The impact of socio-economic factors on the Arctic sea ice cover

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Abstract. The Arctic sea ice is an essential element of the Earth's climate system. It regulates the regional balance of heat and fresh water, the subsequent circulation of the atmosphere and the ocean in the Arctic zone as well as in lower latitudes. The given article demonstrates how socio-economic factors affect the volume of the Arctic sea ice. It also provides the detailed analysis: the climate change assessment in the Arctic zone is presented and the role of various factors intensifying climate changes in the Arctic zone are considered. With the economic growth of the country, the consumption of the population increases and this fact affects the environment; as a result, industrial growth contributes to the increasing of the emissions of pollutants and greenhouse gases. Climate change is not a fiction and it is obvious that anthropogenic emissions have increased. The authors of the article associate the ecosystems of the Arctic zone with economic systems. The measures aimed at the development of the economy and the environment of the region are proposed. Applying new technologies Industry 4.0 will allow the economy to grow exponentially.

Key words: climate, the Arctic zone, ecology, natural resources potential, socio-economic factors

1. Introduction

The Arctic sea ice has an enormous impact on the formation of the climate system of our planet. It protects the planet from overheating by reflecting sun’s rays and plays an important role in the circulation of the Ocean waters.

The recent scientific studies show that a latitudinal temperature gradient decreases due to climate warming in the Arctic zone; as a result, the difference between temperatures at the poles and the tropics decreases. It reduces cyclone intensity, the flow of humid air from the Arctic zone to the middle latitudes and consequently the amount of precipitation in the middle latitudes decreases. It results in a shortage of water resources. In the Arctic zone, the temperature rise is twice the world average, at the same time the temperature rise is strongly influenced by the increase of the amount of greenhouse gases in the atmosphere.

The global warming in the Arctic zone changes the direction of air masses in the south and it can cause colder winters and lead to the stunt of plant growth. The changes in the structure of the Arctic food chain has affected commercial fishing around the world.

The Arctic sea ice melting provides the opportunities for extraction and processing of natural resources [1]. (The Figure 1 – Arctic Sea Ice Volume)

Figure 1 – Arctic sea ice volume (m³)

The development of Arctic hydrocarbons is not always considered safe taking into account extreme working conditions and the excessive risk of further carbon dioxide pollution. The Arctic zone also offers water, wind, geothermal, tidal, and solar power [2]. However, the economic
development of the Arctic zone results in negative aspects: changes in temperature, salinity, sea ice behavior and ocean acidification. All these factors have a significant impact on the flora and fauna of the region.

The article aims to present assessments of the climate change occurring in the Arctic zone in the period of current global warming and to determine the role of various factors, primarily socio-economic, in the terms of global warming in the Arctic zone. The successful economy in the Arctic region should be based on optimal parameters of the ecosystem.

2. Ecological issues facing the Arctic zone

Humans actively intervene into natural processes: the creation of artificial environments, objects of physical and intellectual culture, artificial ecosystems and devices. Humans have currently destroyed almost 70% of the natural ecosystem. It is obvious that people continue destructive environmental activities, since their survival is based on this activity. As a result, ecologists discuss the balance in bio-, noo- and technospheres. The impact on nature must be controlled so that humans do not become biologically extinct [3].

One of the key issues of environmental problems is the impact of the greenhouse effect. It happens due to the use of fossil fuels. Coal, oil and gas have long been excluded from the material cycle. When fossil fuels (coal, oil, gas) are burned, 20 billion tons of carbon dioxide are released into the atmosphere annually. Carbon dioxide has a great impact on the heat balance of the Earth (The Figure 2 - СО₂ Emissions).

Figure 2 – СО₂ Emissions

The greenhouse effect produces global warming. As global temperatures heat up, ocean levels rise. In recent months, NASA has initiated research projects that studied how the human response to the COVID-19 pandemic has affected our environment; for example, the improvement of air quality as a result of the reduction of motor-vehicle traffic in many places.

Another element of the global environmental crisis is the destruction of the ozone layer. The ozone layer is a natural filter that absorbs harmful ultra-violet rays. The destruction of the ozone layer is the result of spontaneous pollution, in which pollutants travel quite rapidly along the Earth's surface and spread over great distances.

Acid compounds also negatively affect the global ecological process. They are released into the atmosphere along with the exhaust of vehicles, heat power plants, etc. As a result, acid depositions are formed and they negatively affect the ecological balance of the planet.

At the same time, the problem of radioactive waste disposal is becoming more and more serious, which, in its turn, is the part of the global environmental problem. The method of transporting radioactive material has not been sufficiently studied [4,5].

Numerous studies carried out by scientists around the world have recorded an increase in the temperature on the Earth's surface, as well as in the atmosphere and oceans. Many other aspects of the global climate are changing as well. High temperature extremes and heavy precipitation are increasing, glaciers and snow cover are shrinking, and sea ice is retreating. The seas are warming, rising and becoming more acidic, while floods are becoming more frequent. The growing season lasts longer and large forest fires happen more frequently. Many species move to new locations, and it leads to changes in the seasonal timing of important biological events and changing of the global climate.

All of these trends are consistent with global warming and they are expected to continue. Much evidence suggests that human activities, especially the emissions of heat traps, greenhouse gases, burning of fossil fuels, deforestation and land use change, are primarily responsible for the climate change that was observed during the Industrial age, especially over the past six decades. The concentration of carbon dioxide in the atmosphere, which is the largest contributor to anthropogenic warming, has increased by about 40% over the Industrial age. This change has
exacerbated the natural greenhouse effect, causing an increase in global surface temperature and other widespread changes in the Earth’s climate that may be considered as unprecedented in the history of modern civilization.

Greenhouse gas emissions caused by human activities will continue to affect the Earth’s climate for the coming decades and even centuries. Humans add carbon dioxide to the atmosphere at a much faster rate than it is removed by natural processes, creating a long-lived reservoir of gas in the atmosphere and oceans and as a result it makes the climate warmer and warmer [6].

Over the next few decades, strong climate change will depend primarily on the amount of greenhouse gases released into the atmosphere, the amount of greenhouse gases absorbed by the ocean, the biosphere and other absorbers and the sensitivity of the Earth’s climate to these emissions. The impact of the Arctic zone on the global climate and the ecology of the planet is undeniable. It is possible to identify the factors on which the stability and ecological balance of the planet depend. Measures to reduce greenhouse gas emissions are being taken at the global, national and subnational levels. The idea of limiting global average warming to a certain value has long been considered in the scientific literature. This issue has become important for political debates [7,8]. The Paris Agreement of 2015 has recently adopted the long-term objective “of holding the temperature increase to “well below 2 °C” above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels”. These targets were developed to avoid the most severe climate impacts; however, they should not be viewed as thresholds below which there are zero risks and above which multiple tipping points occur (i.e. the point at which a change in the climate triggers a significant environmental event that may be permanent). To achieve the long-term temperature target of the Paris Agreement, the parties to the Agreement aim “to reach global peaking of emissions as soon as possible and to undertake rapid reductions thereafter”. The Paris Agreement has been ratified by 180 parties to the United Nations Framework Convention on Climate Change: they together accounted for 88 percent of total global emissions.

3. The impact of socio-economic factors on ecology

More frequent and intense extreme weather and climate-related events as well as changes in average climate conditions will continue to damage infrastructure, ecosystems, and social systems. Climate change is expected to destroy many spheres of life in the years to come, to worsen existing problems of prosperity that are associated with aging and deteriorating infrastructure, strained ecosystems and economic inequality [9]. Global action to decrease greenhouse gas emissions significantly can reduce climate-related risks dramatically.

When there are no significant global mitigation measures and efforts of the countries to adapt, it is expected that an increase in temperature will cause changes in the ecosystem, destroy and damage infrastructure, productivity and human health. Economies and industries that depend on natural resources and favorable climatic conditions, such as agriculture, tourism and fisheries, are vulnerable to the growing effects of climate change. The effects of climate change will negatively impact trade and economy, including import and export prices. Global warming will cause an increase in global greenhouse gas emissions and significant damage to the global economy.

Climate change brings additional risks to interconnected systems that are already affected by a range of stress factors, such as aging and deteriorating infrastructure, land-use change and population growth. Extreme climate and weather impact on one system can increase the risks or crash other fundamental systems, including water resources, production and distribution of food, energy and transport, health care, international trade, and national security. The total risks of climate change for interconnected systems, many of which include regional and national boundaries, often exceed the sum of the risks for individual sectors. Failure to foresee interrelated consequences can lead to missed opportunities to manage the risks of climate change effectively, as well as to the adoption of management measures that increase risks to other sectors and regions [10]. Collaborative planning with concerned parties from different sectors, regions and jurisdictions can help identify critical risks caused by interactions between systems.
The future risks associated with climate change depend primarily on the decisions made today. Since the third National Climate Assessment was released in 2014, there has been a significant increase in the integration of climate risks in the process of decision-making, including financial risk reporting, capital investment planning, engineering standards development, military planning, and disaster risk management. Mitigation and adaptation activities also offer opportunities to get complimentary benefits that are often local in nature, such as improving local air quality and economy through infrastructure investment. Some benefits, such as ecosystem restoration and enhancing community resilience, are difficult to evaluate.

Changes in temperature and precipitation worsen air quality and health risks caused by forest fires and ground-level ozone pollution. Increases in air and water temperature and more extreme climate-related events are expected to increase exposure to waterborne and foodborne diseases. This, in its turn, will affect food and water safety. With continued warming, cold-related deaths are expected to reduce and heat-related deaths are expected to increase; in most regions, the increases in heat-related death are projected to outpace the reductions in cold-related deaths. The frequency and severity of allergic diseases, including asthma and hay fever, are expected to increase as a result of global climate change.

Climate change is threatening more and more livelihoods, economies, health and cultural identity of indigenous communities and destroying interconnected social, physical and ecological systems.

Many indigenous people depend on natural resources for their economic, cultural and physical well-being and they are often affected by unique climate change. The impacts of climate change on aquatic, land, coastal and other natural resources, infrastructure and related services are expected to undermine livelihoods and economies of indigenous peoples, including agriculture, farm forestry, fishing industry, recreation, and tourism. Adverse consequences for human life are already being observed. As climate change continues, adverse impacts on culturally significant species and resources are expected to result in negative physical and mental health consequences. Climate impacts make some indigenous people consider or pursue relocation as an adaptation strategy; as a result, it causes challenges in maintaining cultural identity and community continuity. At a time when economic, political and infrastructural limitations can affect the ability of these communities to adapt, closely connected social and cultural networks offer opportunities to build community capacity and enhance resilience [11]. A lot of indigenous people undertake adaptation measures due to climate change impacts. They are based on self-determination and traditional knowledge; some tribes are pursuing mitigation actions by means of developing renewable energy on tribal lands.

Ecosystems and the benefits they bring to society are changing as a result of climate change, and these impacts are expected to continue. Without significant and sustained reductions in global greenhouse gas emissions, there will be transformative impacts on some ecosystems; some coral reef and sea ice ecosystems are already affected by such transformational changes.

Numerous advantages provided by ecosystems and the environment, such as clean air and water, coastal flood protection, wood and fiber, crop spraying, hunting and fishing, tourism, cultural identity and many other things will continue to worsen under the impact of climate change. Increases in the frequency of forest fires, changes in insect population, disease outbreaks, and other stress factors are expected to reduce the ability of forests to support economic activity, recreation and subsistence production. Climate change has significantly affected biodiversity, ecosystems and those benefits it brings to society [12]. These impacts include the migration of indigenous people to new areas and the spread of invasive species. According to projections, such changes are expected to continue, and without significant and sustained reductions in global greenhouse gas emissions, it is impossible to avoid extinction and transformational impacts on some ecosystems over the long period of time. Valued aspects of regional heritage and quality of life tied to ecosystems, wildlife, and outdoor recreation will transform along with climate change; as a result, future generations are expected to experience and interact with the environment in ways that are much different than today. To resolve the issues related to climate change impacts, it is necessary to understand that CO2 emissions are one
of the key factors affecting the Arctic sea ice cover. Despite the fact that some counteracting measures are currently being implemented, many consequences, including the loss of unique coral reef ecosystems and sea ice, can be avoided by means of significant reduction in global emissions of carbon dioxide and other greenhouse gases. Let us turn to the processes taking place in the Arctic zone. When the climate gets warmer, the increase in the surface air temperature in the Arctic zone rises at a more than twice the rate of global mean temperatures due to anthropogenic increase in the concentration of carbon dioxide; thus, it is necessary to understand the mechanism of this amplification. In this regard, it is necessary to identify macroeconomic, social factors reflecting human activity and their impact on the environment, the climate in general and the Arctic sea ice in particular, as well as the mechanism and lever of influence of human activity on the Arctic climate.

4. Data, variables and model
A standard linear model, that is estimated by means of using the method of least squares (LSM, OLS), has been used in the given work.

where \( Y_t \) is the dependent variable per year, \( X_t \) is the vector of independent variables per year, \( \beta \) is the parameter vector of the variables of the regression. Using this approach is due to the lack of autocorrelation, which is confirmed by the corresponding tests.

Time series from 1990 to 2014, annual date have been used. The volume of ice was taken as a dependent variable (http://psc.apl.uw.edu/research/projects/arctic-sea-ice-volume-anomaly/data/). Energy use (kg of oil equivalent per capita; \( X_1 \)); electricity power consumption (kWh per capita, \( X_2 \)); GDP per unit of energy use (constant PPP $ 2017 per kg of oil equivalent, \( X_3 \)); Patent applications, nonresidents (PAF) (\( X_4 \)) have been used as independent variables. The last variable is the proxy variable for R&D [13]. Information about regressors has been collected from the World Bank database [https://data.worldbank.org/indicator?tab=all].

According to Perry Sadorsky [14] it is important to analyze the factors affecting CO2 emissions and related to socio-economic indicators. The Kaya identity is used as a starting equation. The factors associated with the use of fossil fuels play an important role in decomposition. The model also considers the population factor. In this regard, energy use (kg. of oil equivalent per capita) and electricity power consumption (kWh per capita) are used.

Peters, et al. [15] analyze the impact of different indicators on CO2 emissions using a similar model. The dynamics of GDP and GDP energy intensity is analyzed as a factor influencing the key variable. In this regard, the opposite indicator characterizing economic energy efficiency was used in the given work. Besides, when a thorough decomposition of determinants was carried out, a particular attention was paid to the technological factor. Based on this, the variable Patent applications, nonresidents (PAF) was used as the proxy variable for technologies.

The Dickey-Fuller tests were conducted to detect stationarity in time-series. All time-series are non-stationary. The first solution to this problem was to use the first difference in the variables, but in this situation, there would be rather difficult to interpret the obtained results. Therefore, the relative variations of the parameters mentioned above (the parameter value for the next year minus the parameter value for the previous year and then divided into the parameter value for the previous year) were used as variables (both dependent and independent). After verification, the Dickey-Fuller tests showed the absence of a unit root of the new series. Table 1 and Table 2 show the results of empirical analysis.

| Table 1. Coefficients |
|-----------------------|
| Coefficient | Standard error | t-statistics | P-value |
| const | −0.0050 | 0.01851 | −0.273 | 0.7874 |
| X1 | 1.28495 | 1.153 | 0.2632 |
Electric power consumption (kWh per capita) is the notable variable. In this case, the dependence is inverse. The reason for this is that electric power consumption per capita leads to climate warming and ice melting, respectively. Global warming can also be caused by the greenhouse effect and other phenomena.

The direct dependence of the regressor on the variable GDP per unit of energy use (constant 2017 PPP $ per kg of oil equivalent) is explained by the fact that the energy efficiency of most processes in the economy and production sphere is currently increasing. This regressor is an indicator of energy efficiency and it indicates that energy costs are reduced in many areas of human activity. This mitigates the negative phenomena that have been described above.

R&D, the proxy of which is the time-series Patent applications, nonresidents (PAF), is not the significant variable. This can be explained by the fact that many studies are not devoted to energy efficiency and environmental friendliness, and numerous implemented innovations do not focus on preserving the environment as the main task. In addition, energy use (kg of oil equivalent per capita) is the insignificant variable too.

5. Conclusion
It is extremely important to observe and understand changes in the Arctic sea ice cover, as it is the main element of the Earth’s climate system. Sea ice affects the balance of freshwater (Aagaard and Carmack, 1989; Serreze et al., 2006) and surface heat (Sedlar et al., 2011) in the Arctic zone, which in turn influences the global climate.

Breaking down barriers to competition, introducing innovative technologies and free trade of energy technologies will help meet the world's energy needs and at the same time reduce emissions. It is necessary to create a policy aimed at the development of the economy and the environment using innovative technologies Industry 4.0 [16,17].

It is obvious that a new global crisis is going to strike. However, this time the crisis will be a health crisis. It is difficult to compare the global financial crisis in 2008-2009 to the current COVID-19 pandemic: the pandemic is a health crisis with far more serious consequences than it was during the financial crisis. Since the COVID-19 pandemic affects financial crisis dramatically, its impact on reducing emissions of carbon dioxide (CO2) will be enormous and it may affect weather conditions.

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