ÉGHAJLATVÁLTOZÁS: GLOBÁLIS ÉS REGIONÁLIS KIHÍVÁSOK

CLIMATE CHANGE: GLOBAL AND REGIONAL CHALLENGES

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ABSZTRAKT

A Föld-rendszer összetevői – a légkör, az óceánok, a szárazföldek, a jégtakaró és a bioszféra – különböző térskálákon folyamatos kölcsönhatásban vannak egymással. Bemutatjuk a közelmúlt legfontosabb környezeti változásait, amelyek elsősorban az antropogén tevékenységgel kapcsolatosak. A vízkörforgás kulcsszerepe globális és regionális skálán egyaránt hangsúlyos, domináns hatással van a környezet állapotára és az emberi tevékenységre.

Kulcsszavak: éghajlatváltozás, Föld-rendszer, víz-ciklus, hidrometeorológia ⦿

ABSTRACT

Components of the Earth System – atmosphere, oceans, land and ice cover, biosphere – interact with each other on several different scales. This paper presents the most important recent environmental changes caused mainly by anthropogenic activity. The key role of the water cycle is emphasized on both global and regional scales, having dominant effects on the state of the environment and any human activities.

Keywords: climate change, Earth system, water cycle, hydrometeorology

INTRODUCTION

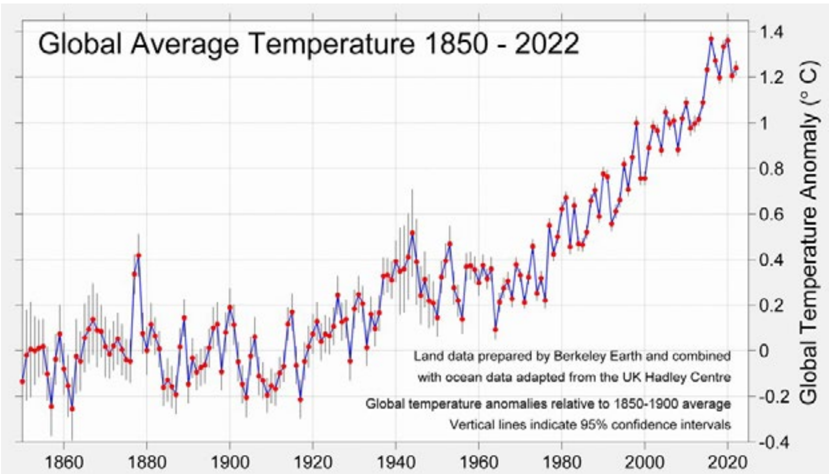
When discussing the phenomenon of global climate change, it has to be stated that the behaviour of the whole Earth system should be considered, instead of limiting investigations only to the atmosphere. The Earth system includes the oceans, atmosphere, land and ice cover, as well as biosphere. These components interact on many different scales in both space and time, causing the climate to have a large degree of natural variability. Human influences such as greenhouse-gas emissions, or changes in land use – which involves the management and modification of natural environment or wilderness into built environment such as settlements and semi-natural habitats such as arable fields, pastures, and managed woods – add further complexity.

GLOBAL ENVIRONMENTAL CHANGES IN THE EARTH SYSTEM

Global average temperature has varied across geological time. Glacials and interglacials occurred at relatively regular (appr. 10-15-thousand-year) intervals due to the variation of Earth's orbital parameters. Recent climate change, however, is unequivocally caused by anthropogenic activities, with global surface temperature climbing to 1.1 °C above 1850-1900 levels in the 2011-2020 period [1]. Temperature variation for the period of 1850-2022 is shown in Figure 1 [2]. Evidence suggests that the troposphere – the lowest layer of our atmosphere, extending up to 8-10 kilometres above the surface – has undergone a significant rate of warming during the past century, while the layer beyond it, the stratosphere, has experienced a similar rate of cooling. It well demonstrates that the greenhouse effect, driven by increasing human activity, is resulting in higher temperatures in the vicinity of Earth's surface. For millennia, atmospheric carbon dioxide concentrations have never been above the current 400 ppm level. When compared with recent temperature changes, it is well demonstrated that both the rate and magnitude of recent warming are unusual relative to the changes of the past 24 thousand years [3].

Jet streams are relatively narrow bands of strong wind in the upper levels of the atmosphere. The winds in jet streams blow from west to east, but the air current often shifts to the north and south. Jet streams follow the boundaries between hot and cold air. Because polar regions of the planet are warming faster than the mid-latitudes, the typical north-south temperature difference is lower. As this temperature difference decreases, it causes a slight drop in zonal winds in the jet stream — which, in turn, leads to more meandering of the jet stream. An unstable jet stream can also lead to severe *heat waves, droughts, or excessive amounts of rain.* A heat wave is an extended period of unusually high temperatures and often high humidity. These are expected to become more frequent and more severe in the future due to climate change. People affected by heat waves can suffer from shock, become dehydrated and develop serious heat illnesses. Heat waves can also worsen chronic cardiovascular and respiratory diseases.

The rate of global warming is not homogenous around the Earth. While the Earth's surface as a whole has warmed by around 1.1 °C since the Industrial Revolution, temperatures are not rising at the same rate in all corners of the world. One difference is the faster pace that land areas are warming compared to the ocean. But perhaps the biggest outlier is the Arctic, which is warming more than two times faster than the global average, as it is shown in Figure 2 [4]. This phenomenon – known as "Arctic amplification" – is causing dramatic changes for Arctic



communities and has also been linked to extreme weather events in the mid-latitudes of the northern hemisphere. The cause of this rapid warming is typically identified as the changing "albedo" of the Arctic's surface – where the loss of snow and sea ice means less incoming sunlight is reflected back out into space.

THE DISTINCTIVE ROLE OF THE GLOBAL WATER CYCLE

Global environmental changes attributable to natural and anthropogenic causes can be linked to a significant degree to the variability of the *global water cycle.* Global natural phenomena on a regional and local scale that can also be associated with such changes may represent a serious risk to life and property, and can additionally affect conditions for agricultural management and cause damage of natural ecosystems. The floods, droughts and atmospheric storms are often accompanied by intense rainfall events which are responsible for a large array of natural disasters.

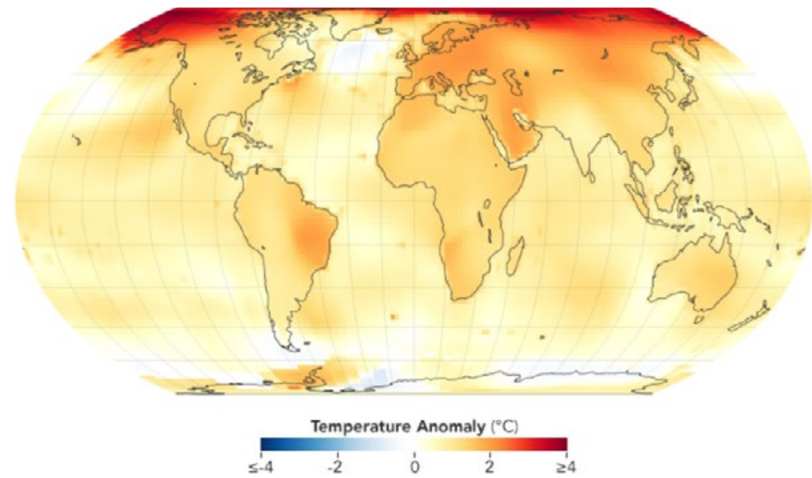
As the water cycle plays a crucial role in our lives, it is worth paying special attention to it. The globally warming atmosphere – according to the laws of thermodynamics – can hold an exponentially increasing amount of water vapor. An estimated 1 °C rise in atmospheric temperature increases the water vapor content of the atmosphere by 6-7%, which also affects the dynamic processes of the atmosphere through latent heat circulation, originating from water evaporation and vapour condensation.

These changes affect the entire global water cycle. Although the amount of precipitation changes by only 1-2%, its spatial and temporal distribution becomes more and more extreme. In general, we can say that areas with good water supply are becoming wetter, and water-scarce areas become drier [5]. Annual rainfall amounts in the tropical zone and the northern parts of America and Europe are rising, while in the Mediterranean region and the southern regions of Africa and Australia, average annual rainfall amounts are decreasing. The middle geographical latitudes are not experiencing a significant change in annual precipitation amounts, but the extremes of distribution are tending to increase.

Ocean heat content is increasing. The top 800-metre-layer of most major ocean waters is getting warmer. The amount of heat absorbed by the oceans has increased significantly over the past two decades. Warmer oceans damage coral reefs, threaten marine ecosystems and disrupt global fisheries. A change in ocean heat content can also alter patterns of ocean circulation, which can have far-reaching effects on global climate conditions, including changes to the outcome and pattern of meteorological events such as tropical storms, and also temperatures in the northern Atlantic region, which are strongly influenced by currents that may be substantially reduced by increasing amounts of carbon dioxide in the atmosphere.

Sea level rise started from the last glacial maximum (about 21,000 years ago). The rate of ascent has not been uniform, but a total increase of around 120 metres has

◂◂**Figure 1:** Global average temperature, 1850-2022
SOURCE: BERKELEY EARTH
Figure 2: Heat map showing the temperature anomaly for the years 2015-2019, compared to the 1951-1980 average
SOURCE: NASA: EARTH OBSERVATORY [4]



been reached during this period. In the last eight thousand years, the rise slowed down, and then the water level stabilized during the last two thousand years. Since the beginning of the 20th century – very likely for anthropogenic reasons – we have experienced an accelerating rate of sea-level rise, the average level of which was 3.6 mm/year. Roughly half of the rise is due to the melting of continental ice sheets, and the other half originates from the thermal expansion of the warming oceans. The continuously rising water level not only threatens populated coastal areas located at sea level, but can also cause irreversible damage in ecosystems and areas of agricultural cultivation.

The decrease in the extent of *permafrost* also convincingly shows the effects of rising global average temperatures. Any ground below the Earth's surface that has been continuously frozen for at least two consecutive years is defined as permafrost; in most cases, the timespan is actually hundreds or thousands of years. Huge wedges of ice are often locked within this frozen ground. When that ice melts, the soil becomes less compact and the ground surface can collapse, forming a sinkhole. Even where no large ice blocks are present, the frozen soil contains enough ice to create water bodies when it melts or sublimates into water. The depth of permafrost containing a significant amount of animal and plant remains varies, but the thickest layers can reach 500 metres. Permafrost is located primarily around the Arctic regions – including Russia, Canada, and Alaska – but it also occurs in high, mountainous regions, for example on the Tibetan Plateau spread inside the Himalayan mountains. The problem is not just the risk of losing the stability of frozen soil with infrastructure built on top of it (roads, railways, buildings, and mining areas for natural gas and oil), but releasing methane and carbon dioxide from the melted soil into the atmosphere, causing a positive feedback loop accelerating global warming by intensifying the greenhouse effect.

The rise of the permanent frost level in Asia in high mountains reduces the natural mass of ice stored here, which is also accompanied by a narrowing of the available drinking water base. This can result in a critical situation in the region, as it directly or indirectly provides drinking water for approximately one billion people over the entire area. It can also influence the winter landscape of famous resort locations at higher mountain altitudes, all around the world.

Summer Arctic sea ice extent is shrinking by around 12% per decade as a result of global warming. This means that over the past 40 years its area has decreased by approximately 2 million square kilometres. Intense melting decreases the salinity of ocean water, and also means a lower amount of solar radiation is reflected back to the space, and a larger amount of it remains within the Earth system, causing a positive feedback loop in the warming process.

The global conveyor belt and thermohaline circulation. Freshwater from melting ice reduces the salinity of the North Atlantic. The melting ice causes freshwater to be added to the seawater in the Arctic Ocean, which flows into the North Atlantic. The added freshwater makes the seawater less dense. This has caused the North Atlantic to become less saline over the past several decades, and has caused the currents to slow.

REGIONAL CHANGES IN HYDROMETEOROLOGICAL PHENOMENA

The weather of the Carpathian Basin is basically determined by large-scale processes. With the increasingly frequent migration of temperate cyclones further north, our region is often affected only by the southern branch of weather fronts. The annual precipitation falling in Hungary is to a large extent determined by these fronts crossing and waving above us. Mediterranean cyclones forming in the Mediterranean basin can also be observed with decreasing frequency. Mediterranean cyclones, or at least their rainfall band, often cause a significant amount of precipitation in our country, so their absence contributes to the development of drought periods. But when, in autumn, the desert effect recedes, the Mediterranean Sea, which has warmed up in the summer, transfers a significant amount of moisture to the cooler atmosphere, it causes heavy precipitation. By analogy to the hurricane, a new phenomenon has recently been introduced in the atmospheric sciences. The *medicane* is a hurricane-like slow air movement characterized by thunderstorm clouds. It gets its kinetic energy and water content from the warm Mediterranean Sea. Significant pressure changes can be measured in the system, wherein heavy rains and very strong winds can be observed. Its frequency and destructive effect are not equal to hurricanes, since the geographical conditions of formation and survival, as well as the depth of the sea water and its thermodynamic characteristics, are different.

Events and periods with higher-than-average rainfall or persistent frequency of drought occurrence can be characterized by a series of extreme precipitation indices and their changes over time. Based on Hungarian observations, during the 1901–2016 period, the number of rainy days decreased in terms of the national average, while on the other hand, the number of rainy days exceeding 20 mm of precipitation shows a slight increase. The daily intensity, also known as the average daily rainfall, fell during the period. This suggests that precipitation events are increasingly short in duration, and fall in the form of intense showers. Due to runoff, its utilization is less effective in the soil cover than more frequent but less intense rainfall, and it also strengthens soil erosion processes.

The increasingly extreme appearance of precipitation also means that soil cover is becoming more vulnerable to drought, constantly decreasing its moisture content and productivity. This danger is already threatening many European regions. In Hungary, the Homokhátság, between the Danube and the Tisza rivers, can be mentioned as an example where, in addition to the continuous lowering of the groundwater level, negative geological and ecological changes can also be observed. Not unconnected to the drying of the soil and vegetation is the phenomenon of the increasing extent and intensity of forest fires. In Europe it used to be a problem only in southern European countries, but now we must prepare for its regular occurrence in central and even northern areas. In North America and Australia, forest fires have become more and more extensive across both space and time, and can disrupt the functioning of entire forest ecosystems.

THE SOCIAL DIMENSIONS OF CLIMATE CHANGE

Climate change is deeply intertwined with global patterns of inequality. The poorest and most vulnerable people bear most of the impacts of climate change, yet contribute the least to causing it. As the impacts of climate change mount, millions of vulnerable people face disproportionate challenges in terms of extreme events, health effects, food, water, and livelihood security, migration and forced displacement, loss of cultural identity, and other related risks. The most vulnerable are often also disproportionately impacted by measures to address climate change. In the absence of well-designed and inclusive policies, efforts to tackle climate change can have unintended consequences for the livelihoods of certain groups, including by placing a higher financial burden on poor households [6].

CONCLUSIONS

The effects of climate change are already being felt, so mitigation processes are important. These can include, among others, reducing the release of heat-trapping greenhouse gases into the atmosphere. This involves cutting greenhouse gases from main sources such as power plants, factories, cars, and farms. Forests, oceans, and soil can also absorb and store some of these gases, and are an important part of the solution. In addition, we must adapt more quickly and comprehensively. Countries should focus on supporting the further development and implementation of adaptation strategies and plans at all levels of governance with interconnected priorities, like integrating adaptation into macro-fiscal policy, nature-based solutions for adaptation, as well as local adaptation action. While the case for adaptation is clear, some communities most vulnerable to climate change are the least able to adapt because they are poor and/or in developing countries already struggling to come up with enough resources for basics like health care and education.

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