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NEW TENDENCIES IN GLOBAL CLIMATE CHANGE AND THEIR EFFECTS ON THE CLIMATE OF HUNGARY

A GLOBÁLIS ÉGHAJLATVÁLTOZÁS LEGFRISSEBB TENDENCIÁI ÉS AZOK HATÁSAI MAGYARORSZÁG ÉGHAJLATÁRA

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Abstract

Defining the term of climate, we investigate the role of natural causes and effects of human activities in climate change. The temperature of the Earth is determined by the balance between the amount of radiation energy received from the Sun and that emitted from the surface of the Earth towards the outer space. Greenhouse gases in the atmosphere, including water vapor, carbon dioxide, methane and nitrous oxides, act to make the surface much warmer, because they absorb and emit heat energy in all directions (including downwards), keeping Earth's surface and lower atmosphere warm. The primary cause of climate change is the burning of fossil fuels, such as oil and coal, which emits greenhouse gases into the atmosphere—primarily carbon dioxide. We give a review about the activity of the Intergovernmental Panel on Climate Change and the United Nations Climate Change Conferences. Shortly investigate the different global climate models and some regional climate models. Finally discuss the results of regional climate model simulations for the Carpathian Basin.

Keywords: *Causes of climate change, Intergovernmental Panel on Climate Change, global climate models, regional climate models*

Absztrakt

A klíma definícióját követően vizsgáljuk az éghajlatváltozás jelenségében szerepet játszó természeti folyamatokat, valamint az emberi tevékenység hatásait. A Föld hőmérsékletét a Napból érkező sugárzás és a Föld felületének hő-visszasugárzása együttesen határozza meg. Az üvegházhatású gázok a légkörben, mint a vízgőz, szén-dioxid, metán vagy a nitrogén-oxidok elnyelnek és kisugároznak energiát minden irányban, így a Föld felszíne felé és így a felülethez közeli légkör melegebb lesz, mint a be- és kisugárzott energia által várható lenne. A globális éghajlatváltozás elsődleges oka a fosszilis tüzelőanyagok nagymértékű égetése, ami üvegházgázokat, elsősorban széndioxidot bocsájt a légkörbe. Rövid áttekintést adunk a Klimaváltozást vizsgáló Kormányközi Testület munkájáról, valamint az ENSZ klímaváltozással foglalkozó konferenciáról. Röviden bemutatjuk a különböző globális klíma modelleket és néhány regionális modellt. Áttekintjük a regionális klímamodellek Kárpát-medencére vonatkozó szimulációs eredményeit.

Kulcsszavak: *éghajlatváltozás okai, Éghajlatváltozási Kormányközi Testület, globális klímamodellek, regionális klímamodellek*

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INTRODUCTION

Weather means prevailing atmospheric conditions, a set of defined values of atmospheric parameters (temperature, air pressure, wind speed, precipitation, humidity and cloud conditions). Climate is the sum of entire atmospheric conditions that are characterized by averages and distribution of extreme values, at daily, monthly and yearly levels.

The climate has been constantly changing throughout the geological periods and the history of mankind, and so does today. However, over the past 200 to 300 years, mankind – by its activities – has become capable of significantly influencing the climatic system on a local, regional and global level [1]. As we all know, the Earth has gone through warm and cool phases in the past, and long before humans were around. Forces that contribute to climate change include the Sun's intensity, volcanic eruptions, and changes in naturally occurring greenhouse gas concentrations. But records indicate that today's climatic warming – particularly the warming since the mid-20th century – is occurring much faster than ever before and can't be explained by natural causes alone. There are natural sources and radiation energy coming to the Earth from the Sun can be changed for several reasons [2]. Such reasons include: changes in the internal energy generation of the Sun, changes in the surface of the Sun (sunspot activity); „cleanness" or "dustiness" of the cosmic space located between Sun and Earth; changes that occur in the circulation of Earth around the Sun; changes in the course elements such as changing or turning the elliptical orbit, pitching or wobbling of the inclination angle of the Earth's axis and its precession [3].

THE CLIMATE CONTROLLING PROCESSES

The effects of the Sun and the orbit of the Earth

The solar constant is the average radiation intensity falling on an imaginary surface, perpendicular to the Sun's rays and at the edge of the Earth's atmosphere. The value of the constant is changing in the year by about 7% between 1st January and 3rd July. A yearly average value is thus taken and the solar constant equals 1,367 W/m^2. Even this value is inaccurate since the output of the Sun changes by about ±0.25% due to Sun spot cycles. The elements of Earth's orbit are changing with a different frequency.

The term eccentricity refers to the shape of the Earth's orbit, as a measure of the degree to which it departs from a circular shape. The orbit typically varies from near circular (low eccentricity: 0.005), to near elliptical (high eccentricity: 0.058). The mean eccentricity is 0.028, and at present is approximately 0.017. Changes in the orbital shape arise due to a combination of factors, which combine to produce a periodicity of change over approximately 100,000 years. The shortest distance is termed the perihelion, the longest distance is the aphelion. When the orbit is at its most elliptical, the amount of solar radiation at perihelion is 23% more than at aphelion.

The obliquity refers to the angle of the Earth's axial tile in relation to its orbit. Obliquity varies from 22.1° to 24.5° (an angle of 2.4°) and back again, over a time period of approximately 41,000 years. When obliquity increases (i.e. the Earth is tilted at a greater angle) there is a greater variation between winter and summer insolation – in summer there is more solar radiation, and in winter there is less. This solar radiation is not equally distributed, however, due to the shape of the Earth's surface. With an increase in obliquity, high latitudes (towards the poles) receive an increase in insolation, while lower latitudes receive a decrease in insolation. The Earth is currently tilted at approximately 23.44°, so it is half way through its cycle of tilt from 24.5° to 22.1°.

Precession is the direction of the Earth's rotation (or 'wobble') on its axis. This motion occurs due to the tidal forces exerted by the Moon and the Sun on the Earth. The impacts of precession are largely felt at perihelion (when the Earth is at its closest proximity to the Sun) due to increased solar radiation. For example, when the North Pole is directed towards the Sun, the northern hemisphere receives much more insolation in summer, and experiences a colder winter. Meanwhile the Southern Hemisphere would experience milder seasons. In contrast, when the South Pole is directed at the Sun, it is the South Pole that experiences the larger seasonal variations. In its current state, perihelion is reached during the Southern Hemisphere summer, and aphelion is reached during the southern hemisphere winter. This is why the southern hemisphere often experiences greater seasonal extremes than the northern hemisphere [4].

The atmosphere scatters and absorbs some of the Sun's energy that is incident on the Earth's surface. Scattering of radiation by gaseous molecules (e.g. O_2, O_3, H_2O and CO_2), that are a lot smaller than the wavelengths of the radiation, is called Rayleigh scattering. Roughly half of the radiation that is scattered is lost to outer space, the remaining half is directed towards the Earth's surface from all directions as diffuse radiation. Because of absorption by oxygen and ozone molecules the shortest wavelength that reaches the Earth's surface is approximately 0.29 μm.

Scattering by dust particles larger than wavelengths of light is called Mie scattering. This process includes both true scattering (where the radiation bounces of the particle) and absorption followed by emission, which heats the particles.

Clouds reflect a lot of radiation and also absorb a little, the rest is transmitted through. Globally, clouds reflect a lot of radiation and help regulate the surface temperature.

The fraction of the total solar radiant energy reflected back to space from clouds, scattering and reflection from the Earth's surface is called the albedo of the Earth-atmosphere system and is roughly 0.3 for the Earth as a whole.

The amount of energy reflected, scattered and absorbed depends on the amount of atmosphere that the incident radiation travels through as well as the levels of dust particles and water vapor present in the atmosphere.

A part of this radiated energy (about 31%) is reflected back to interplanetary space primarily by clouds and air, another part (approximately 20%) is absorbed in air and the balance (about 49%) reaches the surface of the Earth and would be absorbed by it. Absorbed energy keeps the surface of Earth at a certain temperature and, as a consequence of this, Earth itself as a solid body of a given temperature also emits electromagnetic radiation in the form of heat emission.

Heat radiation leaving the Earth is absorbed with high (approximately 90 %) probability by certain components of air that are present usually in very small quantities – water vapor, carbon dioxide, methane, dinitrogen oxide, halogenated hydrocarbons and ozone. These components are called – in a very descriptive way – greenhouse gases. Approximately 62% of the emitted energy gets back to the surface of the Earth for spatial reasons and would be absorbed, while the remaining 38% (235 W/m^2) goes to the interplanetary space. As a consequence of the energy absorbed and given back by the greenhouse gases, global average temperature at the surface of the Earth is +15 °C, as opposite to the -18 °C that would prevail without the aforementioned gases.

Volcanic activities

During volcanic eruptions, solid material mass of which exceeds several thousand km^3 erupts into the atmosphere. Majority of it is settled within a period of a few days or washed out by rains. During large volcanic eruptions that have the power of an explosion, the very small particles (sulfate aerosols) get up to the lower stratosphere even up to a height of 30 km. At this level practically no cloud and rain formation takes place so it may even take 1-2 years while these particles get out from the atmosphere. Rays coming from the Sun are scattered on the particles originating from volcanic eruptions, so they have a cooling effect because of increasing the planetary albedo.

Oceanic circulation

Direct effect of the oceans on the climate is originating from the fact that atmospheric circulation and oceanic currents transport heat from the tropical zone towards the poles. These flow systems are affected and modified by a very large number of factors in regional and global scale. Oceans affect greenhouse gases as well as they have important roles in determining the concentration of carbon-dioxide in the atmosphere. On longer terms there is an equilibrium between atmospheric carbon-dioxide and carbon-dioxide dissolved in surface waters of the oceans.

Changes in the use of land

Effects of the spheres that are in contact with the atmosphere: lithosphere (land masses), hydrosphere (oceans), cryosphere (surfaces covered with snow and ice) and biosphere (living creatures) are among the planetary factors that affect climate. Out of all living creatures, the activity of mankind has the largest effect on the climate of our planet.

Men also transform the surface of the Earth; for example, forests are transformed to cultivated plough lands (that shows significant surface changes in a cycle of annual period), or a natural surface is transformed to a city environment covered by concrete, asphalt and roofs of buildings. These changes modify the local/regional climate e.g., by the formation of urban heat islands.

Human activities and greenhouse gases

The question is whether the atmospheric concentration of greenhouse gases has been changed in the last two centuries to a detectable extent. Apparently the answer is: YES.

Almost half of the carbon-dioxide of anthropogenic origin (46%) is emitted to the atmosphere by power plants and oil refineries. Deforestation (23%), concrete manufacturing (12%) and gas manufacturing (9%) also contribute significantly to increase the quantity of carbon dioxide in the atmosphere. In addition to the industrial sources, components of methane emission include mining (25%) and agriculture has a significant role as well. Contributions of animal husbandry, rice production and breaking of plough-lands to increase atmospheric methane concentration are 28%, 15% and 7%, respectively [3].

INTERNATIONAL COOPERATIONS IN THE FIELD OF THE STUDY, ADAPTATION AND MITIGATION OF CLIMATE CHANGE

The United Nations Intergovernmental Panel on Climate Change (IPCC) is the international body for assessing the science related to climate change. The IPCC was set up in 1988 by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) to provide policymakers with regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation.

The authors producing the reports are currently grouped in three working groups – Working Group I: the Physical Science Basis; Working Group II: Impacts, Adaptation and Vulnerability; and Working Group III: Mitigation of Climate Change – and the Task Force on National Greenhouse Gas Inventories (TFI). As part of the IPCC, a Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA) facilitates the distribution and application of climate change-related data and scenarios. IPCC Assessment Reports cover the full scientific, technical and socio-economic assessment of climate change, generally in four parts – one for each of the Working Groups plus a Synthesis Report. Special Reports are assessments of a specific issue. The IPCC does not carry out research nor does it monitor climate related data. Lead authors of IPCC reports assess the available information about climate change based on published sources. The IPCC has published five comprehensive assessment reports reviewing the latest climate science, as well as a number of special reports on particular topics. The IPCC published its First Assessment Report (FAR) in 1990, a supplementary report in 1992, a Second Assessment Report (SAR) in 1995, a Third Assessment Report (TAR) in 2001, a Fourth Assessment Report (AR4) in 2007 and a Fifth Assessment Report (AR5) in 2014. The IPCC is currently preparing the Sixth Assessment Report (AR6), which will be completed in 2022 [5].

As we mentioned, the IPCC's Fifth Assessment Report (AR5) was completed in 2014 and followed the same general format as of AR4, with three Working Group reports and a Synthesis report The Working Group I report (WG1) was published in September 2013 [6].

Conclusions of AR5

Working Group I

- "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia."
- "Atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years."
- Human influence on the climate system is clear. It is extremely likely (95-100% probability) that human influence was the dominant cause of global warming between 1951-2010.

Working Group II

- "Increasing magnitudes of [global] warming increase the likelihood of severe, pervasive, and irreversible impacts."
- "A first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability.”
- "The overall risks of climate change impacts can be reduced by limiting the rate and magnitude of climate change.”

Working Group III

- Without new policies to mitigate climate change, projections suggest an increase in global mean temperature in 2100 of 3.7 to 4.8 °C, relative to pre-industrial levels (median values; the range is 2.5 to 7.8 °C including climate uncertainty).

The current trajectory of global greenhouse gas emissions is not consistent with limiting global warming to below 1.5 or 2 °C, relative to pre-industrial levels. Pledges made as part of the Cancún Agreements are broadly consistent with cost-effective scenarios that give a "likely" chance (66-100% probability) of limiting global warming (in 2100) to below 3 °C, relative to pre-industrial levels [7].

The United Nations Climate Change Conferences are yearly conferences held in the framework of the United Nations Framework Convention on Climate Change (UNFCCC). They serve as the formal meeting of the UNFCCC Parties (Conference of the Parties, COP) to assess progress in dealing with climate change. Some significant conferences were the followings:

COP 3, Kyoto, Japan, 1997

COP 3 took place in December 1997 in Kyoto, Japan. After intensive negotiations, it adopted the Kyoto Protocol, which outlined the greenhouse gas emissions reduction obligation for Annex I countries, along with what came to be known as Kyoto mechanisms such as emissions trading, clean development mechanism and joint implementation. Most industrialized countries and some Central European economies in transition (all defined as Annex B countries) agreed to legally binding reductions in greenhouse gas emissions of an average of 6 to 8% below 1990 levels between the years 2008-2012, defined as the first emissions budget period. The United States would be required to reduce its total emissions an average of 7% below 1990 levels; however US Congress did not ratify the treaty after Clinton signed it. The Bush administration explicitly rejected the protocol in 2001.

COP 16, Cancún, Mexico, 2010

The outcome of the summit was an agreement adopted by the states' parties that called for the 100 billion USD per annum "Green Climate Fund", and a "Climate Technology Centre" and network. However, the funding of the Green Climate Fund was not agreed upon. Nor was a commitment to a second period of the Kyoto Protocol agreed upon, but it was concluded that the base year shall be 1990 and the global warming potentials shall be those provided by the IPCC.

All parties "Recognizing that climate change represents an urgent and potentially irreversible threat to human societies and the planet, and thus requires to be urgently addressed by all Parties,". It recognizes the IPCC Fourth Assessment Report goal of a maximum 2 °C global warming and all parties should take urgent action to meet this goal. It also agreed upon greenhouse gas emissions should peak as soon as possible, but recognizing that the time frame for peaking will be longer in developing countries, since social and economic development and poverty eradication are the first and overriding priorities of developing countries. [6]

COP 21 Paris, 2015

The COP 21 was held in Paris from 30 November to 12 December 2015. Negotiations resulted in the adoption of the Paris Agreement on 12 December, governing climate change reduction measures from 2020. The adoption of this agreement ended the work of the Durban platform, established during COP17. The agreement entered into force (and thus become fully effective) on November 4, 2016. On October 4, 2016 the threshold for adoption was reached with over 55 countries representing at least 55% of the world's greenhouse gas emissions ratifying the Agreement.

CLIMATE MODELLING

Climate models use quantitative methods to simulate the interactions of the important drivers of climate, including atmosphere, oceans, land surface and ice. They are used for a variety of purposes from study of the dynamics of the climate system to projections of future climate.

All climate models take account of incoming energy from the Sun as short wave electromagnetic radiation, chiefly visible and short-wave (near) infrared, as well as outgoing long wave (far) infrared electromagnetic. Any imbalance results in a change in temperature.

Models vary in complexity [8]:

- A simple radiant heat transfer model treats the Earth as a single point and averages outgoing energy.
- This can be expanded vertically (radiative-convective models) and/or horizontally.
- Finally, (coupled) atmosphere–ocean–sea–ice global climate models solve the full equations for mass and energy transfer and radiant exchange.
- Box models can treat flows across and within ocean basins.
- Other types of modelling can be interlinked, such as land use, allowing researchers to predict the interaction between climate and ecosystem.

At their most basic level, climate models use equations to represent the processes and interactions that drive the Earth’s climate. These cover the atmosphere, oceans, land and ice-covered regions of the planet. The models are based on the same laws and equations that underpin scientists' understanding of the physical, chemical and biological mechanisms going on in the Earth system [9].

Global climate models

Global climate models are mathematical frameworks that were originally built on fundamental equations of physics. They account for the conservation of energy, mass, and momentum and how these are exchanged among different components of the climate system. Using these fundamental relationships, GCMs are able to simulate many important aspects of Earth's climate: large-scale patterns of temperature and precipitation, general characteristics of storm tracks and extratropical cyclones, and observed changes in global mean temperature and ocean heat content as a result of human emissions. The complexity of climate models has grown over time, as they incorporate additional components of Earth's climate system. Today, global climate models simulate many more aspects of the climate system: atmospheric chemistry and aerosols, land surface interactions including soil and vegetation, land and sea ice, and increasingly even an interactive carbon cycle and/or biogeochemistry.

Regional climate models

Dynamical downscaling models are often referred to as regional climate models, since they include many of the same physical processes that make up a global climate model, but simulate these processes at higher spatial resolution over smaller regions [10].

Four regional climate models (RCMs) were adapted in Hungary for dynamic downscaling of the global climate projections over the Carpathian Basin [11]]:

- the ALADIN-Climate model;
- the PRECIS model;
- the RegCM model;
- the REMO model.

The RCMs are different in terms of dynamical model formulation, physical parametrizations; moreover, in the completed simulations they use different spatial resolutions, integration domains and lateral boundary conditions for the scenario experiments. Therefore, the results of the four RCMs can be considered as a small ensemble providing information about various kinds of uncertainties in the future projections over the target area, i.e., Hungary.

After the validation of the temperature and precipitation patterns against measurements, mean changes and some extreme characteristics of these patterns (including their statistical significance) have been assessed focusing on the periods of 2021-2050 and 2071-2100 relative to the 1961-1990 model reference period. The ensemble evaluation indicates that the temperature-related changes of the different RCMs are in good agreement over the Carpathian Basin and these tendencies manifest in the general warming conditions. The precipitation changes cannot be identified so clearly: seasonally large differences can be recognized among the projections and between the two periods. An overview is given about the results of the mini-ensemble and special emphasis is put on estimating the uncertainties in the simulations for Hungary. Heat wave events are important temperature related hazards due to their impacts on human health. Projected changes in the frequency of different heat wave warning levels are analyzed for the 21st century. For this purpose, outputs of regional climate model PRECIS (Providing REgional Climates for Impacts Studies) are used taking into account three different global emissions scenarios (A2, A1B, B2). The results clearly show an increase in occurrence and length of heat waves with respect to the underlying emission scenarios and regional climate model used. Moreover, the potential season of heat wave occurrences is projected to be lengthened by two months in 2071-2100 compared to 1961-1990.

There is growing evidence that greenhouse gas emissions from human activity are causing climate change. Over the last 100 years, the global average surface temperature has increased by 0.74°C, and sea level has risen by 17 cm during the 20th century. Current trends are projected to continue and accelerate in the coming decades. Europe will also be increasingly confronted with the impact of climate change. Climate change will come about gradually in the form of average temperature increases, with the main impacts of gradual changes being felt in the long term. However, the impact of more frequent extreme weather events will be felt in the short and medium term. Climate change is one of the main long term drivers of economic, social and environmental changes. Its impact is global with very different regional expressions. It influences regional growth potential, regional sustainability as well as the quality of life via changing natural conditions. The impact of climate change is asymmetric across European regions, and depends on the magnitude and rate of climate change, the exposure and sensitivity of ecological and socio-economic systems, and the ability of societies to adapt to these changes [12].

SUMMARY

Climate change, also called global warming, refers to the rise in average surface temperatures on Earth. The Sun serves as the primary energy source for Earth's climate. Some of the incoming sunlight is reflected directly back into space, especially by bright surfaces such as ice and clouds, and the rest is absorbed by the surface and the atmosphere. Much of this absorbed solar energy is re-emitted as heat (longwave or infrared radiation). The atmosphere in turn absorbs and re-radiates heat, some of which escapes to space. Any disturbance to this balance of incoming and outgoing energy will affect the climate. If all heat energy emitted from the surface passed through the atmosphere directly into space, Earth's average surface temperature would be tens of degrees colder than today. Greenhouse gases in the atmosphere, including water vapor, carbon dioxide, methane, and nitrous oxide, act to make the surface much warmer than this, because they absorb and emit heat energy in all directions (including downwards), keeping Earth's surface and lower atmosphere warm. If all heat energy emitted from the surface passed through the atmosphere directly into space, Earth's average surface temperature would be tens of degrees colder than today. The primary cause of climate change is the burning of fossil fuels, such as oil and coal, which emits greenhouse gases into the atmosphere – primarily carbon dioxide. Other human activities, such as agriculture and deforestation, also contribute to the proliferation of greenhouse gases that cause climate change. Climate models are based on well-established physical principles and have been demonstrated to reproduce observed features of recent climate and past climate changes. There is considerable confidence that Atmosphere-Ocean General Circulation Models (AOGCMs) provide credible quantitative estimates of future climate change, particularly at continental and larger scales. Confidence in these estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation). According to the simulation by the different Regional Climate Models are in good agreement over the Carpathian Basin and these tendencies manifest in the general warming conditions. The precipitation changes cannot be identified so clearly: seasonally large differences can be recognized among the projections and between the two periods.

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