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CLIMATE CHANGE - THEN AND NOW

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Abstract: *During the last five decades, we have systematically recorded an increase in temperature, accompanied by the melting of ice sheets in the polar regions and an increase in sea level. Although the discussion of climate change may date back to the 19th century, today, thanks to advances in science and technology, we have the ability to make accurate measurements that significantly contribute to our understanding and prediction of these changes. However, despite this progress, there are two opposing views on the causes of climate change: one claims that the changes are caused by human action, while the other emphasizes natural processes as dominant factors, independent of human influence. This document leads us to the conclusion that it is necessary to take urgent and effective measures to reduce greenhouse gas emissions in order to avoid catastrophic consequences for life on Earth. This includes switching to renewable energy sources, increasing energy efficiency and applying technologies to remove carbon dioxide from the atmosphere. Without these steps, the forecast is bleak, with significant impacts on the environment, economy and society around the world, including our region. Global awareness and action are needed to ensure a sustainable and acceptable life for future generations.*

Key words: *Climate change, Human activities, Environment, Global warming, The Sun*

1. INTRODUCTION

Over the last five decades, we have systematically recorded an increase in temperature, accompanied by the melting of ice sheets in polar regions and rising sea levels. Although the discussion of climate change may date back to the 19th century, today, thanks to advances in science and technology, we are able to make accurate measurements that significantly contribute to our understanding and prediction of these changes. However, despite this progress, there are two opposing views on the causes of climate change: one claims that the changes are caused by human action, while the other emphasizes natural processes as dominant factors, independent of human influence.

Consideration of climate change requires a precise definition of this concept. If climate change involves significant global variations in climate parameters such as seasons, average monthly temperatures, insolation and precipitation patterns, the question arises as to whether concepts such as the melting of polar ice caps and glaciers can be considered relevant enough to be

labeled as climate changes, especially if they indicate an increase in average annual temperatures at the global level. The main argument of those who dispute the existence of global climate change lies in the claim that this term is not adequate until there are meteorological models that can predict not only daily and monthly weather patterns, but also seasonal cycles. Analysis of multi-year measurements unequivocally indicates the existence of an increase in the average annual temperature in recent decades, both in the air and in the oceans, which results in other meteorological changes.

This paper explores the contemporary understanding of climate change that relies on precise measurements of meteorological parameters, improvement of meteorological models and development of climate theories. Interpreting the causes and predicting the consequences of climate change require dealing with different theoretical concepts. Through empirical insights and contributions from other exact scientific disciplines, the work attempts to capture the complexity and dynamics of climate systems.

2. STANCE THAT CLIMATE CHANGES ARE A NATURAL PHENOMENON

For some scientists, climate change is a purely natural phenomenon. Climate change includes climate changes that are directly or indirectly attributed to human activities that affect the composition of the atmosphere. These changes, unlike short-term climate variations, are recorded over a longer period of time.

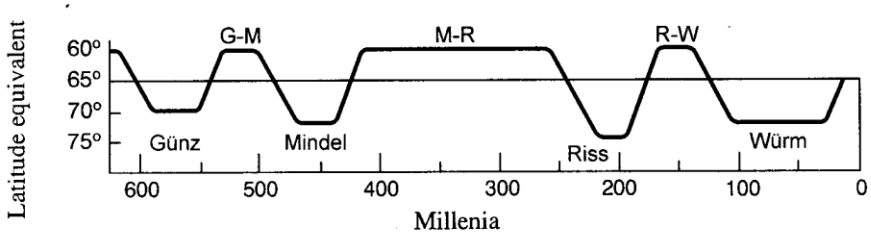
Advances in neural network technology and artificial intelligence have enabled more accurate calculations and projections regarding climate change on Earth. By using artificial intelligence to calculate the growth rate of the average temperature on the planet, the obtained results convincingly show that the expected increase in carbon dioxide emissions will not have a significant impact on the increase in the rate of global warming.

Analysis of sediments in the polar ice indicates periodic cycles of warming and cooling in Earth's history, which cannot be unambiguously attributed to human influence. In the period from 986 to 1234 AD, a gradual global warming was observed that was more pronounced even than the current increase in global temperature, which resulted in the almost complete disappearance of the polar cap and significantly higher sea levels compared to today. Thus, the increase in global temperature since 1980 can be interpreted as part of a periodic cycle of warming, which will probably end in the coming centuries with the opposite phenomenon, like the Little Ice Age that was recorded in Europe in the middle of the 18th century.

This is often attributed to changes in the Gulf Stream, which are caused by changes in sea salinity due to the melting of the Arctic ice cap.

The view that climate change is a natural phenomenon is based, among other things, on the famous Milankovic theory that explains glacial and interglacial cycles in the history of the planet Earth. According to Milutin Milankovic, the Sun has the greatest influence on these major climate changes, such as the Ice Age. First of all, he highlighted important factors such as the angle of insolation, the duration of light and the space of the Earth in relation to the Sun, as key determinants of climate change on the planet. Since other external factors, such as meteorite impacts or geological activity, contributed to climate change, Milankovic's arguments emphasize significant solar activity. The periods of insolation depend on the characteristics of the Earth's orbit and the angle at which sunlight reaches the surface of the planet (Milankovic, 2008).

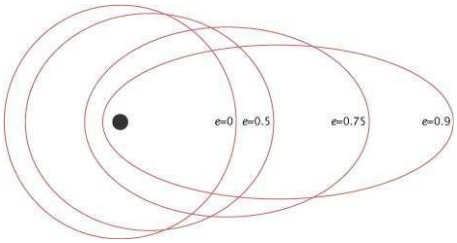
Milankovic derived his theory of climate change from an astronomical perspective, inspired by the works of Penk and Bruckner from the beginning of the 20th century. These works highlighted the existence of four ice ages in the last 660.000 years.



Picture 1. Bruckner's model of ice ages
Source: Smith, 2022.

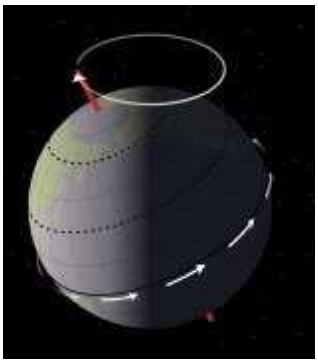
Bruckner's Ice Age model failed to provide a complete explanation of the causes of these phenomena (picture no. 1). Before Milankovic, the proposed mechanisms were not strong enough for the mathematical effects to lead to such dramatic climate changes. Milankovic recognized the importance of the Sun, i.e. the degree of insolation of the Earth, as the basic factor of major climate changes. His theory was based on the assumption that the eccentricity of the Earth's orbit, precession and tilt of the Earth's axis of rotation significantly affect the level of insolation, which is key to understanding climate change (Smith, 2022).

The eccentricity of the Earth's orbit around the Sun refers to the variation in the shape of the ellipse during the annual cycle, which results in a change in distance from the Sun. The greatest amount of heat is obtained when the orbit is almost circular, while less heat is obtained with elongated elliptical orbits, which imply proximity to the Sun in a relatively short period of time (picture no. 2).

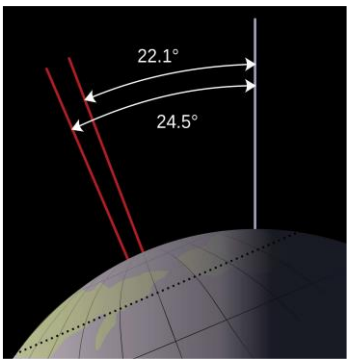


Picture 2. Differences in Earth's ellipse around Sun by Milankovic model
Source: Emetere & Fayomi, 2020.

Another important factor is precession, which represents the movement of the Earth in relation to the axis of rotation (picture no. 3). The Earth, rotating around the Sun, has an oscillating axis that can be described as moving back and forth in the axis of rotation. The smaller this shift, the smaller the oscillations in insolation, which results in a decrease in the mean annual temperature. In addition, the tilt of the Earth's axis of rotation also changes periodically (Fig. 4). This slope is not constant and can range from almost zero to 45 degrees. The insolation of the hemispheres is proportional to the decrease in the tilt of the rotation. Thus, in periods with a lower slope, less sunlight leads to the expansion of the polar caps and the onset of glacial periods (Emetere & Fayomi, 2020).



Picture 3. Precession of the earth's rotation



Picture 4. The inclination of the axis of rotation axis

Source: Emetere & Fayomi, 2020.

Variable periods of insolation thus lead to significant contrasts, which are mathematically precisely measurable:

SIN 80◦ = 0.98 or 98%
SIN 70◦ = 0.94 or 94%
SIN 60◦ = 0.87 or 87%
SIN 50◦ = 0.77 or 77%
SIN 40◦ = 0.64 or 64%
SIN 30◦ = 0.50 or 50%
SIN 20◦ = 0.34 or 34%
SIN 10◦ = 0.17 or 17%
SIN 0◦ = 0.00 or 0%

Based on these factors, Milankovic calculated the cycles of major climate changes. The eccentricity of the Earth's orbit causes significant changes in insolation approximately every 100.000 years, while the tilt of the Earth's axis of rotation varies every 41.000 years and precession occurs every 21.000 years.

New research that follows Milankovic's theory emphasizes the influence of the trajectories of large planets whose mass affects all three insolation factors, which additionally contributes to changes in the Earth's climate. On the other hand, according to some calculations, the new glacial period should already begin, but is delayed or even stopped of this process can be attributed to anthropogenic factors, which encourages the theory of human influence on climate change.

3. CLIMATE CHANGES AS A RESULT OF HUMAN ACTIVITIES

In addition to groups that claim that climate change is a purely natural phenomenon, there is also an opposing opinion. On the other side are those who believe that the main cause of these changes lies in the anthropogenic factor - human activities, especially in production and the negative impact on the environment.

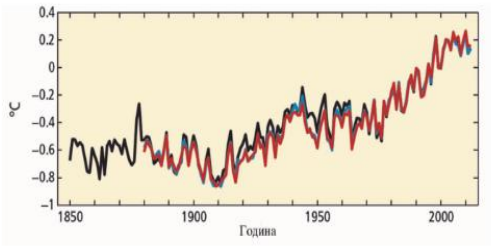
James Canton, in his book "Extreme Future" claims that human activity is responsible for global warming. He points out that the 10 warmest years were recorded in the last 15 years of the 20th century, which indicates alarming trends. According to him, there is only one convincing reason for this warming: human activity. Factory plants, cars and other sources of pollution emit greenhouse gases such as carbon dioxide, methane and nitrogen oxides, which lead to atmospheric pollution. These gases trap heat in the atmosphere, causing the temperature to rise (Canton, 2009). A careful analysis of the data indicates that anthropogenic influences

play a key role in climate change. There is a parallel between the growth of industrial production and the increase in average annual temperatures, whereby it is noted that the intensification of heavy industry, especially since the 1970s, is moving from North America and Europe to Africa and Asia.

The average global temperature has increased by approximately 0.78 degrees Celsius since 1901. Although average temperatures have changed in the past without anthropogenic influences, they have always been linked to the level of CO2 in the atmosphere. In the distant past, natural factors influenced the concentration of carbon dioxide and the greenhouse effect, while in recent times industrial production is the key factor. Also, never in the last six and a half centuries has the concentration of CO2 in the atmosphere been as high as it is now, with values exceeding 387 ppm, increasing by about 2 to 3 ppm per year (Canton, 2009).

For decades, the role of human activities in climate change has been neglected. For this reason, in 1988, the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) established the Intergovernmental Panel on Climate Change (IPCC), with the intention of scientifically investigating current knowledge about climate change and its impact on climate change. Reports published by this panel from 1990 to 2014 emphasize that climate change is occurring in the present and that its main cause is mainly human activities (IPCC, 2014).

Reproducing an analysis of air temperatures since 1850, a 2014 IPCC report found that each of the last three decades was warmer than the previous one, with the period from 1983 to 2012 highlighted as the warmest 30-year period in recent years (picture no. 5). The increase in the average combined temperature over land and sea on Earth from 1880 to 2012 was 0.85°C, while the total increase between the average of the period from 1850 to 1900 and the period from 2003 to 2012 was 0.78 °C (IPCC, 2014).



Picture 5: Anomalies of the global and annual mean combined temperature over land and sea compared to the average of the period 1986-2005. year.
Source: (IPCC, 2014).

In the Sixth Report of IPPC Working Group 1 (IPPC 2021, AR6 VG1), different impacts on the climate system were observed. In addition to anthropogenic climate change caused by increased greenhouse gas emissions, this report also includes factors such as population growth and increased food and energy needs for life. Many relevant elements affecting the climate system are analyzed, including emissions of various gases and aerosols, changes in land use, as well as possible impacts of natural processes on climate change, such as solar activity and volcanic eruptions.

The increase in greenhouse gas (GHG) emissions is considered a key factor in increasing global temperatures. Several gases have the greatest impact on global warming:

(a) carbon dioxide (CO2), which accounts for about 50-55% of global warming, and its concentration is increasing due to the use of fossil fuels and deforestation;

(b) chlorofluorocarbons (CFCs), which contribute about 25% to global warming, and are used in the production of plastics and as cooling agents;

(v) methane (CH4), which contributes about 12% to global warming, and is produced by the decomposition of organic matter and industrial processes and

(g) nitrogen oxides (NOx), which are thought to contribute 6% to global warming and are released mainly by industry and volcanic eruptions (Pollution Probe, 2004).

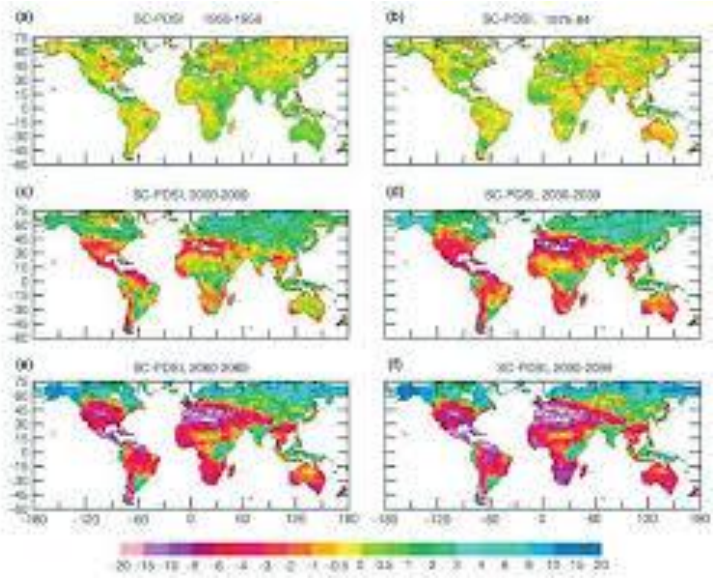
The total effect of man-made greenhouse gases on climate change in 2022 is about 4 W/m². This effect is partially mitigated by the production of aerosols, which increase the reflectivity of the atmosphere and have an effect of about -1.5 W/m². The rest of about 2.5 W/m² contributes to the warming of the air, land surfaces and, above all, the oceans, as well as many other changes and disturbances in the climate system.

The main indicator of this impact, the mean global air temperature at a height of 2 meters, shows that the global average temperature has increased by about 1.1°C compared to the pre-industrial period (IPPC, 2021). This rise in temperature would not have occurred without the effect of greenhouse gases. Therefore, the Earth system, in its current state in 2022, receives about 1 W/m² more energy than it radiates into space (Hansen, 2022).

Accurate data and predictions based on it contribute to apocalyptic attitudes about climate change. According to the conclusions of the International Panel on Climate Change, presented by the World Meteorological Organization in 2008, an increase in the concentration of carbon dioxide is expected until the year 2100, which will result in an increase in the global temperature by 1.4 to 5.8 degrees Celsius, and in the North America even by 3.5 to 7.5 degrees. This will cause the disappearance of the polar ice, a significant increase in sea and ocean levels by one to three meters, which will lead to the submergence of many inhabited places. Pronounced meteorological extremes, droughts and heavy rainfall are also expected, which can significantly reduce food production, which will have catastrophic consequences considering the increase in world population (Canton, 2009).

The reduction of the surface of the glacier and the deviation from the normal values of the renewal of the sea ice, which has been constantly increasing since 2008, already significantly affects the stability of the ecosystem (picture no. 6).

According to some meteorological models, the Arctic could be completely ice-free during the summer months by 2030. In addition, mountain glaciers are shrinking rapidly, which creates glacial lakes. These lakes destabilize large mountain massifs through erosion. The process of warming and melting ice can further accelerate climate change (Giddens, 2010). The great peatlands stretching from western Siberia to northern Scandinavia, Canada and Alaska are covered with a thick layer of snow. However, that snow is starting to melt, which worries even the oldest scientists. The snow covers very large amounts of decaying carbon-rich vegetation, whose melting and rotting releases CO2 and methane. Methane is a significantly more dangerous gas than CO2. The lack of research into these processes, especially in Siberia where access is limited, is an additional problem. According to estimates, the emission of methane from West Siberian peatlands already exceeds the total annual emission of harmful gases in the USA.



Picture 6: State and projection of global warming
Source: Ciconkov, 2019.

Also, it is important to keep in mind that the burden of curbing global warming would fall mainly on poorer populations in third world countries, given that most of the industries with high carbon dioxide emissions are located in these countries. However, it should be noted that climate change affects people in third world countries the most, which further complicates the situation.

In any case, the proposals for radical measures to reduce pollution, which are mainly based on the opinion of most meteorologists that pollution contributes to global warming and climate change, have wider implications concerning not only scientific aspects but also ethical and political issues.

Scientific discussions about the impact of human activities on climate change inevitably touch on political aspects and create political implications. In this context, globalization is seen as a significant factor that affects the increase in global pollution as a result of intensive production, but also migration from areas that are potentially threatened by climate change to urban areas. These different perspectives shape the narrative framework through which climate change and its impacts are interpreted, influencing the shaping of strategies to respond to this global challenge (Kovacevic and Kovacevic, 2018).

Bill McKibben emphasizes that there is no place on planet Earth that is not affected by human activity and that this change affects all aspects of life, from ecosystems to human communities. From the deepest oceans to the highest mountains, the human footprint is everywhere (McKibben, 2007).

4. WHAT CAN BE EXPECTED IN THE FUTURE?

As is often pointed out, there are three ways to analyze what we can expect when it comes to climate. One is to look at what is happening, the second is to look at what happened to the Earth's climate in the past, and the third is to make numerical simulations with physical-mathematical (dynamic) climate models for the past. and for the future using scenarios of greenhouse gas emissions and other human activities. We can gain more important messages

by considering what happened to the Earth's climate in the past thousands and even millions of years.

If the increase in the content of GHGs were to stop at this moment, the average global air temperature at the ground would increase by more than about 0.5 and maybe even 1°C. Stopping warming is not achievable due to the delayed impact of "slow-reacting feedbacks". In other words, it is quite certain that the temperature of the deep ocean will become higher.

In addition to the "slow-reacting feedbacks" there are also many "fast-reacting feedbacks" in the climate system that affect warming. For example, a warmer atmosphere has the ability to contain more water vapor (a 1°C warmer atmosphere can contain as much as 7% more water vapor), which is a greenhouse gas. Water vapor is like a propellant for disasters, which is why increased disasters, and more frequent and larger floods are expected and are already seen (Mesinger & Vukovic Vemic, 2023).

Stopping global warming at 2°C is not enough to prevent positive global warming feedbacks from intensifying. For this reason, the big question remains where is the "tipping point" for our climate system, i.e. "tipping point" when the process becomes unstoppable and irreversible. Along with the temperature, what will happen to the sea level is an important piece of information, especially for the hundreds of millions of people who live and will live in cities along the coasts (Hansen & Sato, 2012).

In the long term, over the next 2.000 years, if the temperature rise were limited to 2°C, the AR6 sea level rise would be 2-6 m. Sea level change due to thermal expansion (due to temperature rise) and melting glaciers is a good indicator of the climate changes that will occur even if the energy balance in the energy exchange with the cosmos is restored and the rise in mean global temperature is stopped. This means that climatic conditions suddenly thrown out of their equilibrium state continue to change long after the rise in the average global temperature has stopped.

Observing the global shift of the isotherms, ie. northward expansion of warmer belts, changes during the 21st century have been shown to occur at least 10 times faster than at any time in history over the past 65 million years (Diffenbaugh & Field, 2013).

One of the main conclusions of the IPCC AR6 WG1 is that human influence has undoubtedly led to warming of the land, oceans and atmosphere and that the induced change in natural factors affecting the climate system is leading to the intensification of climate change and the intensification of extreme weather events. Under all future scenarios, the mean global temperature will continue to rise. With rising temperatures, natural sinks of carbon dioxide (oceans and the earth's surface) lose their efficiency, which leads to increased retention of gases in the atmosphere and further strengthening of the greenhouse effect (IPCC, 2021).

By the end of the 21st century, we can even expect an increase in the average global temperature at the ground of more than 4°C if energetic measures to mitigate the increase in GHG emissions are not implemented. This increase in temperature is comparable to the increase in temperature since the end of the last ice age and took place over thousands of years, while the time scale of the current increase is occurring during one human lifetime. In other words, during one human lifetime, the human anthropogenic impact on the climate has become comparable to the intensity of the impact of geological forces on a planetary scale (Steffen et al., 2015).

5. CONCLUSION

Understanding climate change includes not only physical and dynamic processes in the atmosphere and other parts of the climate system, but also socio-economic aspects. This means that climate change is present in every science, politics, economy of today's and future society, and even in art that reflects the time in which the artist lives. Therefore, the fight against climate change and the preservation of humanity on Earth requires the involvement of all members of society, from the global one associations to reducing global GHG emissions to changing the behavior of each individual.

Climate change is a serious and urgent global problem that requires swift and comprehensive action. In the last fifty years, we have witnessed a systematic increase in temperature, melting of ice sheets and rising sea levels, and the main cause of these changes is the increased concentration of greenhouse gases in the atmosphere due to the burning of fossil fuels. The data show that the temperature rise has already exceeded 1°C compared to the pre-industrial value, and if the trend is not stopped, the temperature will continue to rise and exceed the critical limit of 1.5°C. Despite numerous international efforts and conferences, greenhouse gas emissions have not only not been reduced, but are also increasing.

This leads us to the conclusion that it is necessary to take urgent and effective measures to reduce greenhouse gas emissions in order to avoid catastrophic consequences for life on Earth. This includes switching to renewable energy sources, increasing energy efficiency and applying technologies to remove carbon dioxide from the atmosphere. Without these steps, the forecast is bleak, with significant impacts on the environment, economy and society around the world, including our region. Global awareness and action is needed to ensure a sustainable and acceptable life for future generations.

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