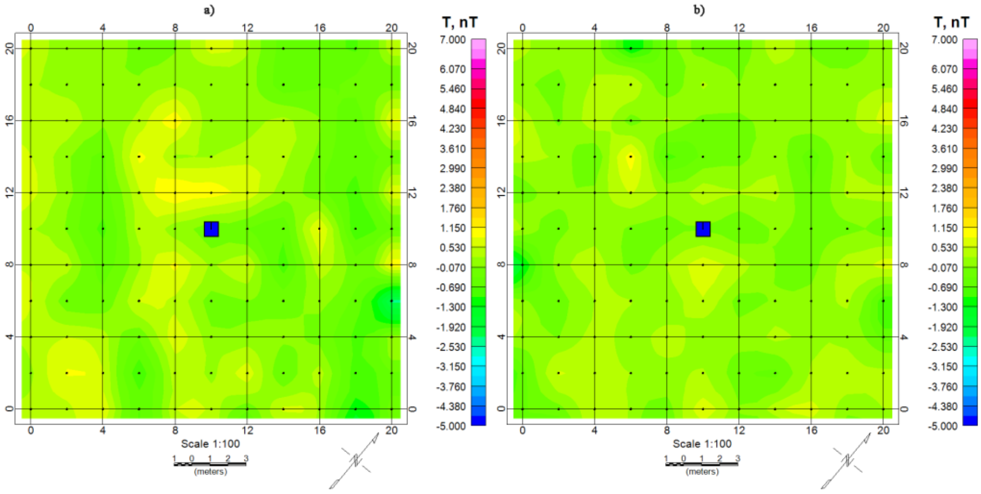

Figure 7 – Map of the magnetic field from the quadcopter: turned on (a) and off (b).

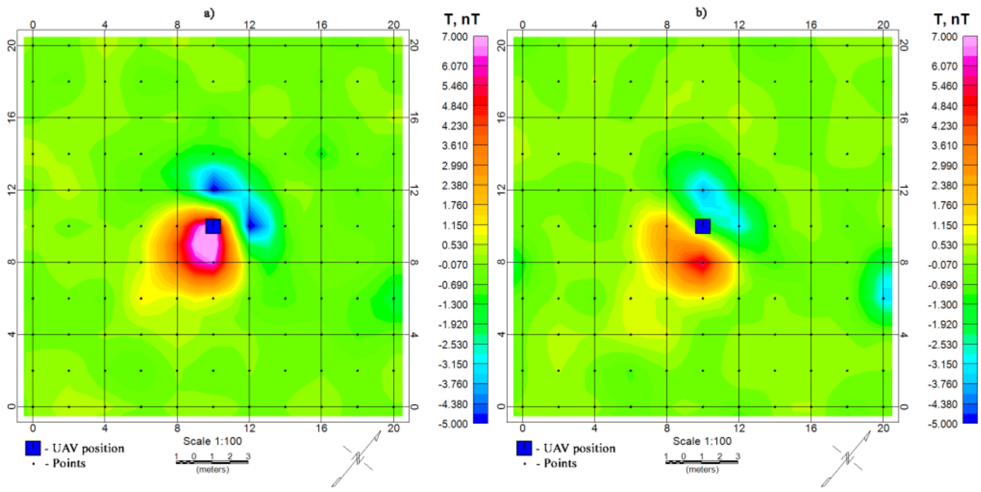

Figure 8 – Map of the magnetic field from the octocopter: turned on (a) and off (b).

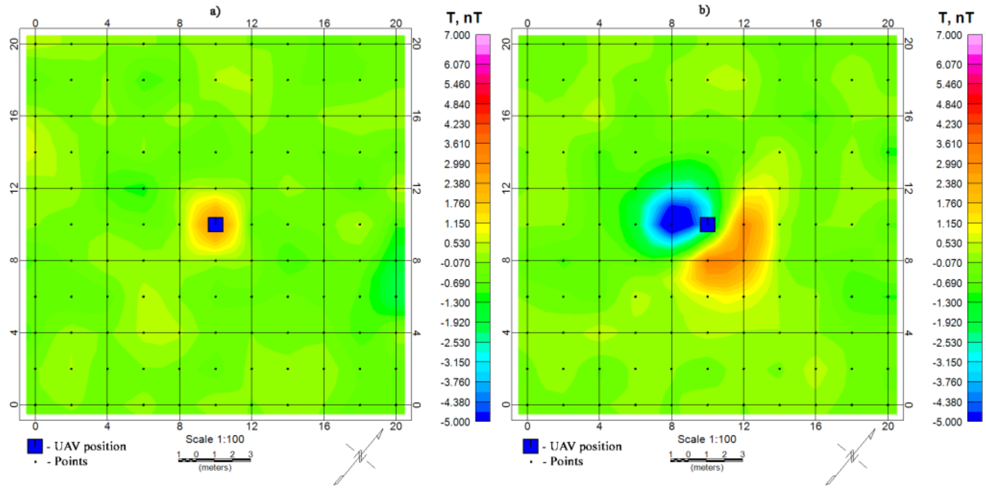

Figure 9 – Map of the magnetic field from the combustion engine: turned on (a) and off (b).

The magnetic field maps obtained with the combustion engine turned on and off differ from one another. The running engine produces a positive unipolar anomaly with dimensions of 2x2 m and maximum amplitude of 3 nT. When the engine is switched off, the anomaly becomes even larger and forms a dipole, 4x6 m in size with maximum amplitude of 9.5 nT.

CONCLUSION

This research, initially aimed at evaluating the influence of UAV (quadcopter and octocopter) motors and combustion engines on the readings of the quantum magnetometer MMPOS-1, showed that these vehicles and engines can make a significant contribution to the magnetic field. Magnetic deviation was not addressed in this work, since this phenomenon is well studied.

Since the quadcopter has a usable payload of only 0.5 kg and a cruise endurance of 15 minutes, it has no effect on the magnetometer readings. Thus, it is possible not only to use the MMPOS-1, but also to mount it directly on the UAV. It should also be noted that the quadcopter is assembled from non-magnetic materials, from carbon fiber and aluminum in particular, which minimizes the magnetic effect from its frame. The UAV of this type can be used in high-precision magnetic studies for solving archaeological problems, for instance.

As can be seen from the analysis, the octocopter had a significant effect on the MMPOS-1 readings. The maximum amplitude of the anomaly produced by the running octocopter is 3 nT more than that appearing with the octocopter switched off. This fact confirms that the running engine affects the readings of the magnetometer. The best decision in this case would be to tow the magnetometer at some distance from the drone with a non-magnetic cable. The distance at which there is no influence from the UAV varies from 4 to 8 m (depending on the direction). The octocopter, like the quadcopter, is built primarily of carbon fiber, but that doesn't really matter since its motors are made of iron-containing materials. Nevertheless, this design increases cruise endurance to 50 minutes and usable payload to 5 kg. However, the readings of the magnetometer in this case are influenced both by the octocopter's frame and its running motors. The octocopter can be used in various aeromagnetic studies of any scale, since the root-mean-square error in this case would vary from 0.5 nT to 25 nT [3].

The magnetic field maps obtained with the combustion engine turned on and off differ from one another. The switched-off combustion engine has a greater effect on the magnetometer, which is most likely due to its design, in particular to the metal housing of cylinders, pistons, etc. However, as soon as the engine starts, the operation of the pistons produces the self-magnetic field, which compensates for the influence from the metal elements. Therefore, the minimum distance to which the magnetic sensor should be carried away from the UAV is 2 m. This can be achieved with towing cables, similar to the case with the octocopter, and will minimize the influence of the running engine and its metal components.

ACKNOWLEDGEMENTS

This work was supported financially by the Ministry of Science and Higher Education of the Russian Federation, contract no. 02.G25.31.0309.

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