EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology, 2025, 26(3), 352–360
https://doi.org/10.12912/27197050/200307
ISSN 2719–7050, License CC-BY 4.0

Received: 2024.12.22
Accepted: 2025.01.22
Published: 2025.02.01

Atmospheric air temperature as an integrated indicator of climate change

Andrii Mats[1], Olena Mitryasova[1*], Ivan Salamon[2], Anna Kochanek[3]

[1] Petro Mohyla Black Sea National University, Mykolaiv, Ukraine
[2] University of Presov, 17. novembra 3724/15, 080 01 Prešov, Slovakia
[3] State University of Applied Sciences in Nowy Sacz, Stanisława Staszica 1, 33-300 Nowy Sącz, Poland
* Corresponding author's e-mail: lesya.solis28@gmail.com

ABSTRACT

Atmospheric air temperature serves as a fundamental indicator of climate change, directly influencing ecosystems, water resources, and human livelihoods. The study of temperature trends is essential for understanding the impact of global warming as well as developing strategies for environmental sustainability and climate adaptation.

The purpose of the research was to study the dynamics of atmospheric air temperature as one of integrated indicator of climate change and the main factors influencing the state of water resources on the example of the territory of Mykolaiv city and the Mykolaiv region. The study methods involved observations, comparisons and analogies, analysis, synthesis, and generalization. Also, the research was carried out using Microsoft Excel and mathematical modeling through the use of regression analysis. The method involved constructing statistical models to predict the dependent variable based on one or more independent variables. The findings derived from regression analysis were visualized through scatterplots, regression lines, and confidence intervals, allowing for a clear interpretation of trends and patterns. Over the period 1991–2024, the average annual temperature in the Mykolaiv region increased by 1.2 °C, and its growth rate is three times higher than the global rate. The highest temperature was recorded in 1998 (40.1 °C), the lowest in 2006 (−25.9 °C), and recent years (2023–2024) have become the warmest in the entire period of observations. The summer months show the greatest temperature extremes: the average maximum temperature in August reaches +29.6 °C, and the number of hot days is steadily increasing every year. Therefore, the data indicate a steady increase in days with temperatures above 25 °C during the analyzed period. This may be the result of global warming and climate change. However, in some years, the number of hot days may be lower or higher than trend values, which indicates natural fluctuations and the possible influence of other climatic factors. In general, the graph shows a clear trend towards an increase in the number of hot days, which is an important indicator of climate change in the region.

Keywords: climate change, atmospheric air temperature, environmental change, sustainable development.

INTRODUCTION

During the twentieth century, as well as in the first quarter of the twenty-first century, there have been significant changes in the temperature regime. According to the Intergovernmental Panel on Climate Change (Climate Change, 2013), abnormally high temperatures are observed in many regions of the planet. It was determined that the first two decades of the 21st century are 0.99 °C warmer than the average temperature of the pre-industrial period (1850−1900), and during 2011−2024 – by 1.09 °C. Climate change poses significant challenges to achieving the Sustainable Development Goals (SDGs), directly impacting global ecosystems, economies, and societies (Pohrebennyk et al., 2016, 2017; Mitryasova et al., 2018). Addressing climate change is essential to ensuring sustainable development and protecting the planet for future generations (Ishchenko et al., 2019; Kochanek et al., 2024.).

Studying the impact of environmental parameters on aquatic ecosystems offers valuable insights into maintaining biodiversity and ecosystem resilience (Kwaśnicki et al., 2024; Mitryasova et al., 2016;). This research provides a foundation for developing sustainable water resource management strategies in the face of global environmental changes (Bernatska et al., 2023; Bezsonov et al., 2017, 2021).

Temperate climates are characterized by the following features:

- there is a pronounced seasonality due to the allocation of four seasons – winter, spring, summer and autumn, each of which has its own characteristic temperature and weather conditions.
- moderate temperatures that do not reach extremes. Winters can be cold but not too harsh, and summers can be warm but not too hot.
- the variety of rainfall can vary depending on the geographical location, but in general, temperate climates are characterized by having sufficient rainfall that is distributed throughout the year. Precipitation can be in the form of rain, snow, fog, etc.
- mild transitional seasons because spring and autumn in temperate climates are usually characterized by mild temperatures and a gradual transition from cold winters to warm summers and vice versa.
- there are significant changes in the length of the day throughout the year. In summer, the days are long and the nights are short, while in winter it is the opposite.
- the diversity of landscapes can include different landscapes, such as forests, steppes, mountains, and coasts, which create diverse ecosystems.

The main feature of the temperate climate is the presence of four seasons: two main ones, winter and summer, and two intermediate ones – spring and autumn. This peculiarity of the climate is also characteristic of Mykolaiv, Ukraine.

An anomaly of the average values of global temperature during 2013−2024 was detected, namely 1.14 °C (1.02 °C to 1.27 °C), which indicates the continuation of the warming period (WMO, 2024). Such abnormally high temperatures were observed 125.000 years ago, when the global temperature was 0.5−1.5 °C higher than the pre-industrial period. This time is known as the Aemic Interglacial Period, when climate changes led to rising sea levels and warmer conditions over much of the Earth. Modern climate change caused by anthropogenic factors shows similar trends in temperature increase. Since 1970, global temperatures have been the highest in the last 2.000 years, and the last decade is the warmest in 6.500 years. Before that, the last decade was the warmest in the last 6.500 years. This highlights the seriousness of today's climate change as well as the need to take action to reduce greenhouse gas emissions and slow global warming (IPCC, 2021; EEA, 2023).

A change in air temperature indicates a significant change in the temperature regime of the entire climate system of the planet. According to scientists, the effects of climate change are predominantly negative and are projected to intensify in the future.

Meteorological observations have been carried out in Ukraine since 1881. Over the past decades, significant changes in the climate system have also been identified in Ukraine, the indicator of which is the temperature regime of atmospheric air (Shevchenko et al., 2014).

The study (Tuz, 2022) provides an analysis of changes in annual temperature in Ukraine since 1901. The thesis that the stability of the modern low-water phase of the Southern Bug River is caused by a steady increase in the annual temperature in Ukraine, which has been observed since 2000 to the present, is substantiated.

The authors consider it necessary to focus on the fact that during 1991–2024, the highest rates of change in the average annual atmospheric air temperature were observed compared to 1961. They were almost three times higher than the rate of change in the average annual global temperature (0.21 °C/10 years) during this period. As a result, according to the UN, Ukraine fell into the regions of the planet, except of polar latitudes, where the temperature increase occurred at the highest rate (UN Framework Convention on Climate Change, 2024).

According to the Copernicus Climate Change Service analysis, the global average surface air temperature of April 2024 was higher than any previous April in the reanalysis dataset since 1940 (Copernicus, 2024). According to the Ukrainian Hydrometeorological Center, over the past 30 years, the average temperature in Ukraine has increased by 1.2 °C. The rate of increase in air temperature in some regions of Ukraine has reached 0.82 °C over the past 10 years, while in neighboring countries – 0.47–0.59 °C/10 years, and in the northern hemisphere and Europe – 0.34 and 0.47 °C/10 years, respectively. These data indicate that the rate of increase in air temperature in Ukraine is significantly higher than global and European rates (Ukrhydromet, 2024).

April 2024 is the eleventh consecutive month, which is the warmest of the corresponding month of the year. April and July 2024 were 1.58 °C warmer than the average for the pre-industrial baseline period (1850−1900). For example, the global surface air temperature in April 2024 was 15.03 °C, 0.67 °C higher than the average for April 1991–2023. and 0.14 °C above the previous high set in April 2016. This is the month in which temperature records are set for the corresponding period. Overall, globally, the 12 months (May 2023 to April 2024) were warmer than any previous 12-month period, 0.73 °C above the 1991–2023 average. and 1.61 °C above the pre-industrial average (April, 2024).

Thus, open data from monitoring observations of the Copernicus Climate Change Service show that global temperature records are observed during the last months of 2023 and 2024 in various regions of the World Ocean. July 21, 2024 is the hottest day on record. The average temperature on the planet on this day was 17.09 °C. This is the highest temperature recorded since 1940. The previous record was set in 2023 at 17.08 °C (Copernicus, 2024; Ventusky, 2024; UNEP, 2023).

The key characteristics of atmospheric air temperature include average monthly and seasonal indicators, which are critical for understanding temperature distribution throughout the year. Average monthly temperature represents the mean temperature for a specific month, offering insights into temperature trends during individual months. It highlights monthly variations and helps identify short-term climatic patterns. Seasonal average temperature reflects the mean temperature for each season—winter, spring, summer, and autumn—providing a broader view of temperature trends over longer periods. These metrics are vital for analyzing climate change, improving weather forecasting accuracy, optimizing agricultural planning, and supporting various industries. They allow for a detailed understanding of temperature distribution throughout the year, facilitating the identification of long-term climate trends and their potential impacts.

The main feature of the temperate climate is the presence of four seasons: two main ones, winter and summer, and two intermediate ones – spring and autumn. This peculiarity of the climate is also characteristic of Mykolaiv, Ukraine.

Weather and climate observations in the city are carried out by a meteorological station located in Mykolaiv. Mykolaiv is located in the steppe agro-climatic zone of Ukraine, in the basin of the lower reaches of the Southern Buh and Inhul rivers. Thus, according to long-term data from meteorological observations, it was determined that during 1991−2024. The climate of the city was temperate continental, arid. Thus, in Mykolaiv, about 60–67 days with a negative average air temperature per day, which is a characteristic feature of the winter period, and about 32 days with a negative maximum air temperature per day, are recorded. The duration of the period with a negative minimum air temperature can be three times longer – an average of 93 days per year: 64 in winter, 16 in spring and 14 in autumn.

The purpose of the research was to study the dynamics of atmospheric air temperature as one of integrated indicator of climate change and the main factors influencing the state of water resources on the example of the territory of Mykolaiv city and the Mykolaiv region. These territories geographically belong to the Northern Black Sea region.

The object of research corresponded to the city of Mykolaiv and Mykolaiv region. The Mykolaiv region is located in the south of Ukraine, within the Black Sea lowland. The region occupies the territory in the basin of the lower reaches of the Southern Buh River and is washed by the waters of the Black Sea. Its geographical position is characterized by a temperate continental climate with warm summers and mild winters. The Mykolaiv is a regional center and is located at the mouth of the Inhul River, where it flows into the Southern Buh (Mats et al., 2025). The geographical coordinates of the city are 46°58′, and 31°48 approximately. The Mykolaiv region has a variety of landscapes: from steppes to forest-steppes, as well as significant water resources.

MATERIALS AND METHODS

The following study methods were used: observations, comparisons and analogies, analysis, synthesis, and generalization. Also, the research was carried out using Microsoft Excel and mathematical modeling through the use of regression analysis. Mathematical modeling, specifically regression analysis, was a key component of the study, applied to quantify and analyze the relationships between variables. The method involved constructing statistical models to predict the dependent variable based on one or more independent variables. The findings derived from regression analysis were visualized through scatterplots, regression lines, and confidence intervals, allowing for a clear interpretation of trends and patterns.

The research materials were data from the regional hydrometeorological service. In order to assess the parameters of the environment of Mykolaiv and Mykolaiv region s within the city of Mykolaiv, databases of strategic and program documents were used (National Report, 2023). The data from the Ventusky resource were used as a tool that provides accurate meteorological indicators and weather changes over time of the entire planet and at each specific point of the globe (Ventusky, 2024).

The weather and climate observations in the city are carried out by a meteorological station in Mykolaiv. Mykolaiv is located in the steppe agro-climatic zone of Ukraine, in the basin of the lower reaches of the Southern Buh and Inhul rivers. Thus, according to long-term data from meteorological observations, it was determined that during 1991−2024. The climate of the city was temperate continental, arid.

RESULTS AND DISCUSSION

In Mykolaiv, about 60–67 days with a negative average air temperature per day, which is a characteristic feature of the winter period, and about 32 days with a negative maximum air temperature per day, are recorded. The duration of the period with a negative minimum air temperature can be three times longer – an average of 93 days per year: 64 in winter, 16 in spring and 14 in autumn (Table 1).

The temperature regime begins to change for the study area from February. Thus, there is an increase in the influx of solar radiation, which leads to an intensive increase in air temperature, so March is warmer than February by almost 5.1 °C, and April is warmer than March by 7.0 °C.

The warm period in the Mykolaiv region lasts about 300 days. May is dominated by summer temperatures, with an average monthly temperature of around 17.01 °C and an average maximum of 23.6 °C.

Thus, in the Mykolaiv region, spring is quite warm, as evidenced by the average air temperature for the season of 10.3 °C (Table 1), which, in general, is higher than the temperature of the growing season. Therefore, in the spring of 2024, the flowering of many plants in the Mykolaiv region began three weeks earlier than the average period. Then, it is believed that the average start of active vegetation in the Mykolaiv region is mid-April, and the end of the growing season is October 15. The active growing season lasts about 187 days.

The average summer temperature is 22.3 °C. September in the Mykolaiv region covers an

Table 1. Values of temperature characteristics for the year and season in Mykolaiv and Mykolaiv region during 1991−2024

Indicator	Season	Mykolaiv	Mykolaiv region
Average temperature, °C	Winter	-0.9	-1.1
	Spring	10.4	10.3
	Summer	22.7	22.3
	Autumn	10.9	10.6
	Year	10.1	10.5
Maximum average temperature, °C	Winter	2.2	2.0
	Spring	15.7	15.9
	Summer	29.0	28.6
	Autumn	15.0	15.5
	Year	15.7	15.4
Minimum average temperature, °C	Winter	-3.7	-3.9
	Spring	5.6	5.3
	Summer	16.9	16.3
	Autumn	6.8	6.4
	Year	6.4	6.0

average of 20 days. The highest temperature is observed mainly (58%) in August, the average temperature of which is 24.3 °C, the average maximum is 29.6 °C, and the average minimum is 17.2 °C. Much less often (43%) the highest temperature occurs in July.

The analysis of winter temperatures showed that the average winter temperature is about -1.01 °C, and has a range of fluctuations from -0.27 °C to -1.71 °C. It was determined that in the south of the Mykolaiv region, the average temperature below 0°C is observed only in January and February. The coldest month in the Mykolaiv region is January. The average temperature regime in January is -2.02 °C, but the average minimum is -4.75 °C, and the average maximum is 0.91 °C.

In a large area of the Mykolaiv region, autumn is warmer than spring, as evidenced by the data in Table. 1. Thus, the average air temperature for the season is 10.6°C, the average maximum is 15.4 °C, and the average minimum is 6.4 °C. In the Northern Black Sea region, the maximum and minimum temperatures in autumn are higher than in spring.

A graphical analysis of the dynamics of changes in average annual temperatures in Mykolaiv in the period from 1980 to 2024 is shown in Figure 1. The graph in Figure 1 indicates the presence of a stable linear trend in the direction of a gradual increase in average annual temperatures. The warmest years for this period of observations are 2023 and 2024, the coldest are 1985 and 1987. It is important to note that the growth of the average temperature is 0.61 °C for every ten years. When separately analyzing trends in changes in maximum annual temperatures, shown in Figure 1, it is also possible to note a gradual stable dependence on the increase in maximum annual temperatures. The trend line relative to minimum temperatures highlights constancy. By determining the correlation coefficient, which is 0.7 and is positive, it indicates that when one variable increases, the other also tends to increase. A correlation coefficient 0.7 indicates a strong relationship between variables, but not absolute, i.e. variables tend to change together, but with some variation. This concerns the correlation between the year and the average temperature.

However, the defined correlation does not mean causation, i.e. a correlation of 0.7 indicates a linear relationship, but does not take into account nonlinear relationships. The temperature maximum in the city during 1980–2024 was recorded in 1998 (+40.1 °C); temperature minimum − in 2006 (−25.9 °C).

The trend equation $y = 0.0215x - 32.59$ means that the average annual temperature increases by about 0.021 °C each year. From Figure 2 it can be seen that there are some temperature fluctuations around the trend line, which is common for climate data. If this trend continues, it can be predicted that the average annual temperature will continue to rise. On the basis of the trend equation, 2050 the average annual temperature may be approximately: $0.0215 \times 2050 - 32.59 = 10.7175 - 32.59 = 11.4$ °C. Therefore, the graph in Figure 1 shows a long-term increase in the average annual temperature, which may be a sign of global warming or other climate changes. This is an important indicator for environmental research and planning of climate change adaptation measures.

At the same time, it was determined that in the region during the period from 1991 to 2024, February was colder than January in 37.0% of years. During the winter period in the Mykolaiv region, up to 10 days are observed with a minimum air temperature below −10.0 °C, of which, up to 3 days with severe frosts, when the air temperature was observed below −20.0 °C. Orange dots indicate the maximum temperatures, and blue dots indicate the minimum. Trend lines show trends of change for both temperature series. According to trend lines, maximum temperatures are increasing at a rate of 0.0884 °C per year; minimum

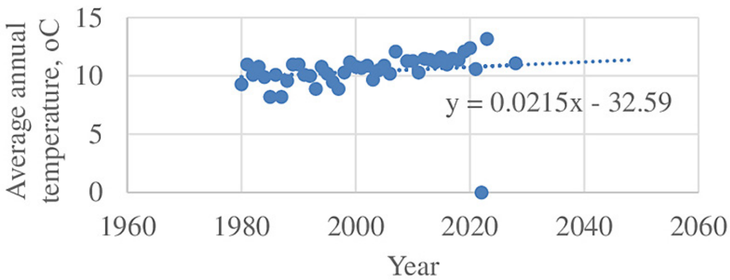

Figure 1. Dynamics of changes in the average annual temperature from 1980 to 2024

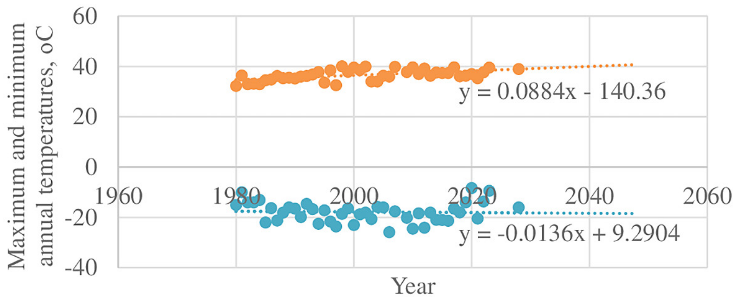

Figure 2. Dynamics of changes in maximum and minimum annual temperatures from 1980 to 2024

temperatures are decreasing at a rate of 0.0136 °C per year. Both trends indicate a change in temperature extremes over time, which may be related to global climate change. Also, it was determined that in the Mykolaiv region during 1991−2024, not a single case was recorded when the highest temperature in June was noted.

An increase in maximum temperatures may indicate a general warming of the climate. A decrease in minimum temperatures indicates that colder winters or nights are possible. An increase in maximum temperatures can lead to an increase in the frequency of heat waves, which can affect human health, agriculture, and energy needs.

Using the obtained trend line equations (Fig. 2), it is possible to make a forecast for future maximum and minimum temperatures. The method used to generate the trend lines in the graph is linear regression, a statistical technique that models the relationship between a dependent variable (temperature) and an independent variable (year). The orange points represent the maximum annual temperatures. The blue points represent the minimum annual temperatures. The trend lines are fitted by minimizing the sum of the squared differences between the observed data points and the predicted values on the line. The rate of change in temperature per year are indicated. Positive values correspond to maximum temperatures and negative to minimum temperatures. This method provides insights into long-term temperature trends, making it useful for climate change analysis and environmental planning. For example, for 2030:

- Maximum temperature:

$$y = 0.0884 \times 2030 - 140.36 = +39.09 \quad (1)$$

- Minimum temperature:

$$y = -0.0136 \times 2030 + 9.2904 = -18.32 \quad (2)$$

During the study period, about 98 days of hot weather were observed in the region, when the maximum air temperature exceeded 25.0 °C. Temperature conditions under which the minimum air temperature exceeds 20.0 °C are typical for tropical latitudes (“tropical nights”), typical for the Mykolaiv region. On average, there are about 20 tropical nights per year. Such extreme temperature conditions are most frequent during July – August, which causes heat stress and heat load on living organisms. In addition, an increase in this load is facilitated by an increase in relative humidity, a decrease in wind speed, as well as an increase in the influx of solar radiation.

It is known that at the same temperatures, air humidity and wind speed, the heat load on the human body will be greater in cloudless weather, compared to the same meteorological conditions in cloudy weather. The largest number of days accompanied by heat stress (up to 90%) is observed in July - August.

An important characteristic of the temperature regime is the deviation of the daily values of the minimum and maximum temperature from their average long-term values. Such jumps in temperature conditions determine the intensity and duration of periods of warming and cold snaps, which create certain environmental risks for water resources.

The values of the 5th percentile of the minimum air temperature characterize very severe cold snaps. In summer, with a very strong cold snap in the Mykolaiv region, the same air temperatures can be observed as in winter, with extreme warming. It is determined that the season will last up to 5 days with such extreme temperatures.

Extreme warming is when the maximum daily air temperature is more than 95 percentiles of its long-term average values for that day, and cold snaps, in which the minimum air temperature per day is below the 5th percentile for this day. Such heat waves are observed in summer, average 35.6 °C per season and characterize very intense heat in the region.

At the same time, during the winter period, there are from 3 days with very high air temperature, when its maximum values exceed 95%, and the average maximum excess is 2.6 °C. Strong warming in spring is observed more often than in autumn (4.08 and 3.06, respectively). On average, in the Mykolaiv region, about 15 days with a very high maximum air temperature for this season is observed. The year 2024 is shown in Figure 3, from which a steady gradual increase in the number of hot days each year can be traced. The slope ratio of 1.9353 shows that, on average, the number of hot days increases by 1.9353 days each year. The intercept of 226.18 indicates the initial value of hot days in a year, when x=0. The highest number of hot days is observed closer to 2024, confirming the trend towards rising temperatures.

For about 30 years, there have been anomalies in the latitude and longitude of Mykolaiv and the region. In general, if earlier intra-latitudinal circulation prevailed 3/4 days a year, then in recent decades the interlatitudinal direction of movement of air masses has significantly increased, as evidenced by numerical maps of the movement of air masses of hydrometeorological centers (Copernicus Interactive Climate Atlas, 2024). According to the research by the Copernicus Climate Change Service global monitoring system, it was determined that a high-pressure ridge has been established between two areas of high pressure – over tropical North Africa and the Arctic. This leads to the formation of stable and dry conditions characteristic of anticyclones. For summer in the northern hemisphere, this is the norm. However, earlier such a ridge passed much further west, namely such countries as Italy, Spain, France. In 2024, this crest moved to the countries of Eastern Europe, in particular to Ukraine. A high-pressure crest is usually accompanied by stable weather conditions, clear skies, and low humidity. The following questions arise: are 2023 and 2024 isolated cases in terms of installing a high-pressure crest? Will this nature of circulation become a pattern?

So far, it has been impossible to unequivocally answer this question, since abnormal heat waves were observed in the summers of 1998, 2000, 2002, 2010, 2017. From later periods, these were 1934, 1946, 1975, and in the summer of 1934, the drought in Mykolaiv lasted 137 days. Nevertheless, changes in terms of a gradual increase in temperature have taken place recently. The question of whether 2023 and 2024 are isolated cases of high-pressure crest installation, or whether this nature of circulation will become a pattern, is complex and requires the analysis of various factors, including climate change and long-term trends in atmospheric circulation.

To answer this question, let us outline the factors affecting the installation of a high-pressure crest. Changes in global climate can lead to changes in atmospheric circulation behavior, including the frequency and duration of high-pressure ridges. An increase in global average temperature can affect pressure distribution and the formation of high-pressure ridges. Greenhouse gas emissions, land-use changes, military actions and other anthropogenic actions can alter regional climatic conditions and affect atmospheric circulation. Natural climatic phenomena, such as El Niño and La Niña, can affect pressure distribution and the formation of high-pressure ridges.

In addition, the answer to the question posed requires the analysis of historical data and modeling. Analysis of climate data from recent decades can help determine whether recent years are isolated occurrences or part of a longer trend. The study already shows that the frequency and duration of high-pressure ridges are increasing due to global warming, leading to more frequent extreme weather events, such as heat waves and droughts.

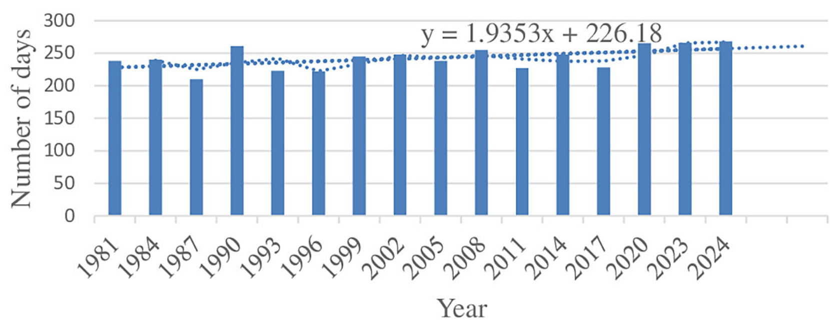

Figure 3. Dynamics of changes in the number of hot days (Tmax ≥ 25 °C) from 1981 to 2024

Forecast calculations indicate a significant probability of an increase in the frequency and intensity of such phenomena in the future if global warming continues.

However, in order to give an accurate answer to the question of whether such phenomena will become a pattern, further research and analysis are needed. At the moment, there is a tendency to increase the frequency and duration of high-pressure ridges due to climate change, but long-term observations and improvements in climate models are needed to determine the exact pattern.

CONCLUSIONS

Over the period 1991–2024, the average annual temperature in the Mykolaiv region increased by 1.2 °C, and the rate of temperature increase in some regions reached 0.82 °C per decade, which exceeds the global rate of increase (0.34 °C/10 years). The maximum increase in average annual temperatures was recorded in 2023 and 2024, while 1985 and 1987 were the coldest. The growth rate of the average temperature is 0.61 °C in 10 years. The summer months show the greatest extreme temperatures, with an average maximum temperature of 29.6 °C in August and up to 20 tropical nights in July with minimum temperatures above 20 °C.

Over the past 30 years, the average number of hot days in the region has increased by 1.94 each year. In 2024, the number of such days has significantly exceeded the average values for previous decades. The global temperature in April 2024 was 15.03 °C, which is 0.67 °C higher than the average for 1991–2023 and is a new record. However, the temperature maximum in Mykolaiv was recorded in 1998 (40.1 °C), the minimum in 2006 (−25.9 °C).

Climate changes have caused an increase in the duration of the warm period to 300 days a year, active vegetation lasts about 187 days, which shifts the flowering period 3 weeks earlier than average.

Acknowledgements

We would like to thank the EU Erasmus+ Programme for supporting the research work in the framework of the JM project based on Petro Mohyla Black Sea National University in collaboration with colleagues from the University of Presov, Slovakia, and State University of Applied Sciences in Nowy Sacz, Poland.

REFERENCES

1. April 2024 – 11th consecutive warmest month globally. URL : http://surl.li/tsbdm
2. Bernatska, N.; Dzhumelia, E.; Dyakiv, V.; Mitryasova, O.; Salamon, I. (2023). Web-Based information and analytical monitoring system tools–online visualization and analysis of surface water quality of mining and chemical enterprises, *Ecological Engineering & Environmental Technology, 24*(3), 99–108.
3. Bezsonov, Ye.; Mitryasova, O.; Smyrnov, V.; Smyrnova, S. (2017). Influence of the South-Ukraine electric power producing complex on the ecological condition of the Southern Bug River. *Eastern-European Journal of Enterprise Technologies, 4*(10), (88), 20–28.
4. Climate Change (2013): *The Physical Science Basis. IPCC Working Group I Contribution to AR5: Approved Summary for Policymakers.* URL : http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf
5. Copernicus Interactive Climate Atlas. URL : https://atlas.climate.copernicus.eu/atlas
6. European Environment Agency (EEA), 2023. URL: https://www.eea.europa.eu/en
7. IPCC, 2021: Climate Change 2021: Climate Change 2021*: The Physical Science Basis*. https://www.ipcc.ch/report/ar6/wg1/
8. Ishchenko, V., Pohrebennyk, V., Kochan, R., Mitryasova, O., Zawislak S. (2019). Assessment of hazardous household waste generation in Eastern Europe. *International Multidisciplinary Scientific Geoconference SGEM*, Albena, Bulgaria. 30 June – 6 July 2019, 6.1, 19, 559−566.
9. Kochanek, A., Kobylarczyk, S. (2024). The analysis of the main geospatial factors using geoinformation programs required for the planning, design and construction of a photovoltaic power plant. *J. Ecol. Eng. 25*, 49–65.
10. Kwaśnicki P., Augustowski D., Generowicz A., Kochanek, A. (2024). Influence of Ti Layers on the efficiency of solar cells and the reduction of heat transfer in building-integrated photovoltaics. *Energies, 17*, 5327.
11. Mats, A., Mitryasova, O., Salamon, I., Smyrnov, V. 2025. Spatial-temporal characteristics of surface water quality. *Journal of Ecological Engineering, 26*(1), 204−212.
12. Mitryasova, O., Pohrebennyk, V., Kochanek, A., Sopilnyak, I. (2016). Correlation interaction between electrical conductivity and nitrate content in natural waters of small rivers. *International Multidisciplinary Scientific Geoconference SGEM*, Vienna, Austria, 2 November – 5 November 2016, 3, 357–365.
13. Mitryasova, O., Pohrebennyk, V., Kardasz, P. (2018). Hydrochemical Aspects of Surface Water Quality

Assessment. *18th International Multidisciplinary Scientific Geoconference SGEM 2018*, Albena, Bulgaria. 30 June – 9 July 2018, 5.2(18), P. 513–520.

14. Mitryasova, O., Pohrebennyk, V., Salamon, I., Oleksiuk, A., Mats, A. (2021). Temporal patterns of quality surface water changes, *Journal of Ecological Engineering, 22*(4), 283–295.
15. National Report on the State of the Natural Environment in the Mykolaiv Region in (2023). Mykolaiv, 2023, 221. (in Ukrainian).
16. Pohrebennyk, V., Cygnar, M., Mitryasova, O., Politylo, R., Shybanova, A. (2016). Efficiency of Sewage Treatment of Company «Enzyme». *16th International Multidisciplinary Scientific Geoconference SGEM 2016*, Albena, Bulgaria, 30 June – 6 July 2016, Book 5, Ecology, Economics, Education and Legislation, Volume II, Ecology and Environmental Protection, 295–302.
17. Pohrebennyk V., Mitryasova, O., Dzhumelia, E., Kochanek A. (2017). Evaluation of Surface Water Quality in Mining and Chemical Industry. *17th International Multidisciplinary Scientific Geoconference SGEM 2017*, Albena, Bulgaria, 29 June – 5 July 2017, 51(17), 425–432.
18. Tuz R. (2022). Global climate changes and their impact on the state of water resources in the Mykolaiv region. Preserved for our future. XV Mykolaiv municipal ecological conference, Mykolaiv, November 30, 2022. Mykolaiv, Mykolaiv, 2023, 88–91. (Tuz R. V. Hlobalni zminy klimatu ta yikh vplyv na stan vodnykh resursiv Mykolaivskoi oblasti. Zberezhemo dlia nashchadkiv. XV Mykolaivskykh miskykh ekolohichnykh chytan, Mykolaiv, 30 lystopada 2022., Mykolaiv, 2023, 88–91) (in Ukrainian).
19. Shevchenko, O. et al. (2014). Climate Change Vulnerability Assessment: Ukraine. Kyiv, 2014, 74. URL: https://necu.org.ua/wp-content/uploads/ukraine_cc_vulnerability.pdf (Shevchenko O. ta in. Otsinka vrazlyvosti do zminy klimatu: Ukraina. Kyiv, 2014, 74) (in Ukrainian).
20. Ventusky. URL : https://www.ventusky.com/uk/mykolayiv
21. WMO Provisional State of the Global Climate 2024, WMO, 2024. https://library.wmo.int/index.php?lvl=notice_display&id=22156#.Y4csiHbP02z
22. UN Framework Convention on Climate Change. URL : https://unfccc.int/
23. Ukrainian Hydrometeorological Center. https://www.meteo.gov.ua/en/
24. UNEP Global Environment Monitoring System. https://www.unep.org/annualreport/2023