Computer Application of the New Generation in the Simulation of Climate Change

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***Abstract**: Climate change that has significantly altered the natural environment and living conditions of the people due to the occurrence of extreme and non-extreme weather events have become an area of significant scientific research. Today, scientists have sufficient knowledge and appropriate technology that can explore this area and enable humanity to realize the impact of human activities on the environment and climate change with the aim to anticipate consequences and adaptation. Computer climate models, modern software solutions, especially computers of exceptional processing power, represent new technologies as a function of climate and weather simulation process, predicting climate change and educating people.*

***Key words:** Climate change, Climate models, Computer simulation, Supercomputers*

INTRODUCTION

Climate change alters the natural environment and influences people, their way of life, economy and increasingly ceases to be just a matter of protecting the environment, but also embraces contemporary topics such as economic growth, energy security and sustainable development. As such, climate change is becoming one of the most important issues in international relations in modern society. Global warming, as a result of increased emissions of greenhouse gases in the atmosphere, is the main cause of climate change and unforeseen meteorological phenomena. The amount of these gases in the future will increase, which will further affect the increase of the temperature of Earth. The result will be warming of the ice cover and melting glaciers, rising sea levels and flooding, on the one hand, and drought, on the other hand, and an increase in the frequency of some extreme events (wildfires, tornadoes, hurricanes and tropical heat wave).

Significantly improved the study of climate change, especially since such experiments cannot be realized in real conditions.

1. CLIMATE CHANGE AND EXTREME EVENTS ON EARTH

Climate change on Earth is a long process, but after the Industrial Revolution technogenic activities have significantly affected the climate change altering the natural environment and the living conditions of people. Anthropogenic activities, primarily various industrial processes, emit into the atmosphere a large number of gases (carbon dioxide, methane, nitrous oxides, sulfur dioxide, chlorofluorocarbons and halons). Table 1 shows the percentage prevalence of five major pollutants that influence the formation of greenhouse gases. Reduction of emissions of gases that cause the greenhouse effect, global warming and climate change is becoming a major problem in environmental protection and survival of mankind on Earth.At present, the average temperature on Earth is 0.8 degrees higher than before the Industrial Revolution, and before people began to use massively fossil fuels and carbon dioxide accumulating in the atmosphere [1]. “These changes will affect the physical geography of the world. A radical change in the physical geography of the world must have strong implications on the human geography - where people live and how they live “[3].

We can add that other global environmental issues also affect the geography of the planet. Thus, increase in the acidity of the oceans and precipitation due to rising concentrations of nitrogen and sulfur oxides in the air in the combustion of fossil fuels (coal and poor-quality oil) causes a reduction in the surface of coral islands, dry forests and destroying the fish stocks in lakes in many countries of the world. Acidification of the biosphere causes an increase in fungal diseases in humans, but also in crops with the consequent emergence of cancerous aflatoxins in food and animal feed [4].

Reduction of thickness of the ozone layer (ozone hole) causes amplification of UV radiation and a decrease of yield and growth of cancerous skin disease melanoma with a high proportion of deaths. Thus, the chemistry of the environment causes changes in demographics and physical geography of the world.

Enormous depletion of natural resources (fossil fuels and minerals) in the second half of the twentieth century contributed to the degradation of ecosystems. If a wanton degradation of the ecosystems of our planet is to continue in the future, mankind will be faced with unforeseeable consequences for the survival of the human species [6].

Under the influence of climate change, the frequency of some extreme events has increased. Heat waves have become more frequent over most of the globe while at the same time there are frequent occurrences of heavy rainfall in many areas. Although at high latitudes mortality has reduced due to cold (with a decreasing trend), but climate change will affect the worldwide increase in the number of deaths due to malnutrition and heat stress.Therefore, it is necessary to create national programs of adaptation to climate change as well as applications of repairing damage [4].

2. MODELLING OF THE CLIMATE AND CLIMATE CHANGE

Exploring climate change is an area where there is a high number of scientists, research institutes (centers) and the countries that contribute substantial funds earmarked for this type of research. Information about the climate have become crucially important in decision making in all sectors (from agriculture to insurance), and given the evident climate change, the need will increase for climate forecasts that will allow scientists and decision-makers to understand climate processes and to prepare for future requirements [7].

Climate models are the primary tools that are available to scientists during research of reaction of the climate system to various influences, in seasonal climate forecasts or predictions of climate using decade time scales, as well as the projections of future climate in the next century or longer period. Climate models, as well as numerical models of processes in the climate system, are the superior technology in the study of climate processes. These are systems of differential equations established on the basis of the fundamental laws of physics, fluid motion, and chemistry. Since these models are implemented and run in computer systems, they can be defined as "computer codes that use mathematical representations of known processes of the Earth's climate system (movements and cycles of energy and water in the atmosphere, oceans, land surface, including sea ice and snow) with the aim of simulations of climate conditions in the past and projections of the future "[7].

In recent years, climate models have been mostly used to predict temperature changes on Earth due to increased concentrations of greenhouse gases in the atmosphere (greenhouse effect). Unlike previous climate models, which have based their research on the shorter time periods, current models used by scientists examine possible GFDL climate change that may be caused by increasing atmospheric carbon dioxide over the next few centuries.

Climate information needed by decision-makers and/or climate researchers often require climate model projections of higher spatial resolution and specific timescales than those currently available. There are some limitations when it comes to the reliability of projections provided by climate models. However, current climate models are based on strategies that have proven some gradual improvement of these models using the technique of "finer grids". This technique has enabled the creation of unit climate models that contain information about the physical and climatic characteristics of a particular location, with the addition of new processes for which users are particularly concerned about, such as the interactions between terrestrial ecosystems and the oceans. The main problems, regardless of whether they are global or regional climate models, are related to the fact that the models include a vast amount of data and different ranges of time scales

[2]. Therefore, the contemporary climate models must combine a variety of time scales and subsystems, and different parts of the climate system are divided into millions of network cells. The scientists divide the planet into a three-dimensional grid (Figure 2), apply the basic equations in each cell and evaluate the results. For example, atmospheric models calculate the strength of winds, heat transfer, radiation, relative humidity and the hydrology of Earth's surface within each grid and allow for evaluation of interactions with neighboring cells. According to a report from 2013, which was released by the Intergovernmental Panel on Climate Change (IPCC), it has been estimated that the climate models, such as the Atmosphere-Ocean General Circulation Models, Earth System Models, and Regional Climate Models, have greatly improved. Descriptions of physical processes have been improved, new model components have been introduced, and resolution of the model has been significantly improved, and model parameters have been corrected, all with the aim of creating a stable model [9].

3. APPLICATION OF SUPERCOMPUTER FOR SIMULATION AND PREDICTIONS

Along with the development of climate models, hardware infrastructure that could support the models and their simulation, has also developed. The latest generation of supercomputers has exceeded even the most optimistic predictions in terms of features and speed of operation and has become essential for large scientific projects such as cosmonaut projects, projects that are based on colossal mathematical operations, monitoring climate change, predicting extreme weather events and others [8].

IBM company has developed the newest supercomputer, Blue Gene, which is even more powerful in processing data and climate model simulations. This computer has 131,000 processors and can perform 280 trillion operations per second (as much as a scientist using the calculator could do for 177,000 years).

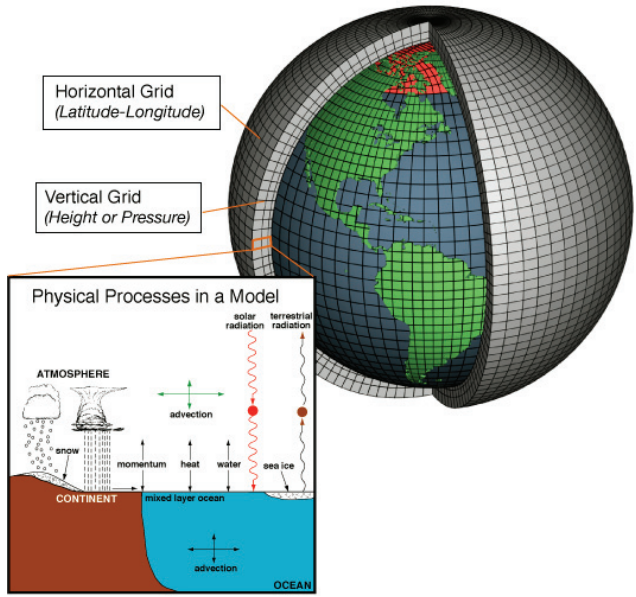

Figure1: Climate models which represent the planet in 3-dimensional grid
Source: http://celebrating200years.noaa.gov/breakthroughs/climate_model

The Japanese NEC built supercomputers that far exceeded the performance of the IBM PC. The latest computer was developed exclusively for the simulation of natural atmospheric and climate change on Earth. “Thanks to its characteristics, this supercomputer is particularly suitable for the simulation of complex, interconnected systems such as Earth's climate, with interactions between masses of water, land and atmosphere. In addition, Japanese scientists intend to carry out research with the aim of predicting earthquakes“. [2]

Figure 2: Earth Simulator
Supercomputer in the space of three tennis courts

This computer, called the Earth Simulator (Figure 2), is currently one of the most powerful systems in the world with the power of 35 teraflops, working memory of 10 terabytes and a data area of 700 terabytes. Compared to IBM's PCs, the computer has far less embedded processors (only 5,104) but using the new structure it achieves far greater data processing speed. The largest number of data come from satellite observations and measurements of the atmosphere, land and ocean, and the computer is used on a daily basis to handle about 8 million observations from satellites, and to implement them in the appropriate models [12].

Figure 3: Supercomputer» Paradox 4«, Scientific Computing Laboratory of the Institute of Physics, Belgrade, Serbia

The Scientific Computing Laboratory of the Institute of Physics in Belgrade, Republic of Serbia, is implementing the project "Climate change and its impact on the environment." The focus of the research is "Implementation of numerical climate models on supercomputing platforms." A supercomputer "Paradox" which consists of 106 HP servers G8 latest generation of the overall performance of 106 teraflops (Fig.3) is available for the research. The computer has more than 1,000 processors and 50 terabytes of storage capacity.

CONCLUSION

Climate changes, and changes in ecosystems are contemporary problems that face human society. The society must cope with them, get to know them and be prepared to adapt to them. Research shows a tendency to increase emissions of greenhouse gases and harmful gases that increase the acidity biosphere, which will inevitably lead to further changes of climate, but also to the emergence of extreme and non-extreme events that will significantly affect the people's lives, their economy and the natural environment.

Modeling of climate processes and climate change, enables scientists to perform significant experiments that will expand knowledge about the effects of various natural and other factors on the natural environment and processes. Software solutions that allow the simulation of these processes provide predictions of climate change and the occurrence of events for which human society must be ready.

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Докладът е рецензиран.