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Stanislav O. Dovgyi

Doctor of Sciences in Physics and Mathematics, Professor,
Academician of the National Academy of Sciences of Ukraine
Presidium of the Junior Academy of Sciences of Ukraine, Kyiv, Ukraine
ORCID ID 0000-0003-1078-0162
gis_rs@man.gov.ua

Svitlana M. Babiichuk

PhD of Pedagogical Sciences, Head of the “GIS and RS Laboratory”
National Center “Junior Academy of Sciences of Ukraine”, Kyiv, Ukraine
ORCID ID 0000-0001-6556-9351
brevus.lana@gmail.com

Olha V. Tomchenko

PhD of Technical Sciences, Researcher
State Institution “Scientific Centre for Aerospace Research of the
Earth of the Institute of Geological Sciences of the National Academy of Sciences of Ukraine”, Kyiv, Ukraine
ORCID ID 0000-0001-6975-9099
olhatomch@gmail.com

EXPERIENCE OF USING PLANET EARTH OBSERVATION DATA IN RETRAINING COURSES FOR EDUCATORS IN THE JUNIOR ACADEMY OF SCIENCES OF UKRAINE

Abstract. This paper discusses the background and presents the results of the first in Ukraine advanced training course for educators in Remote Sensing, “Fundamentals of Remote Sensing: History and Practice”, organized by the Geographic Information Systems and Remote Sensing Laboratory of the National Center, “Junior Academy of Sciences of Ukraine”. The Junior Academy of Sciences of Ukraine is a system of extracurricular education committed to the development and implementation of science education techniques. Currently, the Academy has more than 250,000 students working in 64 scientific areas. In 2018, the Junior Academy of Sciences of Ukraine received the status of Category 2 Science Education Center under the auspices of UNESCO and joined the network of Copernicus Academies. The Junior Academy of Sciences of Ukraine has been promoting the application of satellite imagery in education for over ten years. One of the outputs of this activity is the advanced training course for educators. This paper describes the online training course that was held in spring 2021 and 2022. The course was open to all interested teachers. A total of 41 educators from 13 regions of Ukraine have completed the training course in the span of two years. The paper describes the stages of special course organization, topics, and tools used in the lectures and case studies, including an overview of the data sources, such as EO-Browser, ArcGIS Online, Google my Maps, NASA Worldview and Google Earth, etc. The paper presents a detailed description of one of the hands-on case studies of water bodies in EO-Browser. It was established that the conducted special course promoted the educators’ interest in bringing Earth observation to classrooms. Increased number of GIS and Remote Sensing after-school clubs in the territorial branches of the Junior Academy of Sciences (from 1 in Kyiv as of 2019 to 9 in the regions as of 2022, namely in Poltava, Sumy, Volyn, Kyiv, Kirovohrad, Zakarpattia, Lviv, Kharkiv and Chernivtsi) is indicative of the course’s effectiveness.

Keywords: information technology in teaching natural sciences; special training course on fundamentals of Remote Sensing; satellite imagery analysis; Earth observation as big data

1. INTRODUCTION

Information technology (IT) has become an integral part of human life. It is difficult to imagine a modern student who is not familiar with using the Internet, e-mail or social media. However, IT can be used not only for entertainment or communication; it is a powerful

educational tool. Large arrays of data that appear in public access daily contain a wide range of information: from the consumer purchasing power to the carbon footprint of cargo ships, from the state of renewable energy sources in a particular country to musical preferences of specific age groups. This ever-growing array of information that offers a clear view of the true facts, conscious and unconscious market rules, etc., contributed to the very rapid development of the data science discipline. In the natural sciences, Earth observation data collected daily and providing unbiased, multifaceted information about the state of the geographic envelope represent the real-life application of such IT. With this technology, researchers have been able to review environmental data of any territory on our planet for almost 40 years.

Earth observation data gained new significance for the Ukrainians during the full-scale russia-Ukraine war. Satellite images can be used to obtain information about territories inaccessible for research (e.g., temporarily occupied) where aerial photo-reconnaissance cannot be conducted. The Ukrainian army can monitor these territories with access to satellite data provided by international missions, particularly the ICEYE, Maxar and Planet families, etc.

Earth observation data are a valuable source of information not only for military purposes but also for geography (assessing landscape structures, expansion of urban agglomerations, river behaviour, etc.), ecology (monitoring illegal dumping sites and oil pollution of the ocean, evaluating air pollution and deforestations, etc.), physics (studying the ability of objects to reflect and absorb different ranges of the electromagnetic spectrum, monitoring photosynthesis depending on the effects of an infrared range of the electromagnetic spectrum, etc.).

The Concept titled A New Ukrainian School declares the need to develop students' competences in natural sciences, technologies and information and digital competence. Considering the linkage between the natural sciences and technologies such as GIS and remote sensing, the modern teaching process should provide the students with the basic skills to apply these tools and enhance their opportunities to compete in the international labour market. Therefore, the educational community should be made aware of the opportunities offered by these technologies through upskilling courses for teachers.

Remote Sensing (RS) and Geographic Information Systems (GIS) belong to the scientific fields, which have been actively promoted by the Junior Academy of Sciences of Ukraine (hereinafter referred to as the "JASU"). This is driven by the current need for the use of satellite imagery analysis not only in research but also in education. Since the students already use, directly or indirectly, the results of satellite imagery analysis and GIS-based image processing in their everyday life (electronic maps to find the best route, online resources to analyze the current environmental situation of the locality, Google Earth, etc.), and analysis of satellite data gathered by man-made satellites has become an integral part of current research in Earth sciences, therefore, it is necessary to engage RS scientists in teaching science and provide advanced training for the JASU educators in Remote Sensing [1, 2].

To meet the needs of educators in advanced training and to extend the knowledge, the GIS and RS Laboratory of the "Junior Academy of Sciences of Ukraine" National Center (www.facebook.com/groups/CopernicusUA) held the first in Ukraine special online course for teachers, "Fundamentals of Remote Sensing: History and Practice", in the spring of 2021. The course included real-world examples of satellite monitoring projects, implemented in the educational process.

Statement of the problem. The development of any science, including geography, directly depends on the interest and motivation of students to study this discipline at school, university, and in their future careers. The modern world is changing so rapidly that many things that were familiar 20 years ago are becoming less effective and are being replaced by digital analogs. For example, paper maps are losing their importance in everyday life. Nowadays, you rarely see a person using a paper map or guidebook: all the information is available in electronic maps, which are much more convenient and informative. Information technologies such as remote sensing give

geographers access to research that their colleagues could only dream of decades ago. Satellite images allow us to explore any corner of the Earth without leaving our homes. The goal of a school geography course is not to provide students with theoretical knowledge, but to help them define their own role in interacting with both the natural and human-made environment. After all, one of the main tasks of modern scientists is to study the relationship between humanity and the environment and to predict possible consequences. That is why the introduction of such tools as satellite monitoring of the Earth into geographical education will open up new horizons for the study of changes in our globe in the context of today's challenges.

Analysis of recent research and publications. One of the first sources which emphasized the importance of using satellite data in the educational process was “Remote Sensing in Secondary School Geography: the Place of Landsat MSS” article published in *Geography*, the academic journal, in 1985 [3]. According to the authors, despite broad opportunities for Landsat images’ use in UK schools, the integration of this technology into educational practice has been very slow. However, the satellite monitoring used in the few geography courses has proved to be of great educational value, especially for the mapping of landforms and the study of natural phenomena. The authors specify five reasons for including satellite monitoring data in school education, in particular:

(1) Students enjoy using satellite imagery in learning, especially when it is of an area with which they are familiar.

(2) The small scale of satellite imagery allows detailed study of regional links. This may include both the study of certain generalized topics (deserts, glaciers, etc.) and territories (Africa, South America, etc.).

(3) Since Landsat satellites record images of the same area over time, the students can compare them and explore changes on the Earth's surface.

(4) Because data from Landsat imagery is stored in numerical form, it is possible to generate and update georeferenced archives.

(5) The small-scale satellite imagery can be compared in the educational process with paper maps, layouts, atlases, etc.

This paper presents eight possible resources of Landsat imagery that can be used in the educational process, in particular: textbooks, atlases, sets of slides, collections of satellite imagery, videos, posters, calendars, and original negatives [3].

Germany. FIS is the German acronym for the project’s full name, “Remote Sensing in Schools” (<https://www.fis.uni-bonn.de/en/node/22>). FIS Project is run by the Geographic Institute of Bonn University in cooperation with institutions of general secondary education, and funded by the German Aerospace Center (DLR) and the German Federal Ministry of Economics and Energy (BMWi). To ensure easy and effective implementation of remote sensing in schools, digital learning materials have been developed within the FIS Project, which require no installation, except for the Flash plug-in (<https://www.fis.uni-bonn.de/en/node/22>). The official website of the Project presents detailed lessons for teaching the following subjects at school: Biology, Geography, Computer Science, Mathematics, and Physics using satellite data. Successful integration of Remote Sensing into the German education system is described in the works by Voss [4], Hodam [5], Dannwolf [6], Lindner [7].

Poland. The article “Interdisciplinary Teaching Using Satellite Images as a Way to Introduce Remote Sensing in Secondary School” by Polish scientists from Jagiellonian University Medical College and the Space Research Centre of the Polish Academy of Sciences describes the “Colors of Earth” project that combined knowledge from various subjects and enabled its practical application. The educational content of the Project had direct links with basic school curricula, namely Geography (analysis of land cover near the school), Physics (electromagnetic waves), Information and Communication Technology (use of digital data and software), and Biology (human vision). The Project included 39 high-school teachers and 184

high-school students (K-9 and K-10) and was held during the 2019/2020 summer semester. The teachers that participated in the Project taught the following subjects: Geography (9), Biology (8), Chemistry (4), Physics (9), Mathematics (5), and Computer Science (4). Due to the COVID-19 pandemic restrictions, lessons were conducted online. The participants had the opportunity to access Project data and software in advance. All participants were volunteers from various Polish schools. Upon the Project's completion, the educators and students were interviewed. The four major questions used for interviewing the teachers were, namely: 1) What is your opinion regarding the Project? Do you think it might be of any interest to school students? 2) Do you think this Project may be implemented in school? What are the anticipated difficulties? 3) In your opinion, what are the Project's advantages and disadvantages? 4) Can projects of that type influence students' interests and choices with regard to the future field of study? Replying to the first question, 92% of the teachers said that the Project was interesting and might be considered for diffusion into educational institutions. Answering the second question, all teachers agreed that the Project could or should be implemented at schools. Almost half of the educators, however, suggested its use as an additional lesson, rather than part of regular classes. A total of 15 teachers said that computer availability might be a problem, especially with the whole class engaged in the activities. A quarter of teachers expressed concerns about the need to spend a lot of time preparing students to work with the applications. They suggested that the development of detailed instructions for students in advance would make their work easier and more comfortable. The answers to the third question were distributed as follows: the advantages of the Project included students' work with real data (87%), the possibility to adjust the Project to fit regions and areas of interest (79%), the possibility to generate own color maps (64%) and combine knowledge from different subjects (49%). Interestingly, several (18%) teachers noted the last point as the difficulty of the Project. The educators' request for additional educational materials was the most common disadvantage of the Project, as noted by 64% of teachers. Regarding the last question of the interview (Can projects of that type influence students' interests and choices with regard to the future field of study?), 24 educators suggested that this may depend on the class profile and the subjects the students sought to pursue in their future careers. To their opinion, this Project was unable to change the preferences of a student who joined a biochemistry class because he/she intended to study medicine in the future; the Project, however, could change the attitudes of the rest of the class. This is especially true since a high school student knows only a few popular professions, such as a builder, architect, or land surveyor, and is unaware of many others. The most comprehensive answer was given by a Math teacher, "We definitely need to broaden students' horizons. They usually think about mastering the ordinary professions; they know some of the most popular fields only. Any activity like this introduces something new to them and can inspire at least some of them. Of course, not everyone will consider Remote Sensing as a future career but everyone will know that it exists, and that is a lot." [8].

"*YCHANGE*". The objectives of the International YCHANGE Project (Young Scientists as Change Explorers – Students Evaluating Environmental Change in Europe with Digital Space Technologies) were to improve teachers' and students' competencies in using satellite images and support learning of human-environment interactions and monitoring environmental changes based on satellite imagery. This biennial Project was a cooperation of Tallinn University (Estonia), Charles University in Prague (Czech Republic), Heidelberg University of Education (Germany), and University of Applied Sciences and Arts of Northwestern Switzerland (Switzerland). The YCHANGE Project also explored the teachers' self-reported competences in different countries, in particular: What were the teachers' self-reported competences before the training? Did the competences depend on participants' country of origin and native language, in particular across cantons of Switzerland? Did attending the training improve the teachers' self-reported competences in RS? How did teachers see the curriculum,

the sample projects, student projects, web platform, and efficiency of education using RS data? Most participants from all countries stated that they knew little or nothing about the opportunities of using satellite imagery in the educational process. Participants' average competence with regard to environmental changes analysis was rather low, although environmental changes are central to learning Geography. Surprisingly, some teachers from Switzerland self-reported lower RS competences following the training event compared to those before the event, perhaps as a result of new opportunities for RS use identified by the teachers during the training. In Germany, 100% of teachers believed their competences improved after the training course, 100% of respondents said they improved their ability to use satellite images independently, 85.7% of respondents noted that their ability to use satellite images in classroom practice improved, 100% of respondents said their ability to analyze environmental changes improved. The Project organizers also studied open comments made by participants. One of them said, "Google Earth is a very interesting software but I did not learn anything about remote sensing during the lesson", which indicated that the Project participant did not realize that Google Earth is based on satellite images' analysis. Online survey questionnaires used in some of these training courses had relatively low power due to the small sample size but showed some improvement in the teachers' self-reported competences. In general, it appears that the majority of Project participants found materials of YCHANGE Project and training activities beneficial [9].

In addition to the countries discussed above, the use of remote sensing as a tool for teaching science in primary school classes (second and third years of study) in the United States was described by Adaktylou [10]. This study has shown that it is extremely important to have adequate and appropriate resources available, as well as effective support, for the use of remote sensing in educational practice. The effectiveness of remote sensing use in education in Italy [11] and Greece was also discussed by Asimakopoulou [12], Mouratidis [13], in particular in the climate change effects research.

Ukraine. In Ukraine, the application of satellite data in classroom practices is growing [14]. In particular, the Junior Academy of Sciences of Ukraine has been using satellite imagery in its educational activities for more than 10 years. The number of students and teachers wishing to understand the opportunities provided by satellite imagery analysis increases every year. In particular, the "GIS and RS" sections operate in nine regional JASU divisions and offer students a free course on the fundamentals of remote sensing delivered by leading specialists [15]. The Junior Academy of Sciences of Ukraine organizes international and national educational and training events, http://man.gov.ua/ua/activities/akademiiia_copernicus, that aim at attracting and providing training to interested students. The JASU regularly conducts advanced training courses for natural sciences teachers. The outputs of one of such courses are described below.

The research goal. This research aimed to assess the effectiveness of the special upskilling course for educators, "Fundamentals of Remote Sensing: History and Practice", in particular, through expanding the GIS and Remote Sensing after-school clubs at the territorial branches of the JASU, where course participants work. The growth of the network of GIS and Remote Sensing clubs in the JASU was analysed both based on a quantitative indicator: an increase in the number of clubs in the territorial JASU branches, and a qualitative indicator – assessing the course effects on the interest of participants in the further application of these technologies in teaching Earth sciences.

Originality of Research. In Ukrainian out-of-school education, there is an urgent need to seamlessly integrate IT into Earth sciences teaching and learning practices. This need serves as a basis for bringing Earth observation to classrooms. Following the development of educational and methodological materials, including guidance manual, workbook, programme of study and video tutorials, a special course was organized to train and motivate local educators in the territorial JASU branches to become teachers and/or engage in activities of "GIS and

Remote Sensing” clubs in their regions. In the system of Ukrainian out-of-school education, this marks the first upskilling course for educators on the basics of GIS, which laid the foundation for expanding the network of “GIS and Remote Sensing” clubs from the capital to the territorial branches of the JASU.

2. RESEARCH METHODOLOGY

General Background. The special course consisted of 18 online sessions and included lectures and hands-on activities based on the use of EO Browser, ArcGIS Online, Google Planet Earth, Google my Maps, NASA Worldview and other resources. During the course, participants learned how to use the images collected by Sentinel and Landsat family satellites in a variety of research, including climate, hydrology, forestry, agriculture, etc. In particular, the course covered the following topics: detection of consequences of fires, monitoring of volcanic activity, monitoring of water bodies and air pollution, and changes in agricultural lands and loss of forest resources, analysis of the anthropogenic impact of amber mining on landscapes, etc.

The special advanced training course included lectures and hands-on activities. For each topic, a lecture was first given (one hour) accompanied by presentations and followed by an online demonstration (one hour) of a respective case study. The course participants had to independently perform tasks from the workbook, and additional tasks (descriptive or research) and send the results to the course providers for assessment.

Sample / Participants / Group. The audience of the training course included educators of extracurricular and general secondary education institutions, in particular supervisors of natural science clubs and teachers of natural sciences, as well as professors and associate professors of higher educational institutions.

In 2021, 36 participants pre-registered for the special course, whereupon 21 teachers from 11 regions of Ukraine were actually trained. More than half of all participants were experts in the field of geography, the rest – teachers of Ecology, Biology, Chemistry, Physics, Computer Science, etc. Among representatives of higher education institutions, teachers of Astronomy, Meteorology, Land Management, and Land Cadastre, Cartography, etc. took part in the course. The majority of participants (66%), concurrently with teaching, supervised subject-oriented clubs at the following sections of the Junior Academy of Sciences of Ukraine: Environmental Protection and Environmental Management; Geography and Landscape Science; Hydrology; Ecology; Geology; Research in the field of Geography; Climatology and Meteorology; Geographic Information Systems and Remote Sensing, etc. 33% of participants were not JASU employees and took part in the special course for personal purposes, in order to improve their skills. In 2022, a total of 20 participants from 9 regions of Ukraine completed the course.

In addition, four associate professors and two university professors, and one PhD in Geography took part in the training course.

Based on the analysis of the Registration Form data, 80.6% of registered course participants were women, and 19.4% – men. The gender balance changed slightly at the end of the course, in particular, 66.6% of women and 33.3% of men attended all sessions and completed all tasks of the course. The oldest participant at the time of registration was 65 years old, and the youngest – 30 years old. Among all registered participants, 11% were over the age of 60, 16% over 50, 45% over 40, and 28% over 30. That is, summarizing the above age-specific statistics, we can conclude that the majority of participants were educators with 20 years of experience who needed new knowledge in the field of Remote Sensing because they did not receive the appropriate training at universities since at that time this discipline was not widely represented in the educational system. At the same time, 41% of participants had more than 20 years of work experience (in 2022, this figure was 32%) in the field of education (Figure 1).

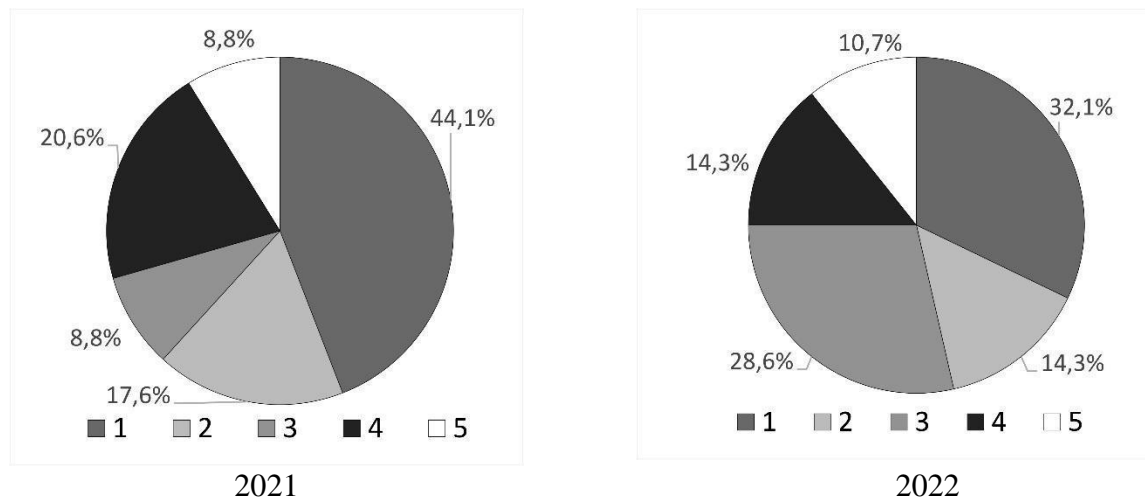


Figure 1. Educational experience of the participants registered for the special courses: 1 – more than 20 years; 2 – up to 10 years; 3 – up to 15 years; 4 – up to 20 years; 5 – up to 5 years

In terms of place of residence, almost all participants were from cities and only 5% from small villages. This can be explained by a better network for informing educators about such events, and high-speed Internet access.

Analysis of the professional profile of the participants shows that more than half of them are teachers of Geography, 14.7% of Ecology and Biology, 5.9% of Physics, 8.8% of Computer Science, 5.9% of Astronomy and Chemistry, 11,6 % are university lecturers in Hydrology, Cartography, Land Management and Cadastre, and Meteorology (Figure 2). Accordingly, we can say that the highest interest in Remote Sensing is seen among the experts in the field of natural science.

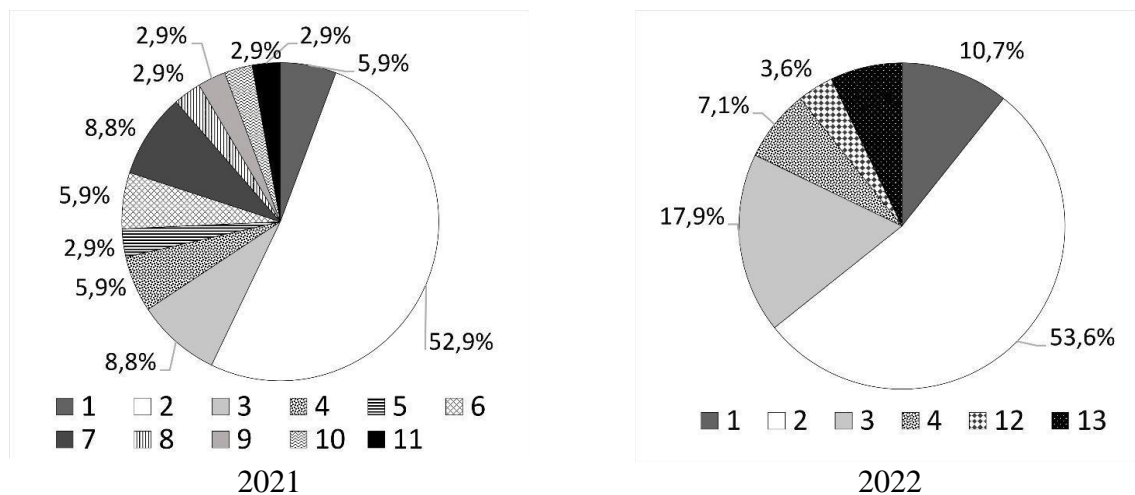


Figure 2. Professional profile of participants registered for the special courses: 1 – biology; 2 – geography; 3 – ecology; 4 – physics; 5 – hydrology; 6 – land management, land cadaster; 7 – computer science; 8 – cartography; 9 – meteorology; 10 – astronomy; 11 – chemistry; 12 – history; 13 – GIS and RS

In terms of the previous participants' knowledge of the fundamentals of RS and experience in the application of satellite data in 2021, at the time of registration for the special course, only 61.8% of participants used satellite images often, and 11.8% of participants have

never used them before. The figure below shows a comparison of these indicators in 2021 with 2022 (Figure 3).

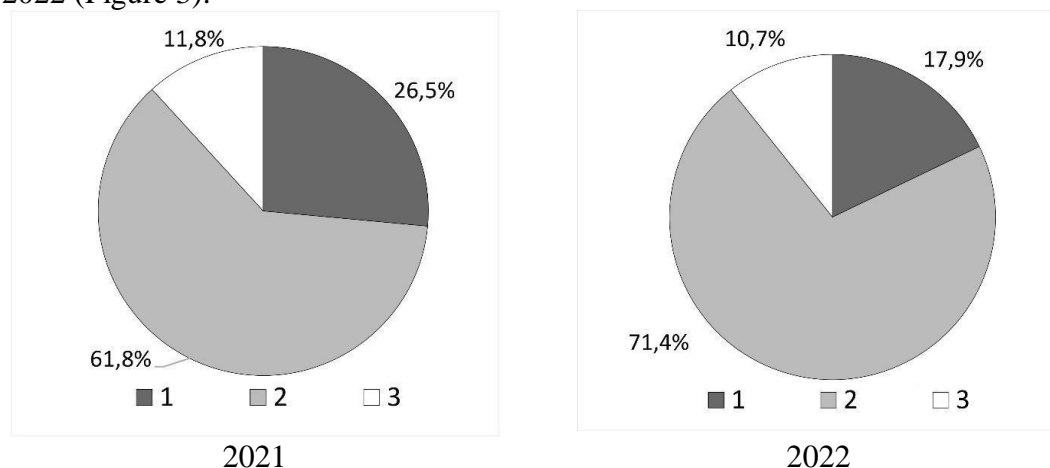


Figure 3. Use of satellite images by participants before the special course: 1 – yes, often used; 2 – yes, used one or more times; 3 – no, never used

The lack of training in Remote Sensing is not limited to Ukraine; it is a global issue that is widespread in the educational systems worldwide. In Europe, there are academic courses, projects, and initiatives related to the use of remotely sensed data that are supported by organizations such as ESA (ESERO Project), Copernicus, ESA Education Programme, etc. However, the educational community of EU countries emphasizes the lack of teaching and learning literature in the native languages for formal and informal school education.

Instrument and Procedures. Since our Laboratory is a part of the Copernicus Academy network (launched under the auspices of the European Commission and the European Space Agency), we focused on freely available/open software and resources developed by the ESA. Therefore, the primary attention in the course was paid to using the EO Browser web platform, which features satellite monitoring data from 1975 to the present. The application of this platform in the educational process is driven by three essential factors, in particular: the Ukrainian-language interface and functionality (developed and regularly updated by the Copernicus Academy of the JASU in cooperation with the Synergise company); an intuitive interface constantly improved by the developers; the integration of certain GIS functionality (area measurement, creating charts, 3D terrain modeling, etc.). We compared the opportunities offered by EO Browser from the ESA with the functionality and content of open NASA tools, such as NASA Worldview, LandsatLook, and Internet resources featuring space images of Earth's surface that reveal the impact of climate change on our planet.

We also used Google's most popular and currently most functional mapping products as a basis, namely: Google Maps, a free web-based mapping service provided by Google, and Google Earth application, which enables viewing detailed satellite images of the Earth's surface, zooming in and out, and building routes. We also introduced the participants to the capabilities of ArcGIS Online, which is the global market leader in educational geoinformation software.

The resources used in the advanced training course are given below. *EO Browser* is a free cloud computing tool for visualization and downloading medium- and low-resolution satellite imagery available at various platforms: Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-5P, Landsat, Envisat Meris, MODIS, Proba-V, GIBS. EO Browser features many functions and makes it possible to compare data, use various parameters of automatic visualization (natural and artificial colors, NDVI, etc.), band synthesis, measure areas, obtain statistics in the form of graphs, and even use some data processing algorithms and scripts. With this application, users can create their own image libraries. Registered users can export data processing results to geo-referenced files

and save image processing algorithms (<https://apps.sentinel-hub.com/eo-browser/>).

Google Earth is a free, open-source program from Google that displays satellite imagery on a 3D globe. Imagery resolution varies from 15 meters for the entire planet (from Landsat 8 satellite) to 15 centimeters for aerial photography of some cities such as Las Vegas, Nevada, Cambridge. Currently, there are two simplified versions of Google Earth app: for browsing the web and for mobile devices, which enables the users to travel the world with a swipe of their finger on a phone or tablet. Google Earth Pro on desktop suits best the users with advanced feature needs. It allows them to import and export GIS data, and go back in time with historical imagery (<https://www.google.com/earth/>).

NASA Worldview is an open source code app from NASA's EOSDIS provides the capability to interactively browse over 1000 global, full-resolution satellite imagery layers and then download the underlying data. Many of the imagery layers are updated daily and are available within three hours of observation - essentially showing the entire Earth as it looks "right now". This supports time-critical application areas such as wildfire management, air quality measurements, and flood monitoring (<https://worldview.earthdata.nasa.gov/>).

With *ArcGIS Online* and *Google My Maps* software users can build interactive web maps, as well as cartographic web services, blocks, stories, and use ready-made resources, publish cartographic services, perform spatial analysis, share data, and access maps from any device.

Research Design. The special training course included:

- information (promotional) webinar to present the special training course; it was held one month before the course start;
- dissemination of information letters about the special training course;
- following the closure of registration for the course, initial testing of registered course participants was held to assess their baseline level of knowledge;
- intensive training sessions (theory and hands-on activities) within the framework of the special course;
- a final closing conference, at which the course participants presented their independent projects developed using the acquired skills;
- final tests to evaluate the course efficiency based on changes in the participants' level of knowledge in the field of remote sensing;
- issue of advanced training certificates for the course participants and provision of participants with learning and teaching support materials;
- interviewing participants in half a year to evaluate the effectiveness of acquired knowledge use in their classroom practices.

The learning and training support materials developed by the authors, in particular, the guidance manual, "Fundamentals of Remote Sensing: History and Practice" [16], and a workbook, "Fundamentals of Remote Sensing" (Part 1) [17], created the basis for a high-quality special advanced training course for teachers.

The subject area of the special training course included the study of the basic concepts and historical development of Remote Sensing, review of opportunities offered by EO Browser, Google Earth Pro and other open sources of satellite imagery, GIS data, and thematic collections of NASA and ESA's Earth observation data that illustrate the effects of climate change (Figure 4). The training course also provided examples of satellite images application during the study of the following topics:

- forest resources;
- water reservoirs;
- agricultural monitoring;
- changes in the urban and anthropogenic landscapes;
- location of landfills;
- development of exogenous processes;

- atmospheric monitoring;
- volcanic activity.

Each topic is organized in the workbook as follows: first, a specific context is given along with a news report about an event under investigation. Then, the task is formulated, which is to investigate the event using the RS data. These are followed by step-by-step instructions for independent performance of the task and several test questions for self-assessment.

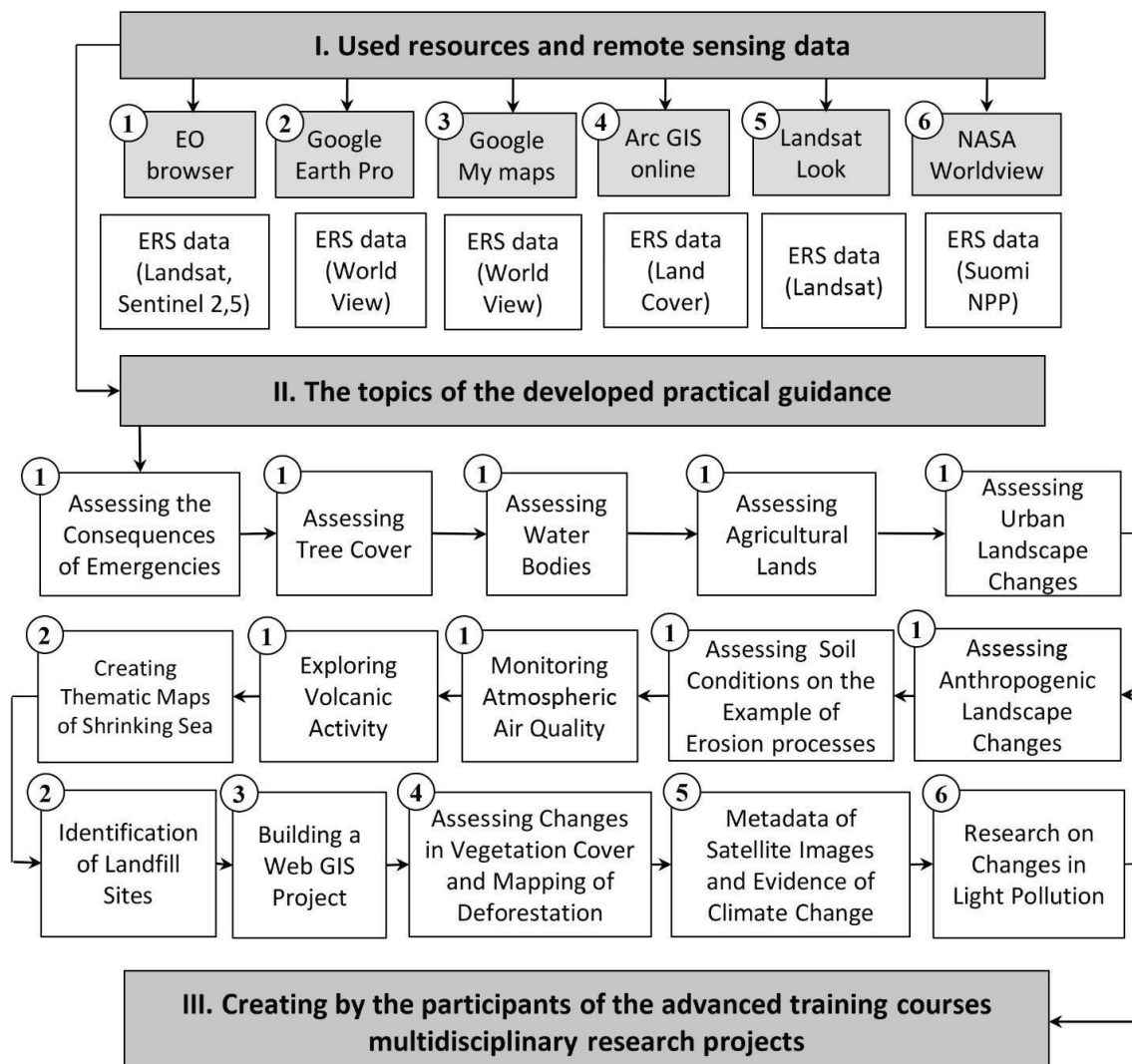


Figure 4. Scheme of thematic areas for researching the environment in geography lessons using satellite images

The example of applied case study. The topic of applied case study: Water body research (on the example of estimation of spring floods dynamics in the north of Kyiv and Chernihiv Region in Ukraine).

Context: The peak of spring floods was observed in Ukraine in May 2013; 9 Regions experienced significant flooding. The most affected was Chernihiv Region. According to media reports, the Director of the Ukrainian Hydrometeorogolocal Center, Mykola Kulbida, said that the maximum water levels on the Desna River, which flows into the Kaniv Reservoir, would be observed on May 15-20.

Task 1: Identify the river of the Kyiv Reservoir where the spring flood began: Desna, Pripyat, or Dnipro; determine the beginning and peak of flooding; calculate the changes in the width of the river channels during the flood.

The step-by-step instructions for performing this task in EO-Browser included the identification of the Dnipro River, selecting a satellite, and entering parameters to search for the images by date and cloud coverage. The following steps were, namely, analysis of the image of the studied area in natural and artificial colors, selection of a suitable bands combination for water body research. The next step was to compare the appearance of the river in the images taken at different times before snow melting, during the flood, and after it. Use of the tools to measure the width of the river channel at different dates (Figure 5).

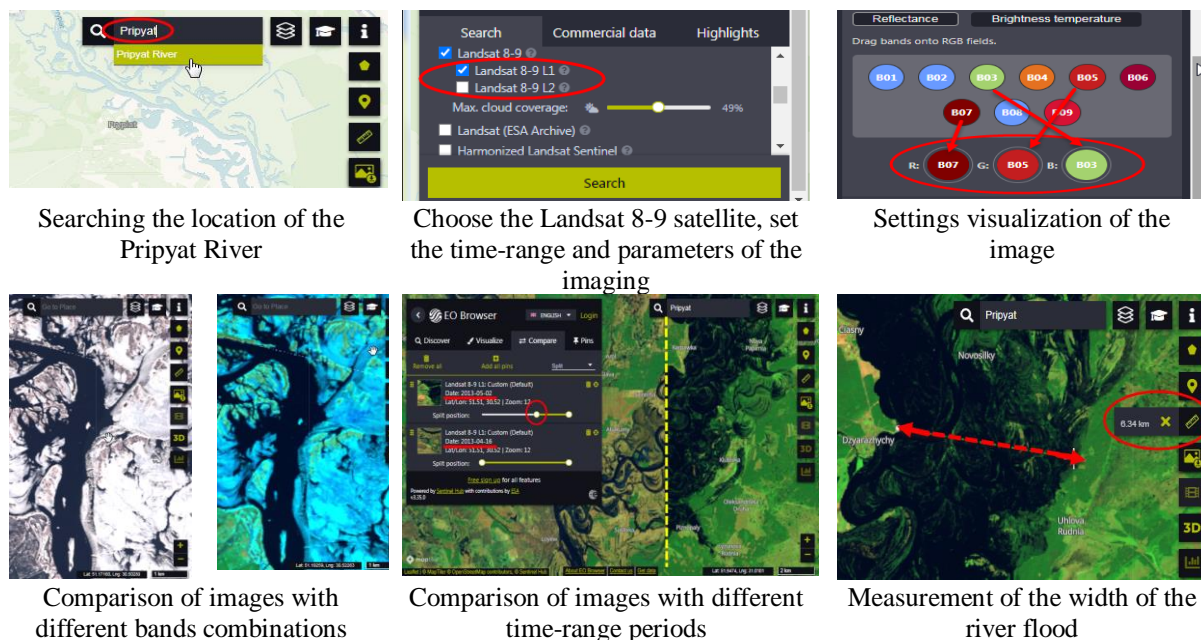


Figure 5. Example of illustrated performance of the first task in the hands-on case study of water bodies: comparison of two images taken at different times (April 9 and May 2) and measurement of the Dnipro River channel width

Questions for self-assessment: Specify what colors identify forests, water bodies, snow, and agricultural fields in different band combinations. Specify the width of the Dnipro River near Slavutytych city (Kyiv Region, Ukraine) in April, May, and June of 2013.

Additional task: Investigate the dynamics of water blooming on the example of the Kyiv Reservoir using NDVI (vegetation index).

The step-by-step instructions for this task included the search for the image of the Kyiv Reservoir in summer for identification of the areas of water blooming and analysis of the vegetation index of this area and generation of a histogram for NDVI change at a particular location of the highest water blooming over three months.

Data Analysis. The results and effectiveness of the advanced training course for educators, “Fundamentals of Remote Sensing: History and Practice”, were assessed in two surveys and an interview. The first survey was conducted at the time of participants’ registration using the Google Forms service to understand the participants’ initial level of knowledge and determine their range of interests. Immediately after the end of the training course, a final survey was held, which goal was to check whether the level of participants’ knowledge in fundamentals of remote sensing increased and reveal the disadvantages and advantages of the course and its organization. In six months after the course completion, the participants were interviewed to collect their opinions and analyze how effectively they were able to use the acquired knowledge in the classroom practice.

3. RESULTS AND DISCUSSION

Below are the results of the surveys and interviewing of participants of the special training course, “Fundamentals of Remote Sensing: History and Practice”.

When replying to the question, "What do you think is the most difficult in mastering the techniques of satellite imagery processing?", more than half of the participants stated the lack of appropriate education in the processing of satellite imagery (Figure 6). This is a logical conclusion since we have already mentioned above that many participants did not receive an appropriate education at universities. In addition, 17.6% of participants pointed to outdated technical equipment. We received the same percentage of answers to this question in 2022.

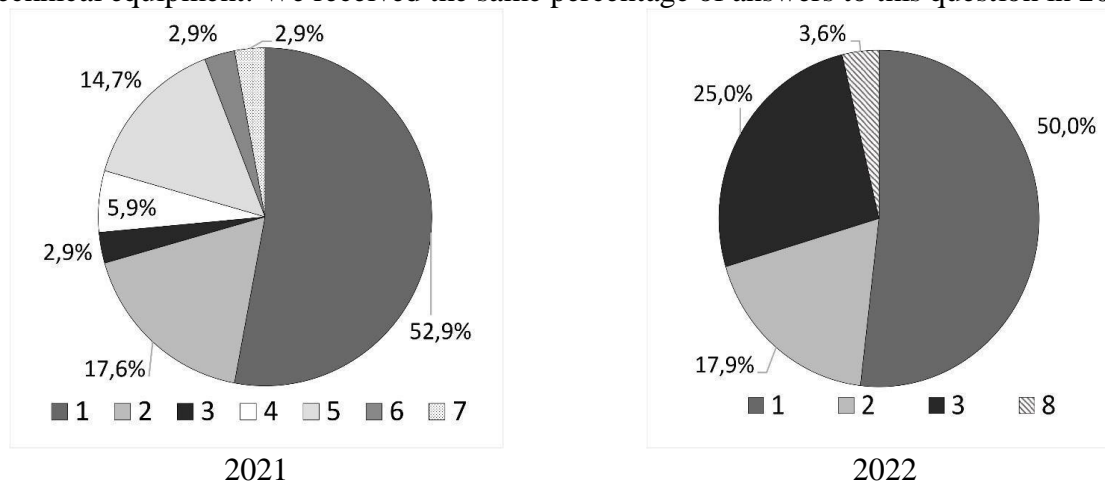


Figure 6. The reasons for the difficulties in using Remote Sensing techniques in education: 1 – lack of appropriate education of satellite imagery processing; 2 – outdated computer hardware/software; 3 – complex algorithms for operating with satellite data; 4 – difficulty to answer; 5 – the unclear purpose of using new techniques in education; 6 – no difficulties; 7 – English language program interfaces; 8 – difficult to get new skills

When replying to the question, “What areas of research are you interested in?”, the majority of participants mentioned landscape science, hydrology, climatology and ecology, etc. Geology, soil science, and programming evoked less interest (Figure 7).

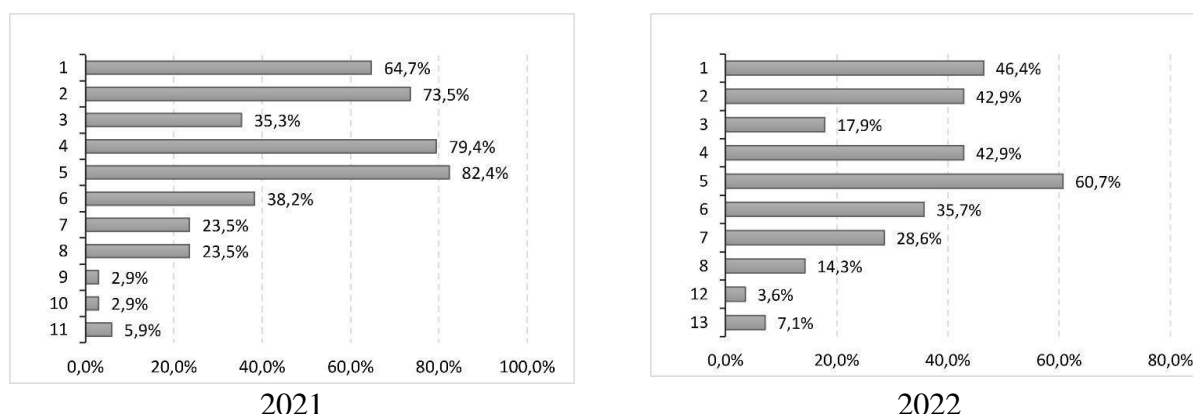


Figure 7. The most interesting research areas for the participants of the advanced training course: 1 – landscape science; 2 – hydrology; 3 – geology; 4 – climatology and meteorology; 5 – ecology; 6 – soil science; 7 – biogeography; 8 – programming; 9 – astronomy; 10 – social geography; 11 – physical, human geography; 12 – urban planning; 13 – consequences of military operations

Upon completion of the special course, we held another final survey, which became the basis for drawing the following conclusions. Due to the intensive and busy two-week training schedule and a large amount of new information, many participants (23.8%) still experienced difficulties and had to spend a lot of time on the activity, 38.1% of participants said that they experienced difficulties with tasks only from time to time, 28.6% said that the tasks were not difficult but required some time (Figure 8). Accordingly, we found it necessary to divide the special course into two parts with a weekly break.

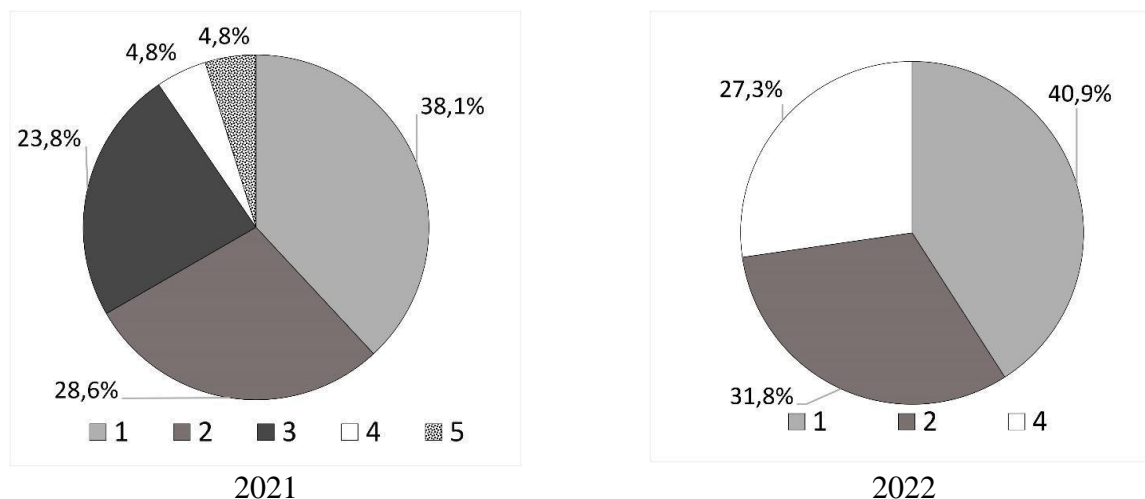


Figure 8. Analysis of the complexity level of the advanced training course: 1 – sometimes difficult; 2 – not difficult but time-consuming; 3 – difficult and time-consuming; 4 – in general, everything is quite simple, a task fulfilled required less than one hour; 5 – have to use additional information from other sources

Upon completion of the course, the participants shared their opinions on the educational disciplines in which it is advisable to use satellite images. Here are some quotes from participants:

- "For almost all topics in Geography course, even in History classes";
- "Inland waters and water resources, soils and soil resources, lithosphere and relief, ways of depicting the Earth";
- "Terrain forms, air mass circulation, and interaction of a man and nature";
- "Insight into the shape of the Earth – the 6th year of study. Map. Topographic map – the 8th year of study, etc.";
- "Physics (electromagnetic waves, atmospheric motion), Ecology (pollution, soil changes, etc.), Biology (vegetation indices), Geography (urbanization, mapping)";
- Chemistry classes: 7th year of study – "Oxygen. Oxidation and Combustion Reactions. Conditions of Fires Occurrence and Extinction", 11th year of study – "Oxides of Non-Metals. Their Content in the Air".

Finally, 92% of participants expressed a desire to join the next special course, "Analysis of Satellite Images in Geographic Information Systems" [18, 19], and mentioned marine research, predicting mineral deposits, studying swamps, reclamation systems, assessment of soil moisture, ice cover, etc. among the areas of their interest which were not covered by the special course program.

In six months upon completion of the special course, we conducted another survey of participants in the form of an interview to establish and analyze how effectively participants used the acquired knowledge in their classroom practices.

During the survey, participants answered eight questions. The list of questions and

analysis of responses are given below:

(1) How often have you used EO Browser for personal purposes and in classroom practice? The majority of participants replied to this question that they used satellite technology in the educational process. In particular, a teacher from the Kyiv Lyceum said that she used teaching materials developed by the Laboratory for the special course as illustrations to the teaching certain topics, including amber mining, and also during review lessons, where she explained to the students why the remote sensing is important. In higher education institutions, teachers used satellite-based monitoring of the Earth more in research than in educational activity, which is primarily due to the fixed educational program, which is difficult to amend; however, teachers successfully applied the acquired knowledge while supervising the students' diploma and masters' degree theses.

(2) What is the feedback from school and university students regarding the use of satellite images in training? According to teachers, in the previous academic year, students have not yet started applying satellite images everywhere, but this year they have agreed to participate in the JASU competitions. Certainly, students are more receptive to such information than teachers since they are well motivated and clearly understand why they need it in the future. In the Kherson Lyceum, thanks to the teacher who is well acquainted with remote technologies, students have already been able to write four scientific papers using remote sensing tools and present them at regional competitions in Ukraine and abroad.

(3) Have you already applied the acquired skills and knowledge in academic courses/subjects? In school practice, the surveyed participants applied the acquired knowledge in the study of anthropogenic impact on nature during the 5th and 8th years of study, in the project studies, and in the technical lyceum at Physics classes when studying the satellites. In university work, the acquired knowledge was used to write master's theses on ecological network research, monitoring the water protection zones, etc.

(4) What knowledge you were lacking to apply remote sensing in your classroom practice? According to teachers and educators, they would like to master professional GIS programs to analyze satellite images in GIS and to connect existing mapping servers with remote sensing data. Another teacher from a Transcarpathian school noted that the lack of knowledge in information technologies and a low level of English language hindered the learning process.

(5) During what classes (lessons/disciplines) it is useful to apply remote sensing? According to teachers, aerospace data can be used at Geography classes in school during 5th - 11th years of study without any restrictions in any curriculum subject as a universal tool, and also in higher educational institutions in master's theses on various themes. In particular, a teacher from the Kherson Lyceum noted that "... having a sufficient level of knowledge in remote sensing technologies, I would first expand my own understanding of GIS and start creating my own GIS project."

(6) Do you need a refresher course related to the same resources or an advanced course? Almost all participants answered that they needed an advanced special course to combine GIS and RS.

(7) Did you use the acquired knowledge to organize/supervise students' research activity, including that at the JASU? All participants of the special course said they planned to manage students' research activity using remote sensing technologies during this academic year.

(8) Would the course help to launch the relevant section at your regional JASU's branch? Participants unanimously confirmed that this course provides for the appropriate level of knowledge and the opportunity to supervise the relevant section, which some of the participants have already successfully implemented, or wish to implement in the future.

Discussion. Satellite observation acts as an integrating research tool in science education because the analysis of satellite images enables studying such disciplines as Geography,

Ecology, Biology, Physics, Mathematics, Computer Science, etc. The key topics proposed for the training courses for both teachers and students included climate change and the study of its impact on nature and mankind. These topics are focused on improving students' climate literacy, which is now critical to rethinking the role of a man in the ecosystem, and to human survival in general. We also believe that individual research (participants freely choose the topics) is an important component of the educational process, which should be mandatory for both teachers' refresher courses and students' education. The teachers can deepen their knowledge of a subject of their interest and get new visual materials using remote sensing tools, while the students have the opportunity not only to gain new knowledge but also to improve research skills. In addition, we suggest that participants choose a research topic relevant to the territory where they live, as this increases individual interest in the research process and creates the preconditions for real action to improve the environmental situation in their localities.

4. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

Evaluation of training effectiveness showed that a special upskilling course for teachers, "Fundamentals of Remote Sensing: History and Practice", is a powerful approach to raising awareness of Remote Sensing capabilities, which promotes the interest of teachers and lecturers in using satellite imagery in the educational process. In particular, this course helped its participants expand the GIS and Remote Sensing after-school clubs network at the regional branches of the JASU. In 2019, before the launch of the special course in Ukraine, there was one GIS and Remote Sensing after-school club in Kyiv (Kyiv Branch of the JASU). At the end of the first year of the special course training programme, three GIS and Remote Sensing after-school clubs were established in Lviv (Lviv Branch of the JASU) and Uzhhorod (Transcarpathian Branch of the JASU). By the end of the second year of the basic-level upskilling courses, eight participants out of 41 became supervisors of the students' research projects in this field, which entered the Final Round of the All-Ukrainian Research Projects Competition for JASU members in 2022. Accordingly, the GIS and Remote Sensing after-school clubs were established in nine regions in 2022 (Poltava, Sumy, Volyn, Kyiv, Kirovohrad, Zakarpattia, Lviv, Kharkiv and Chernivtsi).

The following arguments can be used to summarise whether the special course influenced the participants' interest in further studying these technologies. According to the final survey data, 92% of the special course participants would like to improve their knowledge in the RS fundamentals through the analysis of satellite images in QGIS, so we have ordered such a course ("Analysis of Satellite Images in GIS") although its effectiveness has not yet been determined through interviews and questionnaires. Upon completing the basic course in 2021-2022, more than half of the participants (53%) continued their studies at the next intermediate-level special course. Of all participants, 70% were the Junior Academy of Sciences employees, of which 66% have completed both levels of remote sensing course (basic and intermediate).

Despite the current challenges, such as quarantine and the full-scale phase of the Russia-Ukraine war, 21 participants completed the basic-level special course in 2021, 20 participants in 2022, and 19 are currently studying.

The application of information technology, such as GIS and Remote Sensing, in science education, is driven, on the one hand, by the need to develop students' competence in natural sciences and technologies, as well as information and digital competence. On the other hand, the current conditions of the educational process, which is mainly arranged remotely, encourage the academic community to master quickly and effectively Internet resources and web platforms featuring remote sensing data instead of temporarily inaccessible (and dangerous) field research.

Special course for educators has many unique features. In particular, to achieve the main goal,

i.e. application of knowledge gained during special courses by teachers in their educational practice. Therefore, the course should be practice-oriented and close to the school curriculum. The relevant events and processes, services, and research tools selected for monitoring should be freely available using an intuitive interface. These principles laid the foundation for the arrangement of the course, “Fundamentals of Remote Sensing: History and Practice”. Another important result of the special course is that most of the participants were empowered to implement the acquired knowledge in the educational process and expressed a desire to lead the relevant GIS and RS groups and sections at their educational institutions.

Visual support also has a significant impact on the quality of the educational process, so one of the promising areas for improving special course is the production and release of short thematic videos about satellite monitoring of certain phenomena or processes using remote sensing tools.

In terms of prospects for further activity, it is worth noting that to upskill educators, we have developed a three-level Programme of study, which includes guidance manuals, workbooks and video tutorials for each level. In particular, the Programme’s first level, “Fundamentals of Remote Sensing: History and Practice”, covers basic concepts of remote sensing and examples of Earth satellite monitoring use in various disciplines. The results of this basic-level course have been described in the present paper. The next intermediary-level course of the Programme, “Remote Sensing: Analysis of Satellite Images in Geographic Information Systems”, contains the basic concepts of geographic information systems and satellite data processing in GIS. Upon completing the basic-level course, most participants decided to take the next course to deepen their knowledge. We are currently developing the third advanced-level course, “Fundamentals of Remote Sensing: Processing and Analysing Satellite Images in Google Earth Engine”. This course will cover the analysis of satellite imagery using Google Earth Engine cloud service, providing free access to more than 40 petabytes of remote sensing data.

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ДОСВІД ВИКОРИСТАННЯ ДАНИХ СПОСТЕРЕЖЕНЬ ПЛАНЕТИ ЗЕМЛЯ ДЛЯ ПІДВИЩЕННЯ КВАЛІФІКАЦІЇ ОСВІТЯН У МАЛІЙ АКАДЕМІЇ НАУК УКРАЇНИ

Довгий Станіслав Олексійович

доктор фізико-математичних наук, професор, академік НАН України, академік НАПН України,
президент Малої академії наук України, м. Київ, Україна
ORCID ID 0000-0003-1078-0162
gis_rs@man.gov.ua

Бабійчук Світлана Миколаївна

кандидат педагогічних наук, завідувачка лабораторії «ГІС та ДЗЗ»
Національний центр «Мала академія наук України», м. Київ, Україна
ORCID ID 0000-0001-6556-9351
brevus.lana@gmail.com

Томченко Ольга Володимирівна

кандидат технічних наук, науковий співробітник
Державна установа «Науковий центр аерокосмічних досліджень Землі ІГН НАН України», м. Київ,
Україна
ORCID ID 0000-0001-6975-9099
olhatomch@gmail.com

Анотація. У статті наведено передумови та результати проведення перших в Україні курсів підвищення кваліфікації педагогічних працівників з основ дистанційного зондування Землі – «Основи дистанційного зондування Землі: історія та практичне застосування», організованих лабораторією геоінформаційних систем та дистанційного зондування Землі Національного центру «Мала академія наук України». Мала академія наук України - це позашкільна освітня система, яка розробляє та впроваджує методи наукової освіти. Нині в Академії навчається понад 250 тис. студентів, які працюють за 64 науковими напрямками. У 2018 році Мала академія наук України отримала статус науково-освітнього центру другої категорії під егідою ЮНЕСКО та приєдналась до мережі Академій Коперника. У Малій академії наук України питанням впровадження аналізу супутникових знімків в освітній процес науковці займаються більше десяти років. Одним з результатів цієї діяльності є курси підвищення кваліфікації педагогічних працівників. Курси, які описані в цій статті, проводились навесні 2021-2022 років у режимі онлайн. Долучитись до курсів могли всі охочі освітяни. За два роки курси пройшли 41 педагогічний працівник з 13 областей України. Описано етапи організації спецкурсу, тематику та інструментарій, на базі якого були побудовані лекційні та практичні заняття, зокрема огляд використаних ресурсів, як-от: Eo-browser, ArcGIS Online, Google my Maps, NASA Worldview та Google Планета Земля тощо. Подано розгорнутий приклад однієї з практичних робіт спецкурсу на тему «Дослідження стану водних об'єктів в Eo-browser». Встановлено, що проведені спецкурси сприяли зростанню інтересу освітян до використання матеріалів супутникової зйомки в освітньому процесі. Показником ефективності розробленого спецкурсу є розширення мережі секцій ГІС та ДЗЗ у територіальних відділеннях МАН від однієї секції у Києві станом на 2019 рік до дев'яти секцій по областях станом на 2022 рік (Полтавська, Сумська, Волинська, Київська, Кіровоградська, Закарпатська, Львівська, Харківська та Чернівецька).

Ключові слова: інформаційні технології в природничій освіті; спецкурс з основ дистанційного зондування Землі; хмарні сервіси з аналізу супутникових знімків; матеріали спостереження Землі як великі дані.

