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RADIATION FORCING AND CLIMATE CHANGE

Summary. *Data are presented on the relationship between radiation forcing and Earth's climate change in the format of global warming. The results of studies of the Earth's energy imbalance are considered. The influence of a number of components of radiation forcing has been analyzed.*

Key words: *climate safety, radiation forcing, energy imbalance of the Earth, abnormal temperature of the Earth.*

In connection with the climate threat associated with global warming, issues of climate security are becoming increasingly relevant [1-4]. It is important to analyze changes in the anomaly of the global average temperature of the Earth's surface, as the main indicator of climate change. Particular attention should be paid to considering the influence on this indicator of such a climate-forming factor as radiation forcing.

Radiation forcing is the main driver of climate change in the form of global warming [5; 6]. The definition of this type of forcing undergoes certain changes over time. This article uses this concept in accordance with the International Panel on Climate Change (IPCC) AR6 glossary. Radiative forcing is defined as the change in net radiative flux (expressed in W/m^2) due to changes in the external factor of climate change, such as a change in carbon dioxide (CO_2) concentration, volcanic aerosol concentration, or solar radiation.

Radiative forcing is directly related to the indicator of the Earth's energy imbalance. The latter is the difference between the input energy (solar radiation) and the output energy (the sum of solar radiation reflected by the Earth; long-wave radiation emitted by the Earth). In the 60s of the last century, most climatologists were of the opinion that the trend of the Earth's energy imbalance $EEI < 0$ was more likely and that the global cooling scenario would continue to be realized. Based on instrumental observation data, for two decades (50s - 60s of the last century) the Earth's climate system (ECS) was in a state of relative equilibrium, when the EEI indicator was ≈0. Since the 70s, there has been a clear trend of change in the Earth's energy imbalance`e towards its positive values ($EEI > 0$). The process of increasing the anomaly of the global average surface temperature of the Earth (GAST) corresponds to the beginning of the 70s and has been continuing for the last about 50 years (Fig. 1). At the same time, on a historical scale, modern warming is characterized by a high rate. Thus, the rate of heat accumulation in the period 2006–2020 is noticeably higher than in the period 1971–2020 [6].

As for the energy imbalance of the Earth and stores of excess energy, the main store is the ocean, where 89% of it is stored. The land accounts for 6%, the cryosphere – 4%, the atmosphere – 1% [6]. At the same time, the melting of glaciers, ice sheets and sea ice occurs in a positive feedback loop: an increase in the area with a high albedo leads to a further increase due to additional melting, a decrease in the area of glaciation and, as a result, an increase in the average temperature of the Earth. Analysis of empirical data also shows that these processes are accelerating.

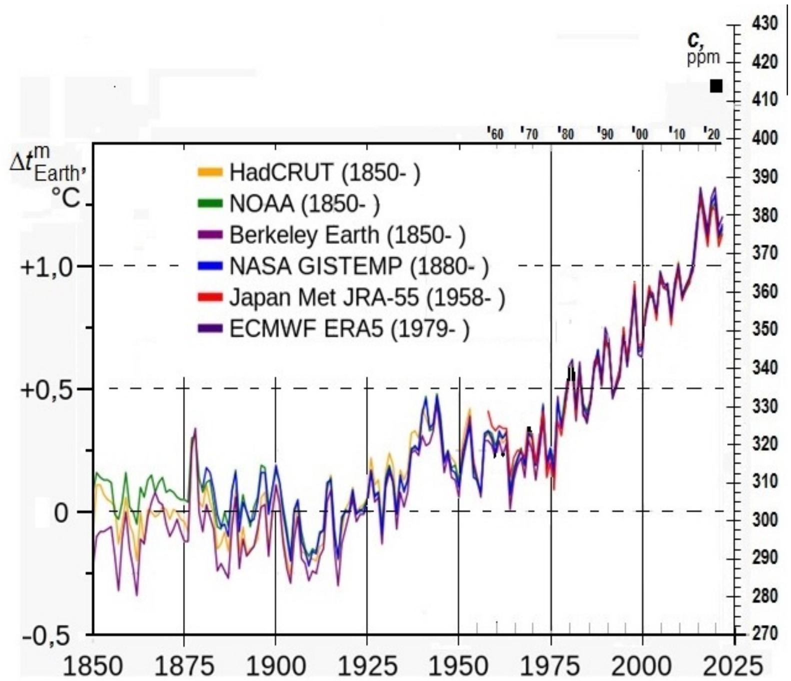

Fig. 1. Change in time of the anomaly of the global average temperature of the Earth's surface Δt^{m}_{Earth} according to data from various sources

Sources: [3; 7; 8]

On a relatively short time scale (several hundred years), the dynamic influence of a number of components of radiative forcing (namely, changes in solar radiation input, albedo, astronomical factors according to M. Milankovich cycles, aerosol content) can be neglected due to their quasi-stationary, and often practically stable nature.

There are some cautions regarding aerosol loading. Under certain conditions, volcanic eruptions can lead to positive EEI. This is evidenced by data from the underwater eruption of the Hunga volcano. Its consequence was the appearance of a large amount of stratospheric water vapor, which resulted in a disturbance in the state of the Earth's climate system, so that the traditionally negative EEI was replaced by a positive one.

In fig. 1 shows six data sets on the behavior of the temperature anomaly Δt^{m}_{Earth} (cluster 1) from the leading climatological centers - two European (HadCRUT and ERA5), three North American (NOAA GlobalTemp, Berkeley Earth, NASA GISTEMP) and one Japanese (Japan Met JRA-5). Four datasets – HadCRUT, NOAA GlobalTemp, Berkeley Earth, NASA GISTEMP – cover full periods of instrumental climate and weather observations. The two other data sets (ERA5 and JRA-55) are products of reanalysis. Anomalies of the data set are calculated relative to the baseline from 1981 to 2010. and shift by 0,69 °C, which is the "best estimated difference for this period from the average value for 1850-1900" given in IPCC AR6.

The intermittent co-phase of El Niño Southern Oscillation (ENSO) events, volcanic activity, and the Killing curve resulted in the "ragged" behavior of the GAST anomaly in the late 20th and early 21st centuries (Fig. 1). Although in general there is a clearly expressed tendency of accelerated growth of the temperature anomaly Δt^{m}_{Earth}. The influence of the cooling phases of La Niña, the heating of El Niño, as well as the shading of atmospheric transparency or its enrichment with greenhouse gases as products of volcanic eruptions were stabilizing and destabilizing impact factors for GAST.

As for the record for summer temperature (JJA), the current year 2023 corresponds to it. According to the climate bulletin (published as part of the large European project Copernicus Climate Change Service, implemented by the European Center for Medium-Range Weather Forecasts on behalf of the European Commission and with financial support from the EU), the top five warmest boreal summers (June-July-August) are regularly updated [9]. The calendar series of generalized climatic data ordered by the authors is as follows (after the year in parentheses, in descending order, summer temperature, its increase compared to the previous summer record): 2023 (16,77 °C, Δt = 0,29 °C); 2019 (16,48 °C, Δt = 0,03 °C); 2016 (16,45 °C, Δt = 0,01 °C); 2022 (16,44 °C, Δt = 0,01 °C); 2020 (16,43 °C, Δt = 0,04 °C); 2021 (16,39 °C).

Conclusion. An analysis of the nature of the impact of radiation forcing as a climate-forming factor was performed. Data from instrumental observations of the Earth's energy imbalance are considered. It is shown that since the 70s of the last century there has been an increase in the anomaly of the global average temperature of the Earth's surface.

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