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Monitoring the environmental and geological-geophysical situation in the Ukrainian-Polish border area using satellite data

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SUMMARY

Geological hazards of the state of the environment, including areas with significant vegetation and forest cover, are analyzed through the utilization proposed to study through observations and mathematical modeling methods especially in cases of simulated thermal processes in the territories. The research is proposed to be conducted in order to study the engineering condition of the surrounding areas and civil protection. To this we relate low-resolution and medium-resolution spatial and satellite images obtained by instrumental means. The practical significance of the planned project for the economy and society is expected to increase the level of public safety related to civil security and fire safety issues. This will be achieved by using a geological information system to solve existing problems. This is proposed to be achieved by using the geological information system to solve existing problems. Increased in formativeness, efficiency, feasibility and an effective solution will make it possible to obtain a result from this. And this will allow implementing the measure of civil facilities utilizing geological and infrastructure data in the conditions of modern natural and man-made human hazards.

Introduction

Modernization of the environmental information system for geological-geophysical monitoring of natural and man-made emergencies is one of the priority and promising global trends. Effective use of monitoring results by civil and fire protection services to prevent disasters are a strategically important problem today.

At present, due to abnormal situations arising from sharp changes in weather conditions, especially in the context of global warming, Europe, and in particular Ukraine and Poland, are experiencing different weather periods associated with abnormal heat or, conversely, cooling at different times of the year which is related to the detailed study of these processes (*Starodub & Havrys, 2018; Starodub, et al., 2020; Nikolaevich et al., 2021*). This results in flooding on rivers and reservoirs, a sharp change in the ice regime, and in summer, to numerous cases of fires and fires due to high summer temperatures (*Starodub, et al., 2022; Starodub & Gnyp, 1999*). In light of these challenges, there is an urgent need to develop effective response strategies to mitigate the potentially disastrous consequences of these weather phenomena, particularly in the context of the ongoing war in Ukraine. The utilisation of Earth satellites and drones for observational purposes offers significant opportunities in this regard. The present paper outlines a project designed to monitor the environmental geological and geophysical situation in Ukraine and its neighbouring countries.

The objectives of the project are as follows:

- To establish the possibilities of studying the environmental and geophysical situation in Ukraine using images from artificial Earth satellites;
- To show an example of studying the situation of flood predicting by modelling it using available data and data obtained with the help of aircraft;
- To show an example of analyzing the extreme temperature situation based on satellite data.
- To analyze the results of processing satellite images of areas with fire hazards;
- To develop preventive measures for the prevention of fire hazards to civilian facilities and buildings in order to eliminate the risk of fire.

Method and Theory

By analysing and comparing data for territories, especially for seismically hazardous areas of Ukraine, where there are dangerous construction objects associated with natural and man-made hazards, as well as forest plantations, which can lead to relevant fire situations, the paper presents the result of a typical approach to analysing the results of satellite image processing for areas where preventive work should be carried out by the units of the State Emergency Service of Ukraine to eliminate fire risks.

To prevent fires, we have developed a unique technology for fire protection of wood and conducted fire tests of wood samples coated with a fireproof composite based on epoxyamine polymers modified with transition metal salts (*Lavrenyuk et al., 2020; Lavrenyuk & Mykhalichko, 2019; Lavrenyuk & Mykhalichko, 2018; Lavrenyuk et al., 2020; Lavrenyuk et al., 2019*). In order to study the ways of obtaining polymeric materials based on metal-coordinated epoxy-amine composites with reduced fire hazard, the sequence of combining ingredients (copper(II) salts, hardener, and binder) was tested to ensure the optimal technological regime for obtaining composite materials necessary for effective protection of wooden constructions from the negative effects of fires in a certain geological environment .

In these areas, to effectively combat forest fires, especially in the regions vicinity of channels and rivers, the detection area should be less than 1 hectare, and the fire area at the time of extinguishing should not exceed 5 hectares. To this end, this methodology for space-based fires monitoring can use

information from the Advanced Very Hugh Resolution Radiometer (AVHRR) carried by NOAA satellite, supplemented by data from drones. The fire detection methodology is based on the use of radiation estimates for AVHRR channels 3, 4, 5 and known Mavic 3D (thermal) drone data corresponding to the infrared spectrum. Fires are defined as extreme values of AVHRR channel 3 radiations. Smoke plumes from fires are well detected in the first and second AVHRR channels (visible and near-infrared, respectively). For more accurate identification of fires, thresholding algorithms can be used to determine the temperature of the radiation on the third and fourth channels. The AVHRR instrument whose images we use is calibrated for temperatures up to 330°C, and a temperature map of Ukraine on hot summer days in 2022 and 2023 was obtained.

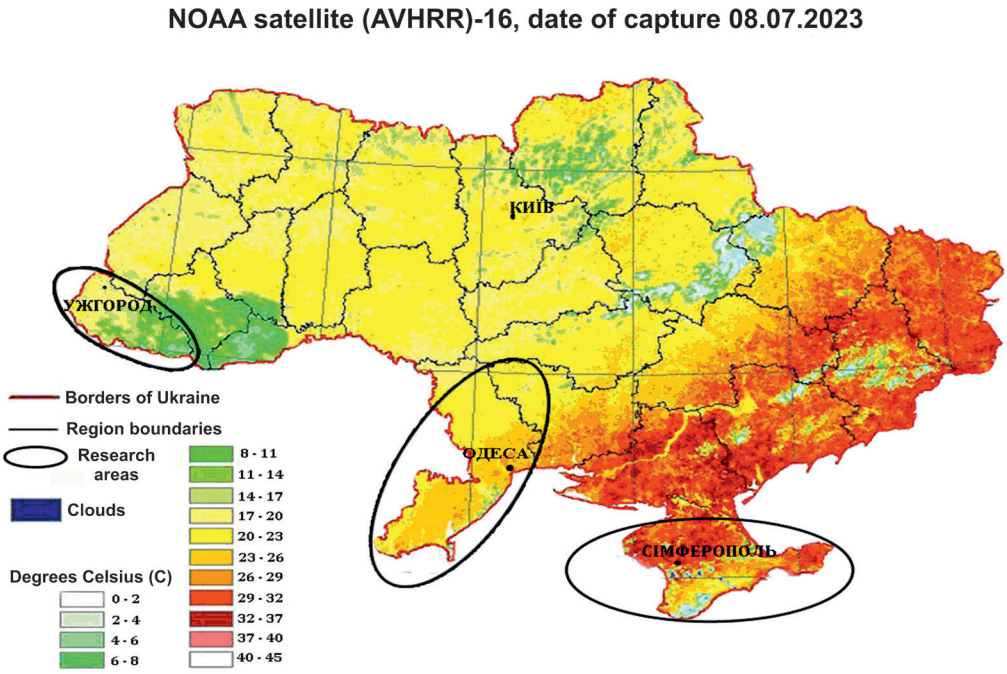

Figure *Temperature map of Ukraine on July 8, 2023.*

Results

The temperature map of Ukraine (see Figure) highlights areas where the risk of destruction is further increased by seismic activity, which is exacerbated by the military situation. The high temperatures inherent in these regions, present in the east of the country, increase the risk of fires there against the background of earthquakes from seismicity and fires associated with all factors combined. The regional seismic data are analysed in conjunction with the critical temperature situation that occurs during the summer months. It is observed that ambient temperatures of 30°C and above are recorded in summer along the seismic belt that extends along the southern coast of Crimea, in seismically hazardous areas of Trans-Carpathia, and in regions with high industrial load throughout Ukraine, particularly predicted in July 2026, when the peak of solar activity is forecast. Statistical estimates indicate a particular risk of man-made accidents, in actually, in the western part of Crimea in the area of the rocky seismic coast during high summer temperatures in the densely populated areas of Sevastopol and the adjacent resort areas.

The proposed algorithm involves modelling the study of flooding of territories and identifying dangerous areas that may pose an additional danger, in particular in the case of fire-hazardous

territories, their delimitation or lead to a Domino effect during the occurrence of catastrophic geological events. Additionally, it is planned to use visual observation data, in particular using unmanned aerial vehicles on the line of water flows of the rivers of Western Ukraine Dniester Western Bug. The developed geoportal allows monitoring the trend of fires in certain areas by entering all calls into the appropriate database and displaying them on the map. According to the map, emergency situations can be monitored and conclusions can be made by management about increasing spending on firefighting equipment and promoting the fight against the causes of geological emergencies in the relevant area and increasing the number of inspections of both residential and industrial premises for compliance with fire and civil safety standards (*Starodub, et al., 2023; Starodub, et al., 2024*).

The developed geo-information system for monitoring emergency situations allows quickly informing civil and firing services about the occurrence of fires both in natural ecosystems and in civilian objects and buildings. In order to minimize the possible consequences of these emergency situations, civil and fire protection units in their practical tasks should use all opportunities to protect civilian objects from fire. In this regard, the developed flame-retardant polymer composites should be considered as the main fire-protective material that will reliably guarantee the fire safety of civilian objects and structures.

Among the main indicators of fire hazard, the flammability parameter characterizes the tendency of substances and materials to burn freely. In fire conditions, the effect of heat on wood coated with metal-coordinated epoxy-amine composites leads to the release of non-combustible volatiles into the gas phase of the flame and accelerates the carbonization process. Polymer structuring that occurs during the curing of metal-coordinated epoxy-amine composites also contributes to a reduction in combustibility.

Other fire hazard indicators, such as flame spread, can significantly affect the flammability of wood coated with polymer composites through heat transfer. The tendency of polymers to spread flames over the surface of samples determines the rate at which combustibles enter the combustion zone. This causes an increase in the ambient temperature, which affects the amount of heat flux that is directed to the part of the polymer material that is not yet covered by the fire. The data analysis shows that the introduction of inorganic copper (II) salts into the polymer matrix can significantly slow down the spread of flame over the surface of a horizontally oriented sample. Wood samples coated with an epoxy-amine composite that does not contain a flame retardant continue to burn until they are forced to extinguish. The average burning rate is 25.2 mm-min^{-1}. During the burning of this sample, we observed that drops from the burning polymer coating fell on the lined cotton cloth. In the case of the copper(II)-coordinated epoxy-amine polymers, the flame was extinguished before reaching the zero mark, the duration of free burning did not exceed 1.5 minutes, and no ignition of the cotton fabric was observed.

Conclusions

Hazards to the state of the geological environment, including both vegetation and forest cover, are typically analyzed through the utilization of mathematical modelling techniques to simulate thermal processes. These analyses are conducted for the purpose of environmental engineering and civil safety. The acquisition of low- and medium-resolution aerial and satellite imagery is instrumental in this regard. The practical value of the planned project for the economy and society is predicated on the increased level of population safety related to civil protection and fire safety. This will be achieved by using a geological information system to solve existing problems. The increased in formativeness, efficiency, reliability, and effective decision-making that will result from this will allow for the reliable preservation of civil facilities and buildings in the conditions of modern natural and man-made threats.

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