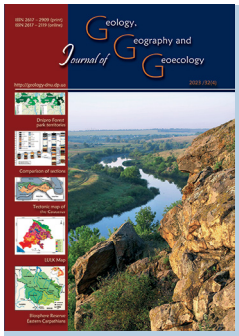

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Innovation and digitalization in environmental education: the case study of climate change adaptation and analysis of land surface temperature

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Abstract. The purpose of the article is to present the research results on the land surface temperature change in the frame of the Educational and Professional Program «Ecology and Environmental Protection» developed at the Department of Environmental Sciences at National Aviation University, where the importance of the development of education in the noosphere paradigm is emphasized, as the most integral bio-adequate basis for the interaction of society and the environment in the conditions of today's challenges. The climate's change and the land surface temperature, as an integral part of it, are highlighted to tackle the environmental challenges including those connected with the warfare activities in the country. Development of the remote sensing technique within the framework of the Educational and Professional Program provides students with the opportunity to perform the environment changes assessment due to long-term anthropogenic stress, and also acquire knowledge and skills from the new course of «Adaptation to Climate Change», introduced to strengthen the ability to survive and effectively work and study in conditions of global climate change. The land surface temperature assessment is considered on the examples of the highly technologically loaded areas within the central part of the Ukrainian Shield, in particular the mining area and thermal power plant. Land surface temperature is one of the key features that could represent environmental changes caused by anthropogenic influence, for example, urbanization. It makes land surface temperature an appropriate Earth's attribute that combines remote sensing and environmental sciences in the sense of environmental education. It is clear, that its influence on environment is intuitive for students and it could be represented using geoinformation systems. Land surface estimation is still a challenging task for non-specialists but its ecological significance makes land temperature mapping useful and important in environmental education.

Key words: global temperature changes, transformation of environmental education, adaptation of educational programs, digital competences.

Інновації та цифровізація в екологічній освіті: формування компетентностей з адаптації до зміни клімату та аналізу температури поверхні землі

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Анотація. Метою статті є представити результати досліджень зміни температури земної поверхні в рамках освітньо-професійної програми «Екологія та охорона навколишнього середовища», розробленої на кафедрі екології Національного авіаційного університету, де наголошено на важливості розвитку освіти в ноосферній парадигмі, як найбільш цілісної біоадекватної основи взаємодії суспільства та довкілля за умов викликів сьогодення. Зміна клімату та, як невід'ємна її складова, зміна температури земної поверхні, визначені з метою подолання екологічних викликів, включаючи ті, що пов'язані з бойовими діями в країні. Розвиток методології дистанційного зондування в рамках освітньо-професійної програми надає студентам можливість здійснювати оцінку змін навколишнього середовища внаслідок довготривалого антропогенного впливу, а також набувати знань і навичок з нового курсу «Адаптація до кліматичних змін», запровадженого для посилення

можливості виживання й ефективної роботи та навчання за умов глобальних кліматичних змін. Розглянуто оцінку температури земної поверхні на прикладі ділянок у межах центральної частини Українського щита, які зазнають високого техногенного навантаженн, зокрема, гірничодобувного району та району впливу теплоелектростанції. Температура поверхні землі є однією з ключових характеристик, яка може відображати зміни навколишнього середовища, викликані антропогенним впливом, наприклад, урбанізацією. Це робить температуру земної поверхні відповідним атрибутом Землі, який поєднує дистанційне зондування та науки про навколишнє середовище в розрізі екологічної освіти. Зрозуміло, що цей вплив на навколишнє середовище є інтуїтивно зрозумілим для студентів і його можна відобразити за допомогою геоінформаційних систем. Оцінка поверхні землі все ще є складним завданням для неспеціалістів, але її екологічне значення робить картографування температури землі корисним і важливим для екологічної освіти.

Ключові слова: глобальні температурні зміни, трансформація екологічної освіти, адаптація освітніх програм, цифрові компетентності.

Introduction

This presented article summarizes pedagogical experience, which brought together specialists in various branches to find ways how to transform current approaches in teaching the environmental disciplines in higher education for the declared sustainable, balanced, environmentally friendly society. It is a continuation of previously published paper, presenting the author's approach to the dissemination of knowledge about the integrity of the world, consciousness, and culture in general; the importance of a sustainable, environmentally safe, environmentally friendly, harmoniously developed balanced society (Dudar et al., 2022).

The environmental science has gone through several stages of development, which reflect its evolution from a narrow branch of biology to a separate field of biological sciences and expansion under the pressure of human industrialization and consumerism to a group of sciences, covering among all environment protection and restoration (Anjarwati et al., 2018). With the arrival of new digital era, the environmental sciences were among the first to encompass opportunities and analytical tools provided by communication and information technologies.

The need in globally «getting greene» (getting through the process of ecologization) is widely recognized by academicians in numerous publications (Radomska, 2021, Saienko, 2020) and should cover all spheres of life, starting with the existing education systems. From this position introduction of environmental issues is considered an element of innovation in teaching wide range of specialties from engineering to political sciences (Feszterova & Jomova, 2015). Both students and educators perceive elements of environmental education in their professional courses as relevant and important, which is seen from the reported survey results for many countries – Great Britain, Malaysia, Nigeria, Canada, Romania, China, and Turkey. However, the need to implement elements of innovation in the educational process is also valid for the students of Environmental Science and Engineering. Thus, new approaches to studying the well-known environmental problems and introduction to newly appearing environmental issues are a must for training environmentalists if to provide them with high-quality and competitive education.

As an integral part of environmental education and innovative element, in parallel with traditional laboratorial research activity (Kovalenko et al., 2023), we would like to emphasize here a systematic introduction of digital technologies, in particular, remote sensing techniques in educational and research process of environmentalists training within the framework of educational and professional program (EPP) «Ecology and Environmental Protection». The specific focus is made on the land surface temperatures (LST) as a new approach to develop students' awareness and competencies about the climate change present-day challenge.

In previous research we have generally overviewed and characterized the peculiarities of our educational and professional program (EPP, taught in English) «Ecology and Environmental Protection» (Dudar et al., 2022). In the frame of this EPP, we have considered the case study of landscape change assessment and its importance for the united territorial communities and their management. This time we are supposed to emphasize the issues of climate change adaptation and land surface temperature changes to tackle with the environmental challenges especially those connected with the warfare activities in the country. Both issues are an integral part of the joint research topic of «Restoration of ecosystems disturbed as a result of warfare actions and other anthropogenic impacts», which was registered under No 0123U101252.

Material and Methods

In the landmark work (Chiras, 2004), the process of environmental science development as a progress of the research problems formulated and solved, was described by the author: from fragmented to comprehensive symptoms-oriented approach to organi-

zation of environmental protection, and then from fragmented to comprehensive root-level system approach. The same way the first two stages tackled the existing problems by removing and mitigating their visual manifestations with the «end-of-pipe» controls. In the next phase, scientists and practitioners started to work with the reasons of problems, trying to find means of avoiding them. Of course, there is much under way to reach full third stage, but paying attention to the roots of problem is much more promising. The reasons for slow progress are diverse, including lack of personal and governmental will to transform conventional practices, low awareness about the possible solutions, and persistent resistance of business entities, to protecting their profits. But the underlying reason is often the lack of in-depth understanding of the problems. Nature is the most complicated research object and authentic knowledge of its regularities can be received only by collecting and analyzing immense volumes of data. This task cannot be accomplished without digital tools, which substitute man in doing multiple technical tasks, and without remote sensing, which sets clear connection with the location of environmental data and increases the level of information received and processed from local to global level. An efficient professional of an environmental profile must possess a broad perspective of the interactions between natural and anthropogenic phenomena in terms of their causative connection and spatial distribution.

Environmental students have to be provided with the knowledge and skills necessary to understand the impact of global climate change on the global environment, on the one hand, and various sectors of human life, on the other, and to be able to work for developing measures on an adaptation of living organisms and humans to climate change. They have to be familiar with theoretical concepts of global climate change, its consequences for the future, national policy on adaptation to the expected processes in the domestic economy and the economies of different countries of the world, and opportunities and obstacles on the way to the implementation of these measures.

Thus, the paper **aims** to present relevant case studies, demonstrating the benefits of implementing digital technologies in the education of students pursuing degrees in Environmental Sciences, not only as a means of study but as an innovative method to explore human-induced problems in nature, their roots and drivers.

Among **the tasks put into consideration**, the following were prioritized: justification of the importance of further development of environmental education in the noosphere paradigm; analysis of digital and remote technologies on a specific case study and their role in modern environmental education.

As to **methods of research**, mainly used a theoretical-logical and historical-methodological analysis of the provisions and concepts of noospheric teaching, as well as a conceptual synthesis of philosophical, psychological-pedagogical and sociological literature, current curricula, programs, textbooks, scientific works, monographs, digital technologies, in particular, methods of remote sensing of the Earth, modeling of the content of environmental education in higher education institutions/universities using digital and remote technologies.

The **practical value** of the presented research lies in the possibility of using the generalizations obtained by the authors regarding the long-term modeling of environmental education in the domestic higher education; practical use of the experience of the teaching staff of the Department for other HEIs in modern conditions; development of curricula, programs, manuals for the dissemination of knowledge about the integrity of the world, noospheric ethics, thinking, worldview, consciousness, culture as a whole for the development of a sustainable, ecologically safe, ecologically clean, harmoniously balanced society.

Digital Technologies in Educational and Professional Program «Ecology and Environmental Protection».

An integral part of environmental education, developing within the framework of the noosphere paradigm, is the systematic implementation of digital technologies in the educational process (Abid et al., 2022, Hodaňová et al., 2020, Lewin et al., 2019, Male, 2016). This issue became especially acute with the onset of the pandemic in 2020 when digital technologies became an urgent need at all levels of education.

Undoubtedly, traditional teaching methods, the use of which involves attending lectures, laboratory, practical and seminar classes, working with literature, remain an important component of environmental education. At the same time, the system of modern environmental education must be flexible and quickly adapt to global changes in the biosphere and society, which successfully enable the implementation of digital technologies.

The key components of environmental education digitalization process are:

- acquisition and constant expansion of digital competencies by professors and teaching staff;
- development and improvement of students' digital competencies;

- hardware and software support of the educational process;
- creation of a unified information environment in a higher educational institution.

The basis of an effective educational process using digital technologies in the teaching of environmental disciplines is a complex combination of:

- use of specialized software necessary to solve environmental problems;
- use of web services for online classes;
- use of digital communication between a lecturer and a student.

Qualified specialists in environmental sciences, in addition to highly specialized professional competencies, must have skills in working with the following software:

– ArcGIS – for working with geodata, which allows studying the state of the Earth's surface, surface water, and air-based on satellite images and thematic maps;
– MathCad, MathLab, Maple, Origin Pro, Excel – for mathematical data processing and modeling of environmental processes.

Common services for online learning are services on the Google platform, namely Google Meet and Google Classroom, but these tools can serve only as a basis for the learning process using digital technologies that allow conducting classes and monitoring knowledge.

Our department uses ArcGIS, Excel, MathCad software in practical classes.

For the maximum efficiency of the educational process and students' assimilation of the material, the use of these tools can be combined with the use of monitor screen capture technologies and video hosting tools. An example of screen capture software is Bandicam, which allows us to save video from the monitor screen in available video formats. Uploading videos to YouTube's hosting site will allow students to access videos at any time of the day from anywhere in the world.

Viber and WatsApp are currently the most popular digital communication tools available. It is best to use Telegram because this product has such advantages over others as the security of correspondence, the speed of operation, and the ability to download large amounts of data.

Thus, taking into account the complex economic, socio-political, and epidemiological situation in Ukraine and the world, to ensure the maximum flexibility of the environmental education system, available digital technologies must be systematically integrated into the educational process.

Results

Climate Change is an educational field and research problem in Educational and Professional Program «Ecology and Environmental Protection».

Environmental issues are frequently considered as a part of educational content for non-environmental professionals. Even though we realize that there is no profession, that is out of the environmental context, there is a clear distinction between the content of study for environmentalists and all other specialists dealing with the use of nature. This is especially true in the case of global environmental problems, which can affect all spheres of human activity and therefore must be integrated into the educational content of all students. Furthermore, environmental components must be tailored according to their major, which defines the list and forms of global environmental problems effects they will have to face in their professional activity. Such an overarching problem is global climate change, which has already grown to the level of everyday concern for people in the developed world. Thus, the survey for the World Economic Forum including the United States, Canada, Malaysia, South Africa, Turkey, Thailand, and Indonesia, showed that more than half of all adults surveyed (56%) say climate change has already had a severe effect in the area where they live. More than seven in ten (71%), including a majority in every single country, expect climate change will have a severe effect on their area over the next 10 years (World Economic Forum, 2022).

At the same time students of the «Ecology and Environmental Protection» consider climate changes deeper and along multiple vectors. For non-environmentalist's climate changes are disclosed in the form of factors, affecting the «rules of the game» in their future profession and are taught with the primary purpose of raising awareness. In contrast, future environmentalists have this problem as a research field and point of professional skills application.

The relations in the system of «environment-human» are extremely dynamic and raise new challenges every day (Scharlemann et al., 2020). The integral competence of environmentalists, set by the State educational standard is formulated as the ability to solve complex specialized tasks and solve practical problems in the field of ecology, environmental protection, and balanced nature management, characterized by the complexity and uncertainty of conditions (Standard of Higher Education: first (Bachelor) level, 2018). This is especially the case for climate change and thus it represents the perfect educational context

for learning and mastering the necessary skills. Following this dynamic system on the example of climate change provides students with an invaluable experience to react to constantly changing demands (Pharo et al., 2012). These knowledge and skills are universal and help work in any professional field, since they basically mean developed creativity, ability to adapt and manage critical situations.

Climate changes could be mitigated and adapted to only via multilateral dialog between representatives of diverse backgrounds and thus its study contributes to the development of abilities to cooperate with various specialists and communicate information to very mixed audiences. Moreover, students can see how many of the offered solutions are implemented and analyze the obtained results, since multiple stakeholders are working under this umbrella problem.

The same standard defines that environmentalists must also possess skills of conducting research, which makes climate change ideal platform developing these set of competencies: it is so wide and fluid, that offers new research inquiries faster than we even realize and it gives objects for observations just around us. However, the amount of information about climate change available now has already gone out of the range, possible for one person to learn over a lifetime. Accounting this, studying climate changes should be based on the case-study principle and application of innovation research and learning tools, as it will extract the most effective approaches to dealing with the problem at local level and will accelerate the work and open the way to international research arena.

Digitalization of research and educational activity of students with the land surface temperature analysis.

The problem of climate change offers a broad field for educational activities, but is overwhelming with information, provided by extensive international research efforts. In order to provide students with an operative understanding of the situation and the ability to make decisions accounting climate issues there is a need to demonstrate the sources of concerns, raised by climate changes, and suitable methods of data acquisition. The ability to manage immense arrays of information is also an important skill, based on the use of digital tools. The most suitable field to form corresponding competencies is remote sensing, in particular, land surface temperature (LST) analysis. The LST is a valuable parameter for the analysis of energy flows between surface and atmosphere, able to demonstrate the physical grounds of the climate changes to the students. In turn, remotely sensed thermal data give the most complete LST estimation over large areas and their daily fluctuations (Duan et al., 2017). It is also an important framework for understanding anthropogenic component of the green-house effect, driving imbalance in the Earth climate system: measurable changes in LST clearly reflect anthropogenic effects and contributions. At the same time LST data are a subject for validation since they are not received directly, but represent a product of processing. The methods of retrieving information about temperature from satellite images and their verification is done using a variety of approaches with different level of reliability (Hulley et al., 2019). As such it is a perfect basis for practicing and forming valuable student competencies of comparative analysis, making decisions about best methods and checking the correctness of the experimental data received. Below we give a few case studies, suitable to demonstrate all the advantages of LST analysis as a research and educational field of students.

Case Study of climate change and the land surface temperature.

Burning fossil fuels, cutting down forests and farming livestock are increasingly influencing the climate and the earth's temperature and are often considered as the main causes of climate change. All mentioned activities add enormous amounts of greenhouse gases to those naturally occurring in the atmosphere, increasing the greenhouse effect and global warming. Mining areas are specially considered at local levels as Land surface temperature (LST) is a very important characteristic feature (environmental hazard index) used for the interpretation of anthropogenic stress of a mining area (Dudar, 2020).

LST is an important factor of climate and biosphere involving ecosystems across scales local to global. It can be defined as the emission of thermal radiance from the land surface as well as the canopy of the vegetated areas. The Landsat 8 thermal band is used to calculate LST (Hulley et al., 2019).

Land surface temperature, a legacy (continuity) National Weather Service (NWS) user requirement, is also an essential climate Variable required by the Global Climate Observing System of the World Meteorological Organization, described in the paper (Yu Y. & Yu P., 2020).

Case study of the mining area.

The analysis of time series of remote sensing data of the study area for long-term trends and periodic components mapping was carried out. Multispectral satellite images of the Earth's natural resource satellites Landsat-8/OLI were used, obtained from the open geographic information service Earth Explorer of the US Geological Survey (Lubskyi et al., 2022, Piestova et al., 2019). In the observation period from

2013 to 2019, the data of the processing Level 1T was used to calculate surface temperatures (Young et. al., 2017). The linear trends of the time series of remote sensing data are described by average values for the entire analysis period and average growths for a certain period. Periodic components are described by the most significant frequency or characteristic period of changes, as well as their contribution to the overall dynamics of the process under study.

Landsat-8 long-wave infrared (8-14 μm) data was used to obtain land surface temperature (LST) distribution within the mining area (Dudar, 2020). The main criteria for the data selection are cloudless over the study areas and the imagery season conformity to maintain the data correlation for time series analysis.

For the direct surface temperature T determination, the inverted Planck's law for «gray body» is applied through the expression (formula 1) for the spectral radiance obtained from the corresponding sensor's bands (Tang & Li, 2014):

$$T = \frac{c_2}{\lambda \ln\left(\frac{\varepsilon(\lambda) c_1}{\lambda^5 L_s} + 1\right)}, \quad (1)$$

where L_s is a land surface spectral radiance, $\varepsilon(\lambda)$ is a «gray body» spectral emissivity, $c_1 = 1{,}191 \cdot 10^{-16}$ W·m^2 and $c_2 = 1{,}439 \cdot 10^{-2}$ m·K are first and second radiation constants, λ – radiation wavelength band.

The L_s value is obtained after the atmospheric correction of the input radiance data. For the most precise temperature estimation, it is necessary to consider the influence of the atmosphere on radiation, since the atmosphere contains a large amount of gas and aerosol fractions capable of absorbing, scattering, and reflecting electromagnetic radiance depending on its wavelengths. The principle of surface emissivity estimation is based on emissivity and vegetation density relation (Jiménez-Muñoz et al., 2006).

The time series analysis was performed for each element of remote data resolution separately, because of which four spatial distributions of each of the time series parameters were obtained in the form of pseudo-images of the same geometry as the input images (Young et. al., 2017).

Since potentially hazardous facilities of the uranium mining and processing industry (Dudar 2015, 2019, Mikhailichenko, 2018) are located within the studied territory at the regional level, analyzing the obtained maps of the distribution of long-term average temperatures and the average annual growths in land surface temperature (maps from 2013-2019), it is possible to study the data of remote thermometry as an indicator of the environmental hazard of the territories adjacent to the mine sites uranium mining and any other area (urban agglomeration near the mine, or granite quarry, etc.) (Fig. 1 and 2 – central part of the Ukrainian Shield).

As an example, Fig. 3 shows the territory (location) of the exhausted (worked-out) Pervomaiske iron-uranium deposit, which is located within the urban agglomeration of Kryvyi Rih city (Terna district) selected by increasing the scale from the maps presented above. There is a clear correlation of waste iron ore pit dumps and uranium mining dumps with areas of increased average temperature and average annual growth in the temperature of the Earth's surface.

Case study of the Thermal Power Plant area.

In the frame of the Bachelor's EPP the research on the LST within high technogenically enhanced areas,

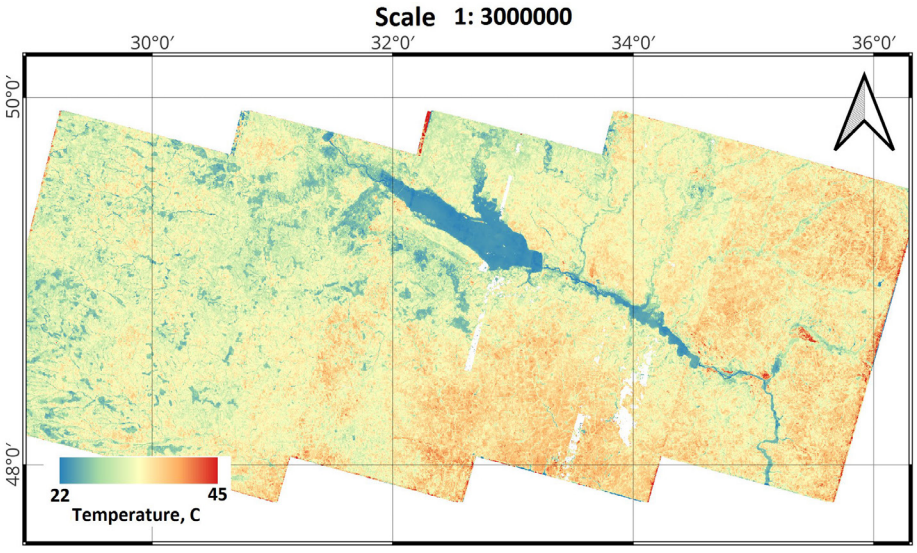


Fig. 1. Map of the distribution of the average long-term land surface temperatures at regional level according to Landsat satellite data

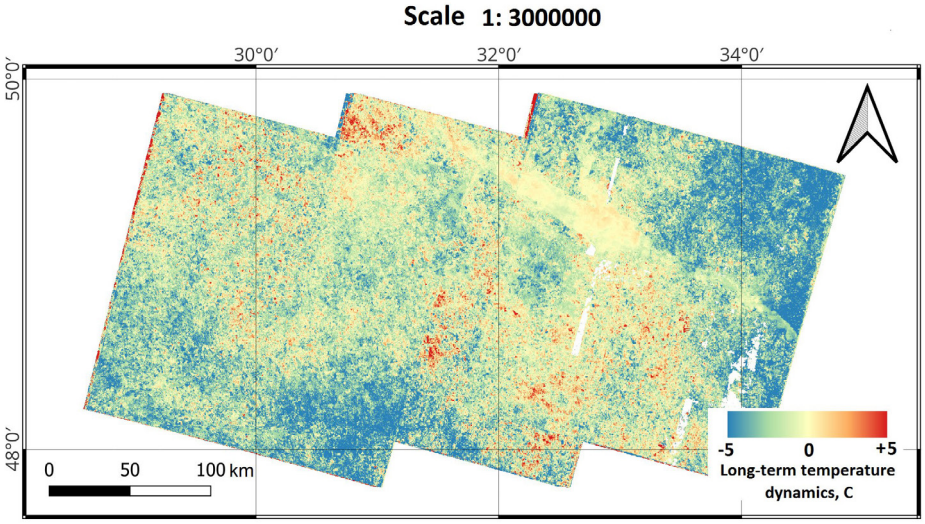
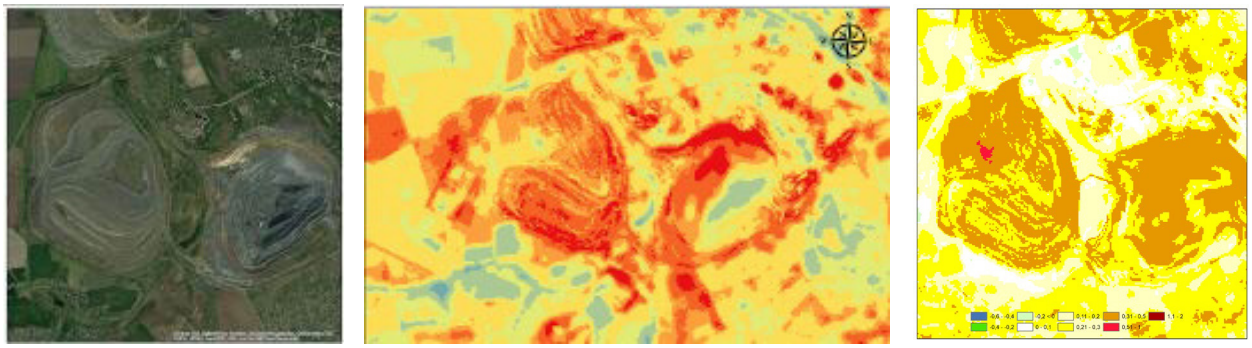


Fig. 2. Map of the distribution of long-term surface temperature dynamics based on Landsat satellite data



a b c

Fig. 3. Location of the exhausted Pervomaiske deposit

a – general view, b – the average land surface temperature, c – average annual growth in the land surface temperature.

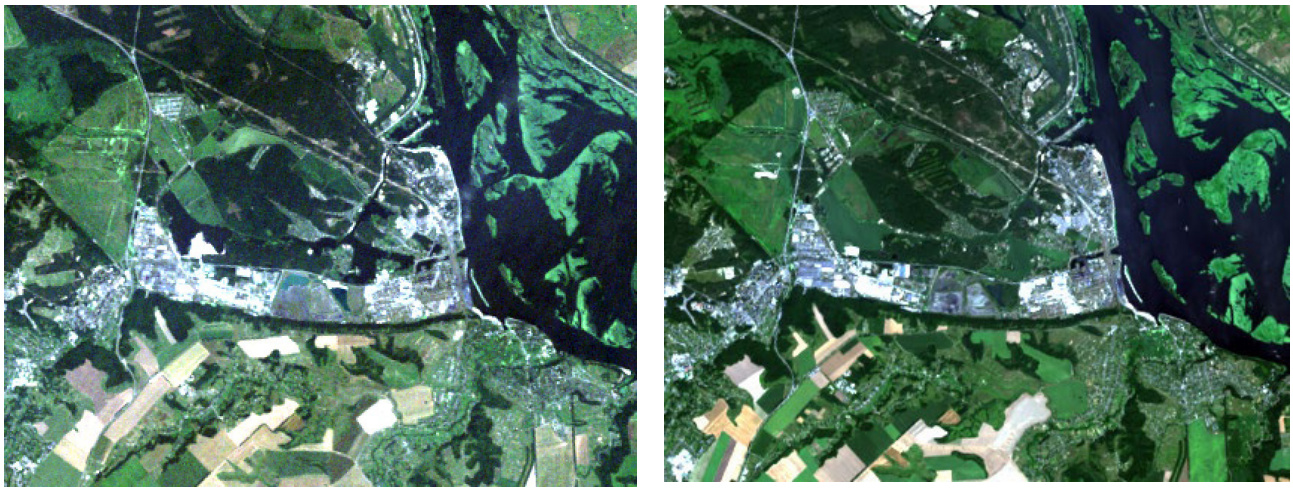
particularly within the Trypillya Thermal Power Plant (TPP), Kyiv region. Fragments of satellite images Landsat-5 and Landsat-8 on the territory of Trypillya TPP, which were used in the study, are shown in Fig. 4.

In order to master the method of working with thermal images, mapping of anthropogenic thermal pollution of was carried out (Rozhko & Dudar, 2022). The results of determining the thermal pollution of the Trypillya TPP are shown in Fig. 5.

Landsat-8 captures images in the visible wavelength range, near infrared and far infrared, with image resolutions from 15 to 100 meters per point. Currently, the main source of data on the thermal fields of the Earth's surface is satellite images obtained in the far infrared range of electromagnetic radiation 8-13 microns. Infrared images of Landsat series satellite systems (5, 7, 8) are now available and distributed free of charge through the web resources of the United States Geological Survey (USGS). The infrared images of the TM and ETM + sensors of the Landsat-5 and Landsat-7 satellites have a spatial resolution of 60 m, and the dual-band images of the TIRS sensor of the Landsat-8 satellites have a spatial resolution of 100 m. with images of other spectral ranges of these satellite systems. To date, only Landsat-8 is active. Landsat-8 is the American remote sensing satellite, the eighth in the Landsat program.

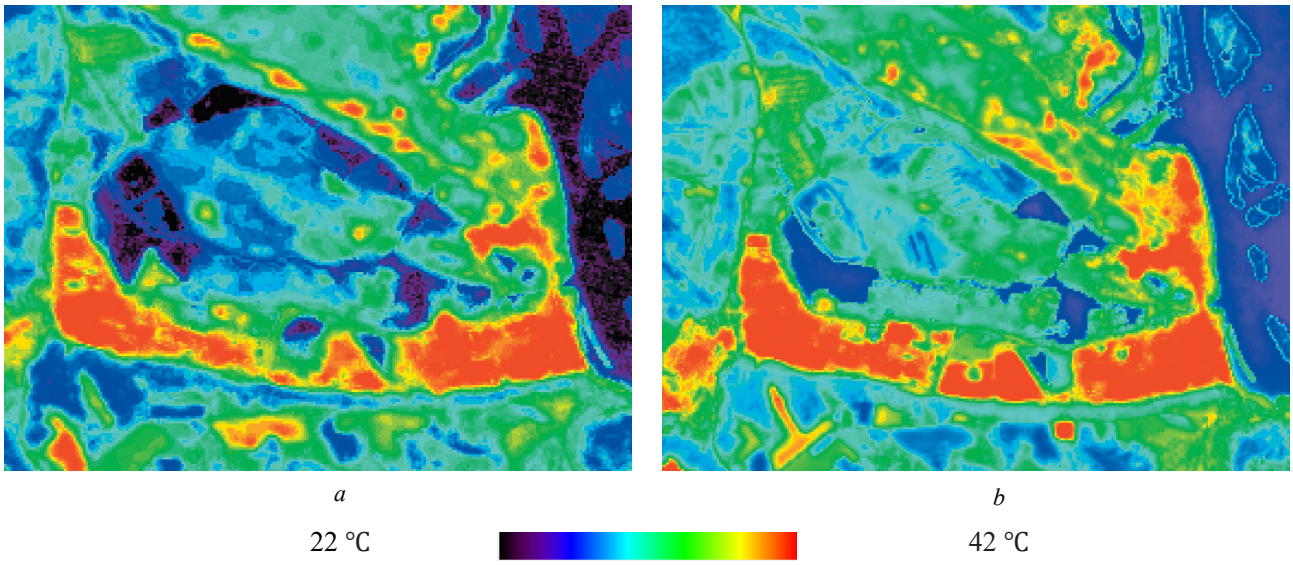
As we can see from the obtained images, the heat generation around the Trypillya TPP increased in the period from August,5 2001, to July, 27, 2021. The dates were chosen because of their warmest temperatures during the period observed. It gives more clarification to the heating background on the figures.

The trend of increasing the temperature is closely connected with extension of sludge fields and the power plant facilities. Newly constructed parts of the Power Plant, more asphalted roads, and other concrete/iron structures have a significant impact on the heat picture around the station. As the Thermal Power Plant uses water for cooling and storing used fuel (sludges), the territory has reservoirs of technician water that can have larger background temperature



a *b*

Fig. 4. Fragments of Landsat satellite images for the territory of Trypillya TPP
a – Landsat-5 (05.08.2001) and *b* – Landsat-8 (27.07.2021).



a *b*

Fig. 5. Temperature field of the territory of Trypillya TPP according to the results of data processing of the Landsat satellite system
a – Landsat-5 August 5, 2001 and *b* – Landsat-8 July 27, 2021.

than other water spots. This water reservoirs haven`t exit to other water sources, so they have a large risk to become a still water bogs. Also, the close location of the sludge storage to the Dnipro River creates the problem of water pollution with chemical and physical pollutants.

From the picture: the red one, the most heated territory (>36 ℃) is the concrete/steel roofs, sludge storages, and water reservoirs. The small red dots and lines on the right top of the image in the Ukrainka are roofs from some warehouses or industrial sites. The other background temperature (<36 ℃) is the territory, green: Ukrainka town, some agricultural lands. The blue one is the water bodies located nearby. As a result, we can say that this geographic location has a significant impact on the environmental health across this region. Every aspect of ecological purity is touched by Trypillya TPP, which proves the antiquity of using Power Plants to generate energy and heat for residential communities.

Conclusions

Within the framework of the educational and professional program «Ecology and Environmental Protection» of the Department of Environmental Sciences of NAU, the priority of the direction of the noospheric component in environmental education is highlighted, which, in our opinion, should be proactive via the integral interaction of human minds, as an important element of noospherogenesis – the only worthy path of civilization development.

The problem of mitigating global climate changes on the planet is the basis for noosphere principles in the modern world, because warming and changes in other parameters of the biosphere will affect each of us both in our personal lives and our professional activities. Therefore, a new course «Adaptation to Climate Change» was introduced at the department, where students should acquire knowledge and skills for survival and effective activity in the conditions of new realities due to improving the ability to adapt, as an important characteristic of the human species, to the highest possible levels. These skills have universal character since they modify student's worldview in a way that makes them more flexible and innovative in the face of professional and personal challenges. The dynamics of the modern world will increase the demand for professionals with such skills and competencies.

The results of scientific research are implemented in the educational and professional program not only by introducing new subjects but also by improving the content of courses that have been taught for a long time. For example, the study of the temperature of the Earth's surface and the assessment of changes in land cover over a certain period have been added to the training program of the course «Remote Methods of Research in the Field of Environmental Protection», etc.

To carry out monitoring research on the vulnerability of the Earth's surface within hard-to-reach areas it is expedient and rational to use multispectral space surveys. The analysis of time series of remote data for mapping long-term trends and periodic components of the study area demonstrated that average values for the entire period of analysis and average growths for a certain period of observation are the most informative for detecting long-term changes in the temperature of the Earth's surface.

Land surface temperature is one of the key features that could represent environmental changes caused by anthropogenic influence, for example, mining activities or urbanization. It makes land surface temperature an appropriate Earth attribute that combines remote sensing and environmental sciences in the sense of environmental education. It is clear, its influence of the environment is intuitive for students, and it could be represented using geoinformation systems. Land surface estimation is still a challenging task for non-specialists, but its ecological significance makes land temperature mapping useful and important in environmental education.

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