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MODELING OF PHYSICAL FIELDS AND MONITORING GEOLOGICAL PROCESSES WITH USING DRONES (UAVs)

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The paper demonstrates the advantages and possibilities of using drones for geophysical research, modeling of some physical fields, and monitoring of geological processes. Drones, which are able to integrate geophysical and other sensors, become a powerful and effective tool for geophysical and geological observations.

Some examples of the use of drones for a detailed study of geological objects (such as slope processes, land erosion, quarries, etc.) are presented. Drones with special geophysical sensors (for example, magnetic) or similar drones to which these sensors can be attached can detect anomalies along the study areas. These data are important for modeling physical fields and monitoring their changes.

Depending on the capabilities and the availability of certain sensors, drones can be used for surveys for various purposes related to magnetic cartography, the study of hidden minerals, the area of karst and flooded areas, etc.

Drone's spatial data and 3D data, processed using special software, contribute to the monitoring of dangerous geological processes during some periods, the search for mineral resources in hard-to-reach places, and the research of the deep structure of the Earth.

Keywords: Drone, Unmanned Aerial Vehicle (UAV), fixed-wing rotary-wing drones, geophysics, geology, geophysical sensors, geological monitoring, modelling.

I. Introduction

Nowadays drones, also known as Unmanned Aerial Vehicles (UAVs) or as Unmanned Aircraft Systems (UASs) or Remotely Piloted Aircraft (RPA), are quite popular in almost all spheres of human activity. Drones are flying object or aircraft whose trajectories can be remotely controlled or programmed in a certain way without a human control on board [1-7].

The main advantages for using drones are economy, accuracy and the ability to work in hard-to-reach places. The cost of using aircraft and helicopters for local large-scale research is quite high. Therefore, the use of UAVs or drone is an alternative solution.

Today, the leaders among countries with the development of drones and sensors for various industries are the United States, China, Iran, India. Seven European countries (Italy, Germany, France, Spain, Greece, Poland and the Netherlands) are participating in programs to produce the next generation of UAVs [2].

The development of UAV technology allows the use of drones more widely as remote sensing platforms to complement satellite and manned remote sensing systems. UAVs are used as portable, scalable, high-resolution imaging platforms that complement satellite imagery that may have gaps in observations due to adverse weather events such as cloud cover, and limited coverage in a specific region. UAVs are also becoming an effective tool for remote sensing in areas inaccessible to conventional manned aircraft platforms due to logistical and human constraints.

In addition, the main advantage of using portable drones is the possibility of repeated observations in difficult or dangerous areas using different sensors for a short period of time to support various spatial analysis. Sometimes the speed of monitoring geological processes or changes in the properties of physical fields in some certain dangerous areas plays an important role.

Drones become popular powerful tools for getting spatial data for different analyses and modeling in geophysics, geology and other geosciences. According to research [2] geological sciences is one of the most promising sectors for the use of drones. The UAVs, equipped with the most modern cameras and various sensors, are quite suitable for monitoring important processes such as geophysical (research features of physical fields), geological, environmental, engineering geology and hydrogeological etc.

II. Purpose

The main aim of the work is to demonstrate classifications of UAVs, the possibilities of using drones for monitoring some geological processes and conducting geophysical surveys for modeling physical fields, and to identify their advantages and disadvantages.

III. Methods

In accordance with the purpose of the study, the size and location of the research area and other optimal parameters, certain types of drones are used. Below is one of the most common classifications of drones. Depending on the type of drone, certain sensors and certain software may be used.

Classification of drones. The configurations of drones are constantly changing and evolving in recent years according to the needs and goals in various fields of science and industry. In the literature there are a huge number of different types of UAVs with different capabilities and needs.

However, the European Association of Unmanned Systems (EUROUVS) has proposed a classification as a reference for the international UAV community with the main purpose of compiling a universal catalog of UAV categories and abbreviations. Thus, drones on the basis of such parameters as their size, altitude, endurance and capabilities are divided into several different groups (table I, II) [1, 2, 7]. According to these information, UAVs are grouped into four main categories: micro/mini UAVs (MAV/Mini), tactical UAVs (TUAVs), strategic UAVs, and special task UAVs. These categories of drones have different uses in various sphere of human activity, science and industry.

Drones also can be divided into four types according to their shape [7]: airships, flying-wing, fixed-wing and rotary-wing (Fig.1).

a

b

Fig. 1. Some example of drones according shape: *a* – fixed-wing (Trimble UX5, *source*: https://www.unmannedsystemstechnology.com/); *b* – multi rotary-wing drones (Phantom 4 Pro; *source*: https://unsplash.com/).

Table 1.
Classification of Unmanned Aerial Vehicles (UAVs) and some properties with Hardware (system configuration) (source European Association of Unmanned Vehicles Systems [1])

Category (acronym)	*Maximum Take Off Weight (kg)*	*Flight Altitude (m)*	*Endurance (hours)*	*Data Link Range (km)*
Micro/Mini UAVs (MAV/Mini)				
Micro/ Mini	*0.1*	*250*	*1*	*<10*
Mini	*<30*	*150-300*	*<2*	*<10*
Tactical UAVs (TUAVs)				
Close Range (CR)	*150*	*3 000*	*2-4*	*10-30*
Short Range (SR)	*200*	*3000*	*3-6*	*30-70*
Medium Range (MR)	*150-500*	*3000-5000*	*6-10*	*70-200*
Long Range (LR)	*-*	*5 000*	*6-13*	*200-500*
Endurance (EN)	*500-1500*	*5000-8000*	*12-24*	*>500*
Medium Altitude, Long Endurance (MALE)	*1000-1500*	*5000-8000*	*24-48*	*>500*
Strategic UAVs				
High Altitude, Long Endurance (HALE)	*2500-12500*	*15000-20000*	*24-48*	*>2000*
Special Task UAVs				
Lethal (LET)	*250*	*3000-4000*	*3-4*	*300*
Decoys (DEC)	*250*	*50-5000*	*<4*	*0-500*
Stratospheric (STRATO)	*To be defined*	*20000-30000*	*>48*	*>2000*
Exo-stratospheric (EXO)	*To be defined*	*>30000*	*To be defined*	*To be defined*

It is often useful to classify UAVs according to their mission capabilities. UAVs differ widely in configuration, size, operational purpose, materials from which they are made, complexity and cost of the control system [8]. Different mission requirements created different types of UAVs. Different types of UAV platforms have different missions and applications (table II). The smallest class of drones are MAV / Mini UAVs, which are mainly used for civilian applications. The largest are Strategic UAVs, which are mostly used for military purposes. MAVs and Mini UAVs become more practical and widespread.

In recent decades, the smallest air drone is being developed and tested, which is called a micro-air vehicle of various shapes and flight modes for special missions and requests [9].

Nowadays, drones have evolved due to advances in the miniaturization of electronic components such as batteries, microprocessors, navigation systems and various sensors [10]. Different types of drones can be equipped with different types of navigation. Drones use various positioning methods such as the Global Positioning System GPS (as well as GLONASS, Galileo, BeiDou in different regions of the world) and the Inertial Navigation System INS. GPS is usually used to determine the exact position, speed and altitude of the drone. However, GPS signals are easily affected by interference, and some drones may temporarily lose their GPS connection. The INS Inertial Navigation System is used to prevent this temporary loss of communication in drones. This system includes gyroscopes and accelerometers, which are used to calculate the position and orientation of drones. Therefore, the combination of two types of signals from GPS and INS allows you to get accurate navigation information. Thus, the extended Kalmanfilter (EKF) [11] is used to estimate the location of drones that temporarily lose their GPS connection, which also expands the use of drones.

Table 2.
Hardware (system configuration) and Uses of UAVs (sourse European Association of Unmanned Vehicles Systems, [1])

Category (acronym) of UAVs	***Hardware (System configuration)***	***Uses (Mission)***
	Micro/Mini UAVs (MAV/Mini)	
Micro/ Mini	*Black Window, Microstar, FanCopter, QuattroCopter, Mosquito, Hornet, Mite*	*Scouting, NBC sampling, surveillance inside buildings*
Mini	*Mikado, Aladin, Tracker, DragonEye, Reven, Pointer II, Carolo C40/P50, Skorpio, R-Max and R-50, RoboCopter, YH-3005*	*Film and broadcast industries, agriculture, pollution measurements,surve*
	Tactical UAVs (TUAVs)	
Close Range (CR)	*Observed I, Phantom, Copter 4, Mikado, RoboCopter 300, Pointer, Camcopter, Aerial and Agricultural RMax*	*RSTA, mine detection, search & rescue, EW*
Short Range (SR)	*Scorpi 6/30, Luna, SilverFox, EyeView, Firebird, R-Max, Agri/Photo, Hornet, Raven, GoldenEye 100, Flyrt, Neptune*	*BDA, RSTA, EW, mane detection*
Medium Range (MR)	*Hunter B, Muske, Aerostar, Sniper, Falco, Armor X7, Smart UAV, UCAR, Eagle Eye+, Alice, Extender, Shadow 200/400*	*BDA, RSTA, EW, mane detection, NBC sampling*
Long Range (LR)	*Hunter, Vigilante 502*	*RSTA, BDA, communications relay*
Endurance (EN)	*Aerosonde, Vulture II Exp, Shadow 600, Searcher II, Hermes 450S/450T/700*	*DA, RSTA, EW, communications relay, NBC sampling*
Medium Altitude, Long Endurance (MALE)	*Skyforce, Hermes 1500, Heron TP, MQ-1 Predator, Predator-IT, Eagle-1/2, Darkstar, E-Hunter, Dominato*	*DA, RSTA, EW weapons delivery, communications relay, NBC sampling*
	Strategic UAVs	
High Altitude, Long Endurance (HALE)	*Global Hawk, Raptor, Theseus, Condor, Helios, Predator B/C, Libellule, EuroHawk, Mercator, SensorCraft, Global Observer, Pathfinder Plus*	*Communications relay, airport security, RSTA, intercept vehicle*
	Special Task UAVs	
Lethal (LET)	*MALI, Harpy, Lark, Marula*	*Anti-radar, anti-ship, anti-aircraft, anti-infracstructere*
Decoys (DEC)	*Flyrt, MALD, Nulka, ITALD, Chukar*	*Aerial and naval deception*
Stratospheric (STRATO)	*Pegasus*	*Aerial and naval deception*
Exo-stratospheric (EXO)	*MarsFlyer, MAC-1*	*Aerial and naval deception*

Commercial drones. Today one of the most popular UAVs is commercial drones. Some UAVs use a GPS connection via a remote control or an airplane, or both. However, commercial drones stand out above the others to use Real Time Kinematic (RTK) or other similar GPS precision tools and offer the best flight accuracy. RTK is a GPS correction technology that combines satellite connections with photos and positioning to a well-known ground station. RTK drone can hover with accuracy as low as a couple of inches.

The manufacture of commercial drone is a serious market. Leaders of modern commercial UAVs are DJI, Parrot, Yuneec, PowerVision, SwellPro, Hubsan, Autel Robotics, Leica Geosystems etc. (Fig. 2).

Fig. 2. Some best commercial drones with special camera and sensors:
a – DJI P4 Multispectral RTK Drone with D-RTK 2 Mobile Station (Multispectral camera); b – DJI Mavic 2 Enterprise Dual Universal Edition Thermal Drone (Integrated Radiometric FLIR Thermal sensor); c – DJI Matrice 210 V2 - Visual/Thermal Response Pack (FPV Camera); d – Parrot Anafi Thermal Drone (FLIR Thermal camera); e – SwellPro Splashdrone 3+ With GC-3 Waterproof 4K Camera [12]; f – Leica Aibot SX [13]

These brands propose different types of drones (the most popular are quadcopters) with different replaceable sensors and cameras (Vision, Radiometric, Multispectral (R,G,B, NIR), Thermal, Infrared, etc.) [12, 13] (Fig. 2). Drones also have several important features: GPS return home; Anti-collision beacon; Circling flight; Way Point Fly; Auto Takeoff & Land, TimeSync; Camera (waterproof, wide-angle, 4K, etc.), Thermal Analysis, Wind Resistant. [12].

Most drone manufacturers use their own patented drone flight control software. Some applications are free and can be downloaded in the Google Play Store or Apple App Store such as DJI GO 4, DJI Fly, Parrot FreeFlight Pro, Yuneec Breeze Cam, Yuneec CGO3, Yuneec Pilot, X-Hubsan, Autel Robotics Starlink etc. However, specialized software or GIS applications will be preferred to control both the unmanned aerial vehicle and the collection and analysis of different type of spatial data. For example, Leica Infinity software (Leica Geosystems) is used for process and quality check all field survey measure data, view millions of 3D points and analyze and evaluate digital images in 3D Reshaper [13].

IV. Results

Using drones in monitoring geological processes.

UAVs have a lot of potential applications in the areas of geological and ecological monitoring, different kinds of smart surveying from remote areas of research. Some drones can support ubiquitous connectivity and collect geological data from remote areas using wireless without human involvement. To efficiently use drones for solving questions for geological applications, important issues need to be investigated [14].

The most common geoscientific application of drones is use aerial imagery to reconstruct digital surface models. Due to the growth of technology of UAVs it became possible to use Structure-from-Motion (SfM) photogrammetry as an inexpensive, effective tool for reconstructing digital surface models, for mapping and to identify the geological structure in outcrops [15,16].

Below is the model of erosion relief. The data was obtained from the Phantom 4 drone and processed by Agisoft (fig. 3). The result of the 3D model of erosion can be opened and processed in a free program software – QGIS. Monitoring changes in land degradation of this research area over a period of time (e.g. annually, seasonally, etc.) will be useful for some forecasting.

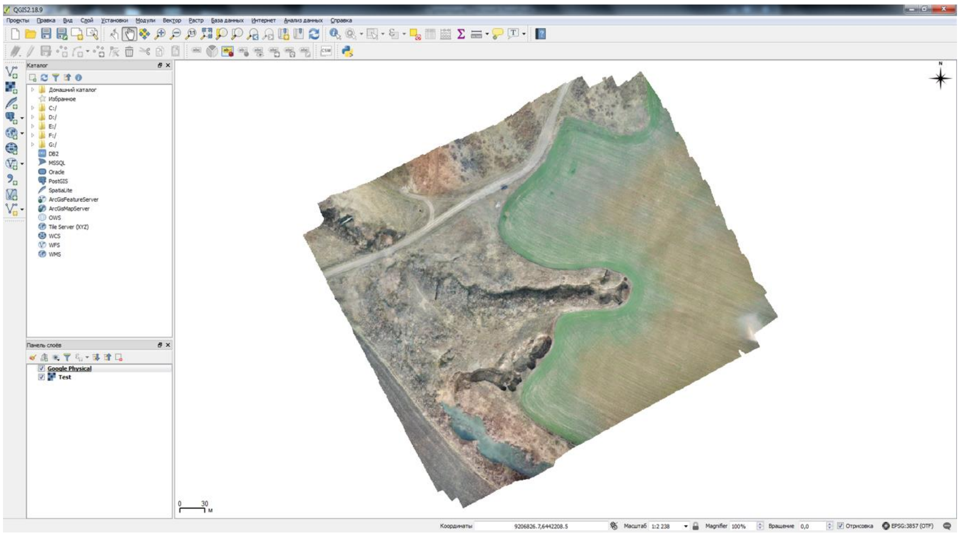

Fig. 3. Land degradation due to erosion in QGIS (developed by Agisoft, data from Phantom 4)

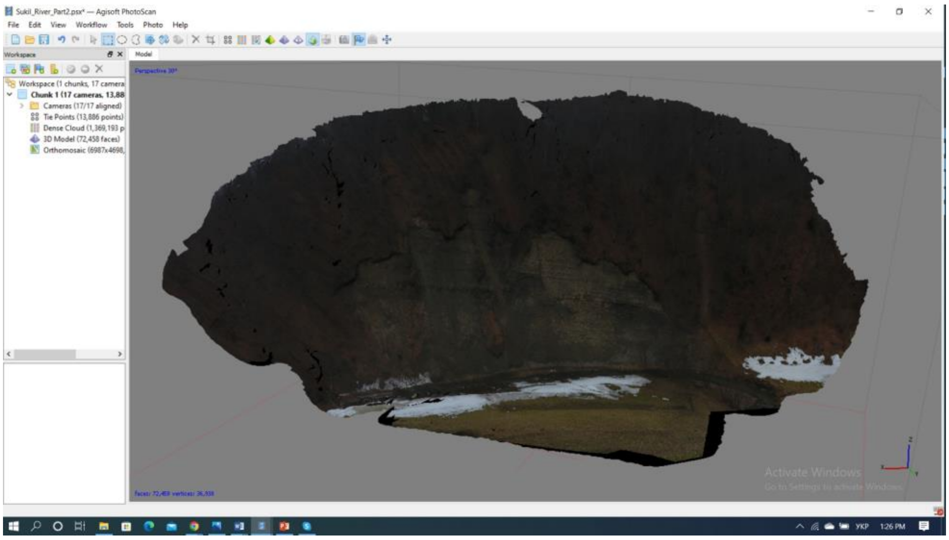

Fig. 4. 3D model of the geological object in the Sukil River Valley (developed by Agisoft) with using Phantom 4 (in manual mode)

Fig. 5. Geological survey of Miocene rocks by drone Phantom 4

SfM data includes orthophotos, 3D point clouds, and three-dimensional digital surface or terrain models for modeling and mapping with high-resolution strain patterns at the level of cm. SfM high-resolution models can be compared in accuracy with other survey methods and mapping technologies, such as light detection and measurement (LiDAR) [17].

Agisoft Metashape, commercial software for working with geospatial data, formerly known as Photoscan, performs photogrammetric processing of digital images, generation of DSM / DTM spatial 3D data, processing of satellite images for subsequent use in specialized software and GIS applications [18, 19].

It is possible to build a 3D model of the outcrop of the geological object of the Sukil River Valley with using data obtained from a drone (Phantom 4) with using program Agisoft (fig. 4). This 3D model can determine the geological structure of rocks in large outcrops.

The next way to use the drone (Phantom 4) is to research the slope wall to the separate the layers of rocks and stratification of different types (Fig 5).

The use of UAVs makes the methodology particularly attractive for immediate response to a disaster (seismic, volcanic, hydrogeological, and hazard by a landslide), as it allows the collection of optical data in areas that are inaccessible or unsafe [20].

Using drones in monitoring in geophysics and modeling physical fields.

Not only digital cameras but also advanced geophysical sensors can be fixed on board unmanned aerial vehicles [21]. Modern UAVs have greater endurance, and therefore can be hang on board drone's miniature geophysical sensors. Geophysicists perform mapping based on drones and use various geophysical sensors mounted on UAVs [21, 22].

Using magnetometers on board the UAVs allows a demonstration survey of deposits. UAV magnetometry is becoming popular in mineral exploration too. The paper [24, 25] contributes to our understanding of the potentials and limitations of UAV-based magnetic imaging.

Sensys portable magnetometers deserve a lot of attention [27] (fig. 6). MagDrone R3 is an ultra-portable magnetometer survey kit to be attached to any UAV / drone with weight 1 kg. Unlike the MagDrone R3, the MagDrone R4 weighs 3 kg. But the MagDrone R4 is made for large area survay, when ground research by man or vehicle is no longer possible. The operating temperature of these magnetometers is -20°C to +50°C, specified measurement range ±75,000 nT.

a

b

Fig. 6. Ultra-portable magnetometer survey kit: *a* – MagDrone R3, *b* – MagDrone R4 [26].

Determining the dynamics of fluvial forms that are formed or modified by flooding, using UAV processes, can enhance or confirm the results using hydrogeophysical methods [27].

V. The practical significance

Different types of drones allow the use of various variable sensors and cameras for monitoring and gathering correct spatial data from the observed territory with specialized GIS applications and geospatial software. Drones, that offer either RTK or other similar precision GPS tools, are the best drones.

Absolute accuracy for most special flights of monitoring geological processes, geophysical surveying and mapping are crucial in the collection and analysis of correct spatial data for modeling of physical Earth's fields and their changes. Due to accuracy, ease of use and cost of drone with replaceable sensors or cameras, some type of Unmanned Aerial Vehicles (UAVs) is becoming more widespread and use in various applications connected with modeling and monitoring in Geoscience.

The UAV-based multi-temporal digital surface models and orthophotos became suitable for detecting changes in the Earth's surface. Automated georeferenced flights with multiple sensors aid repeated surveys along the same transects in difficult/impossible to access areas with collecting data for monitoring changing conditions over time to inform, constrain, and improve site conceptual, geophysical, geological, geochemical, and numerical models.

Conclusions

The rapid development of Unmanned Aerial Vehicle technology has allowed for the wider use of UAVs capable of integrating geophysical sensors such as magnetic, electromagnetic, infrared, radars, natural gamma-ray sensors for geophysical observations and using specialized GIS geospatial software for constructions special database.

UAV technologies have several advantages over traditional geophysical observations – resolution, stability, cost, speed, etc. Such significant advantages of drones contribute to the effective use of UAVs for geophysical measurements in surveys, exploration and monitoring of geological processes, modeling changes in the physical fields of the Earth using specialized GIS software.

Although it should be noted that there are also several shortcomings in the study using drones. First, there are natural conditions that negatively affect the performance of drones and their batteries - snow, rain, wind, etc., and a strong magnetic field. Secondly, the battery does not allow for continuous research with drones. Third, there is the legal side. you need to get permission to use a drone However, with each new generation of drones become even better and contain modern small sensors.

REFERENCES

[1] *Bento M. N.* Unmanned aerial vehicles: An overview / Inside GNSS. — 2008. — Vol. 3. — No. 3. — P. 54–61.

[2] AA.VV. The Future of Unmanned Aerial Vehicles in Europe, Civilian and Military Market Outlook – 2013-2021. — 2012. — P. 209.

[3] *Gupta S. G.*Review of Unmanned Aircraft System (UAS) / S. G. Gupta, M. M. Ghonge, and P. M. Jawandhiya // International Journal of Advanced Research in Computer Engineering & Technology. —2013. — Vol. 2. — No. 4. — P. 1646-1658.

[4] *Whitehead K.* Remote sensing of the environment with small unmanned aircraft systems (UASs), part 1: a review of progress and challenges / K. Whitehead, C. H. Hugenholtz //

Journal of Unmanned Veh. Syst. — 2014. — Vol. 2. — No. 3. — P. 69-85; 10.1139/juvs-2014-0006.

[5] Remote sensing of the environment with small unmanned aircraft systems (UASs), part 2: scientific and commercial applications / K. Whitehead, C. H. Hugenholtz, S. Myshak, O. Brown, A. LeClair, A. Tamminga, T. E. Barchyn, B. Moorman, and B. Eaton // Journal of Unmanned Veh. Syst. — 2014. — Vol. 2. — No. 3. — P. 86-102; 10.1139/juvs-2014-0007.

[6] *Singhal G.* Unmanned aerial vehicle classification applications andchallenges: A review / G. Singhal, B. Bansod, and L. Mathew // Preprints. — 2018. — 2018110601.

[7] *A. Noorwali, M. A. Javed, and M. Z. Khan*. Efficient UAV Communications: Recent Trends and Challenges / A. Noorwali, M. A. Javed, and M. Z. Khan // Cmc-Computers Materials & Continua. — 2021. — Vol 67. — No. 1. — P. 463-476.

[8] *Hassanalian M*. Classifications, applications, and design challenges of drones: A review / M. Hassanalian, A. Abdessattar // Progress in Aerospace Sciences. — 2017. — Vol 9. — P. 99-131.

[9] *Hassanalian M.* Design, manufacturing, and flight testing of a fixed wing micro air vehicle with Zimmerman planform / M. Hassanalian, A. Abdessattar // Meccanica. — 2017. —Vol. 52. — P.1265–1282.

[10] *Floreano D.* Science, technology and the future of small autonomous drones / D. Floreano, R. Wood // Nature. — 2015. — Vol. 521. — P. 460–466.

[11] *Brown R. G.* Introduction to random signals and applied Kalman filtering: with MATLAB exercises / R. G. Brown, P. Y. Hwang // J Wiley & Sons. — 2012.

[12] Drones Direct. [Online]. Available: https://www.dronesdirect.co.uk/st/commercial-drones

[13] Leica Aibot Aerial Data Capture Platform. Leica Geosystems. Available: https://leica-geosystems.com/products/uav-systems/copter

[14] *Niedzielski T.* Applications of unmanned aerial vehicles in geosciences: introduction / T. Niedzielski // Pure and Applied Geophysics. — 2018. — Vol. 175. — No. 9. — P. 3141-3144.

[15] Structure-from-Motion'photogrammetry: A low-cost, effective tool for geoscience applications / M. J. Westoby, J. Brasington, N. F. Glasser, M.J. Hambrey, and J.M. Reynolds // Geomorphology. — 2012. — Vol. 179. — P. 300-314.

[16] *Saputra A.* The application of structure from motion (SfM) to identify the geological structure and outcrop studies / A. Saputra, T. Rahardianto, and C. Gomez // In AIP Conference Proceedings. — 2017. — Vol. 1857. — No. — 1. — P. 030001.

[17] Application of multispectral LiDAR to automated virtual outcrop geology / P. Hartzell, C. Glennie, K. Biber, S. Khan // ISPRS Journal of Photogrammetry and Remote Sensing. — 2014. — Vol. 88. — P.147-155.

[18] Agisoft Metashape. [Online]. Available: https://www.agisoft.com/downloads/installer/

[19] Zhang X. H. The Application of Agisoft Photoscan in UAV Aerial Photographic Image Data Processing. / X. H. Zhang, S. L. Zhao, F. T. Chen // Value Engineering. —2013. — 20. — P. 230-231.

[20] Ground-based and UAV-Based photogrammetry: A multi-scale, high-resolution mapping tool for structural geology and paleoseismology / S. P. Bemis, S. Micklethwaite, D. Turner, M. R. James, S. Akciz, S. T. Thiele, H. A. Bangash // Journal of Structural Geology. — 2014. — Vol. 69. — P. 163-178.

[21] *Hatch M*. Environmental geophysics: Using drones to create base maps / M. Hatch // Preview, 2016. — Vol. 185. — P. 31–32.

[22] *Hatch M.* Environmental geophysics: Developments in miniaturisation technology / M. Hatch // Preview, 2017. — vol. 189. — P. 32–33.
[23] Fluxgate vector magnetometers: A multisensor device for ground, UAV, and airborne magnetic surveys / B. Gavazzi, P. Le Maire, M. Munschy, A. Dechamp // The Leading Edge. — 2016. —Vol. 35. — No. 9. — P. 795-797.
[24] Aeromagnetic surveying with a rotary-wing unmanned aircraft system: A case study from a zinc deposit in Nash Creek, New Brunswick, Canada / M. Cunningham, C. Samson, A. Wood, and I. Cook // Pure and Applied Geophysics. — 2018. — Vol. 175. — No. 9. — P. 3145-3158.
[25] *Prystai A.* UAV application for geophysical research / A. Prystai, B. Ladanivkyy // Geofiz. Zhurnal. — 2017. — 39(2). — P.109–125; https://doi.org/10.24028/gzh.0203-3100.v39i2.2017.97378
[26] SENSY. Magnetometer & Survey Solutions. [Online]. Available: https://sensysmagnetometer.com/products
[27] *Langhammer J.* Detection and mapping of the geomorphic effects of flooding using UAV photogrammetry / J. Langhammer, T. Vackova // Pure and Applied Geophysics. — 2018. — Vol. 175. — No. 9. — P. 3223-3245.

МОДЕЛЮВАННЯ ФІЗИЧНИХ ПОЛІВ ТА МОНІТОРИНГ ГЕОЛОГІЧНИХ ПРОЦЕСІВ З ВИКОРИСТАННЯ ДРОНІВ (БПЛА)

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У статті показані переваги та можливості використання дронів для геофізичних досліджень, моделювання фізичних полів та моніторингу геологічних процесів. Дрони, які здатні інтегрувати геофізичні та інші датчики (радіометричні, мультиспектральні, теплові, інфрачервоні тощо), стають потужним і ефективним інструментом для геофізичних та геологічних спостережень та моніторингу.

Наведено деякі приклади використання дронів для детального вивчення геологічних об’єктів таких, як ерозійні ділянки, геологічні відслонення значних розмірів у долині річки, що є важкодоступними для вивчення і розміщені на схилах. Побудована 3D-модель рельєфу ерозійної ділянки. Моніторинг змін деградації земель у цій зоні дослідження протягом певного періоду часу (щорічно, сезонно тощо) буде корисним для прогнозування. Досліджене відслонення міоценових відкладів на схилі для виділення нашарування гірських порід та аналізу схилових процесів у важкодоступних місцях. Побудована 3D-модель геологічного відслонення долини ріки Сукіль для визначення геологічної структуру гірських порід. Усі дані отримані з дрона Phantom 4 та опрацьовані програмними забезпеченнями Agisoft, QGIS.

Дрони зі спеціальними геофізичними датчиками (наприклад, магнітними) або подібні дрони, до яких можна прикріпити ці датчики, можуть виявляти аномалії вздовж досліджуваних ділянок. Ці дані важливі для моделювання фізичних полів і моніторингу їх змін.

Залежно від можливостей і наявності тих чи інших датчиків, дрони можна використовувати для знімання різного призначення, пов'язаних з магнітною картографією, вивченням прихованих корисних копалин, площ карстових і затоплених територій тощо.

Просторові та 3D-дані дрона, оброблені за допомогою спеціального програмного забезпечення, сприяють моніторингу небезпечних геологічних процесів, пошуку мінеральних ресурсів у важкодоступних місцях, а також дослідженню глибинної будови Землі. Крім того, використання дронів робить методологію особливо привабливою для негайного реагування на катастрофу (сейсмічна, вулканічна, гідрогеологічна, небезпека зсуву тощо), оскільки дозволяє збирати оптичні дані у недоступних або небезпечних районах.

Ключові слова: дрон, безпілотний літальний апарат (БПЛА), дрон з фіксованим крилом, геофізика, геологія, геофізичні датчики, геологічний моніторинг, моделювання

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