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MODERN TRENDS IN THE TRANSFORMATION OF NATURAL-GEOGRAPHICAL PROCESSES UNDER GLOBAL CLIMATE CHANGE

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Abstract
The article analyzes current trends in changes in natural and geographical processes in the context of global climate change, considered as one of the key factors in the transformation of the natural environment at the global and regional levels. The main focus is on changes in temperature and precipitation conditions, which have a direct impact on the dynamics of hydrological, geomorphological, soil and biogeographic processes. It is shown that an increase in the average air temperature contributes to the intensification of evaporation processes, degradation of glaciers and permafrost, as well as changes in the seasonality of river runoff. The intensification of extreme climatic events, including droughts, floods, and heat waves, leads to increased erosion, land degradation, and reduced stability of landscape systems. There is a shift in the boundaries of natural zones, a change in the structure and functioning of ecosystems, as well as a decrease in biodiversity. The article emphasizes that the transformation of natural and geographical processes is complex and interrelated, increasing environmental and socio-economic risks. It is concluded that it is necessary to develop integrated approaches to monitoring climate-related changes and developing adaptation strategies aimed at preserving the stability of natural systems and optimizing environmental management in a changing climate.
Keywords: global climate change, natural and geographical processes, climatic changes, extreme natural phenomena, adaptation to climate change.

Introduction

Global climate change is a long-term modification of changes in the Earth's climatic characteristics (temperature, precipitation, winds, etc.) that occur under the influence of anthropogenic factors (greenhouse gas emissions, deforestation, etc.) and natural cycles. These changes have a significant impact on natural and geographical processes - that is, processes that form the natural environment (soil formation, hydrology, vegetation, relief, etc.).

In the context of accelerating global climate change, natural and geographical processes are undergoing significant transformations that affect the functioning of natural systems and the sustainability of landscapes. An increase in the average global temperature, a change in the nature of precipitation and an increase in the frequency of extreme climatic events create new conditions for the development of the natural environment that go beyond the natural variability of the climate. In this regard, the study of modern trends in natural and geographical processes acquires special scientific and practical significance [Leung L.R. et al., 2023].

Natural and geographical processes, including climatic, hydrological, geomorphological, and biogeographic components, are closely interrelated and form complex natural systems. Disruption of one of the elements under the influence of climatic factors leads to chain changes in other processes, which is manifested in ecosystem degradation, landscape transformation and increased natural risks. In recent decades, these changes have been characterized by increasing intensity and spatial heterogeneity [Balachandran N. et al., 1999].

The relevance of this work is determined by the need for a comprehensive analysis of climate-related changes in natural and geographical processes in order to assess their consequences for environmental management, territorial planning and environmental safety. The purpose of the article is to identify the main current trends in the transformation of natural and geographical processes in the context of

global climate change and substantiate the need to develop adaptive approaches to environmental management [Bender M.A. et al., 2010].

Main body

Global climate change in recent decades has manifested itself in a steady increase in the average temperature of the surface layer of the atmosphere and an increase in climate variability. These changes have a direct impact on the functioning of natural and geographical processes that determine the dynamics of natural systems. The increase in the temperature background is accompanied by an increase in evaporation, a change in the balance of heat and moisture, as well as a violation of established climatic conditions. As a result, new conditions are formed for the flow of hydrological, geomorphological and biogeographic processes, which leads to the transformation of landscapes and a decrease in their stability [Sabine C.L., 2004; Chen I.C. et al., 2011; Kharlamova N.F., 2011].

One of the most sensitive areas to climate change is the hydrological regime. Changes in the amount and seasonal distribution of precipitation, as well as a decrease in snow cover, lead to a restructuring of river flow. There is an increase in the proportion of flood runoff, an increase in the frequency of floods and a decrease in the stability of water resources during dry periods. In mountainous areas, glacier degradation has a significant impact, which leads to a short-term increase in runoff, and in the long term to its reduction. These processes have significant impacts on water supply, agriculture, and ecosystems [Zheleznova I. et al., 2022].

Climate-related changes increase the intensity of exogenous geomorphological processes. An increase in the frequency of extreme precipitation contributes to the activation of water erosion, the formation of ravines and the intensification of slope processes. In arid climates, the role of wind erosion and deflation increases, leading to soil degradation and desertification. The melting of permafrost contributes to the development of thermokarst processes, landslides and deformation of the Earth's surface, which significantly changes the relief and complicates the economic development of territories [Abdusamatov Kh.I., 2009].

Changing climatic conditions affect the structure and functioning of ecosystems. There is a shift in the boundaries of natural zones, a change in the distribution areas of plant and animal species. In a number of regions, there is a decline in biodiversity associated with the inability of individual species to adapt to rapid changes in environmental conditions. At the same time, the processes of landscape transformation are intensifying, resulting in changes in vegetation cover, disruption of soil processes and a decrease in ecosystem services.

Current climate trends are accompanied by an increase in the frequency and intensity of extreme natural events such as droughts, floods, forest fires, and heat waves. These processes have a complex impact on the natural and geographical environment, accelerating the degradation of landscapes and increasing the level of natural risks. The growing number of extreme climate events requires a revision of approaches to assessing the sustainability of natural systems and the development of adaptation measures aimed at reducing the negative effects of climate change.

Recent years on Earth have become the warmest on record. The number of hot days and heat waves had increased in almost all regions of the planet. As a result, the incidence of diseases has increased, leading to restricted outdoor productivity and an increased susceptibility to wildfires. Coastal countries have seen an increase in severe storms (Figure 1).

Due to the increase in temperature and evaporation of moisture, the number of heavy rains and floods has increased. Tropical cyclones, hurricanes and typhoons are born in warm ocean water, which then, growing, destroy houses and entire villages, lead to loss of life and huge economic losses.

Due to climate change, fresh water on Earth is becoming increasingly scarce, especially in regions where water resources were previously scarce. There are more and more agricultural and environmental droughts in the world that affect crops and ecosystems. The area of deserts on the planet is getting bigger and bigger.

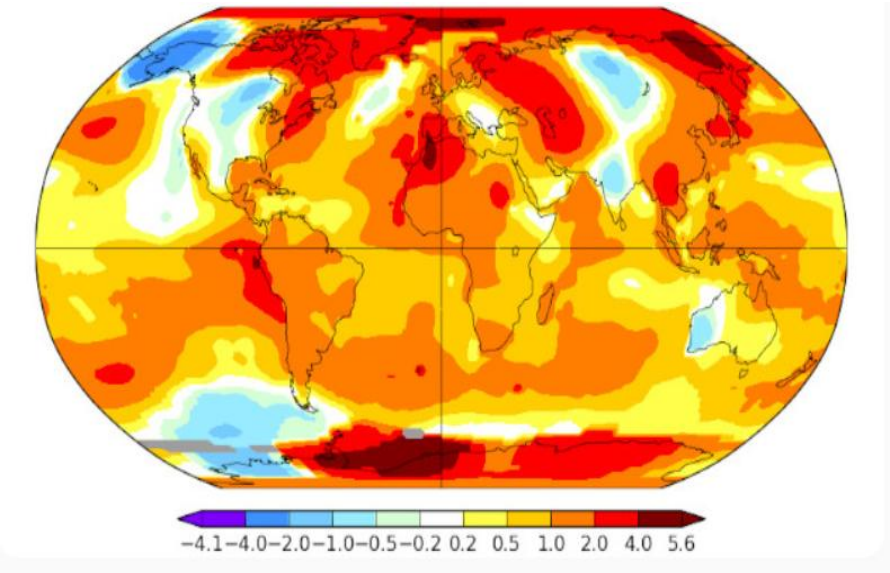


Figure 1. Air temperature change over the last 50 years

The waters of the world's oceans actively absorb the heat generated by global warming. Over the past 20 years, the rate of ocean warming has increased and its volume has increased. The melting of Arctic and Antarctic ice is also leading to an increase in ocean levels. All this threatens the population of coastal countries and islands. In addition, the oceans absorb carbon dioxide from the air. This increases the acidity of the water, which negatively affects coral reefs, underwater flora and fauna.

Literature review

Modern research in the field of climate change demonstrates the undeniable impact of global warming on natural and geographical processes in all elements of the geographical envelope. Hydrological systems are becoming a key object of study: numerous reviews show that climate change significantly disrupts the water cycle, affecting the temperature regime of rivers, changes in the distribution of precipitation and snowmelt, which leads to changes in water availability and sustainability of freshwater ecosystems [Karl T.R., Trenberth K.E., 2003; National Academy of Sciences, 2020].

The literature also pays special attention to the impact of climate change on geomorphological processes. Climate change increases the intensity of precipitation and extreme weather events, which, in turn, leads to accelerated soil erosion, changes in the dynamics of river systems and the redistribution of sedimentary material. These processes are reflected in the formation of new landforms and the degradation of the soil cover.

Studies of the impact of climate change on ecosystems and biogeographic boundaries show that warming of the atmosphere and changes in humidity conditions lead to changes in the habitat of plants and animals, changes in the structure of communities and a reduction in biodiversity. Along with this, the climate risks associated with extreme events (droughts, floods, fires) are increasing, which complements the complex picture of the transformation of the natural environment [Chen I.C. et al., 2011; Lioubimtseva E., Henebry G.M., 2009]. In addition, the scientific literature highlights regional aspects of changes in natural and geographical processes, including research on the adaptation of natural and economic systems to climate change. For example, the analysis of climate trends and their impact on water resources and agriculture in Central Asian countries highlights the need to develop adaptive models of natural resource management [Tursunova A. et al., 2022; Medeu A. et al., 2017].

Thus, modern literature demonstrates the interdisciplinary nature of research in the field of climate change, from hydrology and geomorphology to ecology and adaptation management, which makes it possible to more fully assess the impact of global climate change on natural and geographical processes.

Methodology

The methodological basis of the research is based on the principles of systematic and integrated approaches, which make it possible to consider natural and geographical processes as interrelated elements of a geographical shell, the functioning of which is determined by the combined effects of climatic and natural factors. In the framework of the study, global climate change is considered as a key exogenous factor exerting a multilevel influence on climatic, hydrological, geomorphological and biogeographic processes.

The theoretical and methodological basis of the work is the concepts of sustainable development, landscape and ecological analysis, and the theory of climate-related changes in natural systems. The research uses the provisions of modern climatology, physical geography and geoecology, reflected in the works of domestic and foreign authors.

The main research methods used were the analysis and generalization of scientific literature, comparative geographical and historical geographical methods, which make it possible to identify the spatial and temporal features of changes in natural and geographical processes. The method of data systematization is used to identify the main trends in the transformation of the natural environment in the context of global climate change [Alekseev G.V., 2015; Kharlamova N.F., 2011].

Methods of statistical analysis of climatic series (air temperature and precipitation), as well as methods of interpretation of remote sensing data and cartographic analysis were used to assess climate changes and their impact on natural and geographical processes. The use of geographic information systems (GIS) made it possible to visualize the spatial distribution of climate-related changes and assess their regional characteristics.

The integrated application of these methodological approaches and methods ensured the validity of the conclusions and made it possible to identify current trends in changes in natural and geographical processes in the context of global climate change [Ivchenko G.I. et al., 2023; Kuderin A. et al., 2021].

Results

In the course of the conducted research, stable modern trends in changes in natural and geographical processes caused by global climate change have been identified. It has been established that an increase in the average air temperature is a determining factor in the transformation of climatic and related natural processes. The increase in temperatures is accompanied by an increase in evaporation, a reduction in snow cover and a change in the seasonal dynamics of climatic parameters, which has a direct impact on the hydrological regime and the stability of natural systems.

The results of the analysis of hydrological processes have shown that in various regions of the world there is a redistribution of river runoff, expressed in an increase in the proportion of flood runoff and a decrease in water availability during dry periods. In mountainous areas, a tendency to reduce glacial resources has been revealed, which leads to a short-term increase in river water content followed by a long-term decrease in runoff. These changes increase water scarcity and increase the vulnerability of ecosystems and economic systems.

In the field of geomorphological processes, an increase in water and wind erosion, activation of slope processes and the development of thermokarst landforms in areas of permafrost degradation was established. These processes lead to accelerated transformation of the relief and degradation of the soil cover.

The results of the analysis of biogeographic changes indicate a shift in the boundaries of natural zones, a change in the structure of vegetation cover and a reduction in biodiversity in a number of ecosystems. An increase in the frequency and intensity of extreme natural events, including droughts, floods and forest fires, has been noted, which increases the level of natural and environmental risks. The results obtained confirm the complex and interrelated nature of changes in natural and geographical processes and indicate the need to develop adaptation strategies and system monitoring in the context of ongoing global climate change.

Discussion

The results obtained confirm the conclusions of modern domestic and foreign studies on the systemic nature of the impact of global climate change on natural and geographical processes. The revealed increase in average air temperature and increased climate variability are consistent with the estimates presented in the reports of the Intergovernmental Panel on Climate Change (IPCC), according to which the temperature factor is a key factor in the transformation of natural systems.

Changes in the hydrological regime, expressed in the redistribution of river flow and the growth of extreme hydrological phenomena, correspond to the results of studies indicating an increased water imbalance in the context of climate change. The reduction of glacial resources and the decrease in snow cover of rivers recorded in mountainous areas confirm the conclusions about a short-term increase in water supply followed by a decrease in water resources in the long term. This indicates the growing vulnerability of water resource management systems and the need to review approaches to water resource management.

The results discussed in the field of geomorphological processes reflect the trend of increased exogenous processes, including water and wind erosion, slope deformations, and the development of thermokarst landforms. Such changes are widely considered in the scientific literature as a consequence of increased precipitation and permafrost degradation, which leads to accelerated transformation of the relief and degradation of the soil cover.

The shifting boundaries of natural zones and changes in the ecosystem structure revealed during the study confirm the biogeographic concepts of climate-related changes in species ranges. The reduction of biodiversity and the increase in the frequency of extreme natural events increase environmental risks and indicate a decrease in the sustainability of natural landscapes. Taken together, this highlights the need to integrate climate forecasts into spatial planning systems and develop adaptation measures aimed at increasing the resilience of natural geographic systems in the face of ongoing climate change.

Conclusion

The study showed that global climate change has a complex and multicomponent impact on natural and geographical processes, manifested at the regional and local levels. An increase in the average air temperature and increased climatic variability are key factors in the transformation of natural systems and determine the direction of modern changes. It is revealed that the transformation of the hydrological regime is expressed in a change in the seasonal distribution of river runoff, an increase in the frequency of extreme hydrometeorological events and a reduction in sustainable water resources. Regions with glacial-snow river feeding are particularly vulnerable, where there is a tendency for a short-term increase in water content followed by a decrease in runoff in the long term.

The intensification of exogenous geomorphological processes, including erosion, landslides and soil degradation, has been established, which is associated with an increase in precipitation intensity, melting of permafrost and an increase in anthropogenic load. These changes lead to an accelerated restructuring of the relief and a decrease in the stability of landscapes.

Climate-related changes have been proven to shift the boundaries of natural zones, transform ecosystems, and reduce biological diversity, which increases environmental and socio-economic risks. In general, the results of the study emphasize the need to take into account climatic factors in the system of territorial planning, rational use of natural resources and the development of adaptation strategies aimed at reducing the negative effects of climate change and increasing the sustainability of natural geographic systems.

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Ғаламдық климаттың өзгеруі жағдайында табиғи-географиялық процестердің трансформациясының қазіргі үрдістері

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Аннотация
Мақалада ғаламдық климаттың өзгеруі жағдайында табиғи-географиялық процестердің қазіргі заманғы өзгеру үрдістері талданады, олар табиғи ортаның ғаламдық және аймақтық деңгейлерде трансформациялануының негізгі факторларының бірі ретінде қарастырылады. Негізгі назар гидрологиялық, геоморфологиялық, топырақтық және биогеографиялық процестердің динамикасына тікелей әсер ететін температуралық режим мен ылғалдану жағдайларының өзгеруіне аударылады. Ауа температурасының орташа мәнінің жоғарылауы булану процестерінің қарқындануына, мұздықтар мен көпжылдық тоңның деградациясына, сондай-ақ өзен ағынының маусымдылығының өзгеруіне ықпал ететіні көрсетілген. Құрғақшылық, су тасқыны және ыстық толқындары сияқты экстремалды климаттық құбылыстардың күшеюі эрозиялық процестердің артуына, жер ресурстарының деградациясына және ландшафтық жүйелердің тұрақтылығының төмендеуіне алып келеді. Табиғи аймақтар шекараларының ығысуы, экожүйелердің құрылымы мен қызмет етуінің өзгеруі, сондай-ақ биологиялық әртүрліліктің азаюы атап өтіледі. Табиғи-географиялық процестердің трансформациясы кешенді әрі өзара байланысты сипатқа ие болып, экологиялық және әлеуметтік-экономикалық тәуекелдердің артуына әкелетіні көрсетіледі. Климатқа байланысты өзгерістерді мониторингтеудің интеграцияланған тәсілдерін әзірлеу және өзгермелі климат жағдайында табиғи жүйелердің тұрақтылығын сақтау мен табиғатты пайдалануды оңтайландыруға бағытталған бейімделу стратегияларын қалыптастыру қажеттілігі туралы қорытынды жасалады.
Түйін сөздер: ғаламдық климаттың өзгеруі, табиғи-географиялық процестер, климаттық өзгерістер, экстремалды табиғи құбылыстар, климаттың өзгеруіне бейімделу.

Современные тенденции трансформации природно-географических процессов в условиях глобального изменения климата

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Аннотация
В статье анализируются современные тенденции изменения природно-географических процессов в условиях глобального изменения климата, рассматриваемого как один из ключевых факторов трансформации природной среды на глобальном и региональном уровнях. Основное внимание уделяется изменениям температурного режима и условий увлажнения, которые оказывают непосредственное влияние на динамику гидрологических, геоморфологических, почвенных и биогеографических процессов. Показано, что повышение средней температуры воздуха способствует интенсификации процессов испарения, деградации ледников и многолетней мерзлоты, а также изменению сезонности речного стока. Усиление экстремальных климатических явлений, включая засухи, наводнения и волны жары, приводит к увеличению эрозионных процессов, деградации земель и снижению устойчивости ландшафтных систем. Отмечается смещение границ природных зон, изменение структуры и функционирования экосистем, а также сокращение биологического разнообразия. Подчеркивается, что трансформация природно-географических процессов носит комплексный и взаимосвязанный характер, что усиливает экологические и социально-экономические риски. Сделан вывод о необходимости разработки интегрированных подходов к мониторингу климатообусловленных изменений и формированию адаптационных стратегий, направленных на сохранение устойчивости природных систем и оптимизацию природопользования в условиях меняющегося климата.
Ключевые слова: глобальное изменение климата, природно-географические процессы, климатические изменения, экстремальные природные явления, адаптация к изменению климата.

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