Technical sciences

UDC 697.27:621.365

Fialko Nataliia

Doctor of Technical Sciences, Professor,

Corresponding Member of the NAS of Ukraine, Head of the Department

Institute of Engineering Thermophysics of NAS of Ukraine

Tymchenko Mykola

Candidate of Technical Sciences (PhD), Senior Researcher

Institute of Engineering Thermophysics of NAS of Ukraine

Sherenkovskiy Julii

Candidate of Technical Sciences (PhD),

Senior Scientific Researcher, Leading Researcher

Institute of Engineering Thermophysics of NAS of Ukraine

VOLCANO ERUPTIONS AND THEIR IMPACT ON EARTH'S CLIMATE CHANGE

Summary. *The features of the behavior of the anomaly of the global average temperature of the Earth's surface under the influence of such a natural climate-forming factor as volcanic eruptions are considered. Data are provided to deepen the understanding of the possibility of the impact of volcanic activity on the Earth's climate.*

Key words: *volcanic eruption, global warming, climate security, anomaly of the global temperature of the Earth's surface, greenhouse gases*

Issues of climate security of the Earth are very relevant. Climate change on the planet, global warming is approaching a critical state [1-5]. The global average temperature of the Earth's surface is influenced by many climate-

forming factors, which include, firstly, anthropogenic greenhouse gas emissions, and secondly, the influence of fluctuations in opposite extreme values of water temperature and atmospheric pressure (Southern Oscillation El Niño), but is a phenomenon on a planetary scale and directly or indirectly affects the climate of a significant part of the Earth, and thirdly, volcanic eruptions also affect the climate.

Let's consider the factor of the influence of volcanic eruptions on global warming.

During the period of modern global warming, there are some atypical manifestations of the influence of climate-forming factors on the anomaly of the average temperature of the Earth. For example, the eruption of underwater volcanoes leads to the release of large amounts of water vapor, among other products, and then to an increase in the indicated temperature. Although most eruptions that produce ash, dust, soot, aerosols, etc. usually reduce it. This leads to the need to conduct special studies of such atypical manifestations of climate-forming factors and analyze the scale of their consequences.

The purpose of the work is to analyze the development of ideas about the physical aspects of climate change and study the behavior of the global average surface temperature anomaly in the context of the action of such a climate-forming factor as volcanic eruptions.

The energy basis of the phenomenon of global climate change in the form of warming is made up of low-potential energy flows. The exception is volcanoes; their eruptions, although high-temperature, are short-lived and of low frequency. According to [6], the most powerful eruption in the last ≈10.0 thousand years occurred about 200 years ago. The volume of pyroclastic material from the Tambora volcano (1815) is estimated at 2800 km^3. Then climate anomalies covered large parts of the Northern Hemisphere, in particular Western Europe and North America. Crops and livestock were destroyed, leading to the greatest famine of the 19th century. In Europe, 1816 was called

"the year without summer." The last eruption of the highest class VEI=8 (volcanic explosiveness index) occurred 72 thousand years ago on the island Sumatra (Tobo volcano).

Products of volcanic activity that influence climate change are known to be gases, smoke, ash, dust, soot, aerosols, including sulfate aerosols. Part of them, located in the atmosphere in a suspended, very small state, blocks solar radiation. Therefore, most eruption products usually provide a cooling effect, theoretically up to a state of so-called "nuclear winter". Water vapor and carbon dioxide, also products of volcanic activity, as greenhouse gases, on the contrary, lead to a warming effect. Typically, greenhouse gases from volcanic eruptions constitute a relatively small amount of global emissions and are two orders of magnitude lower in intensity than modern anthropogenic radiation forcing. In most cases, the net net effect of volcanic emissions is temporary (up to several years) cooling. However, in some situations, "volcanic" cooling can lead to an increase in ice, followed by a positive feedback: an increase in the ice surface area reduces the Earth's absorption of energy, and therefore leads to a further increase in the zone with a large area of glaciation and, as a result, a decrease in the average temperature of the Eart and so on.

In Fig. 1 on the time axis shows single and group volcanic eruptions with the volcanic explosiveness index VEI = 3...6. In the time period, the end of the 20th – the beginning of the 21st century, the eruption of large volcanoes (Pinatubo, VEI=6, 1991; Cordon Caule, VEI=5, 2011; Hunga Tonga, VEI=5, 2022) and volcanoes with lower volcanic explosiveness indices (VEI≤4) are correlated by local descending segments of broken line 3 in Fig. 1 annual anomalies Δt^{m}_{Earth}. Apparently, the duration of the noticeable influence of volcanic eruptions is relatively short and is limited to one or two years.

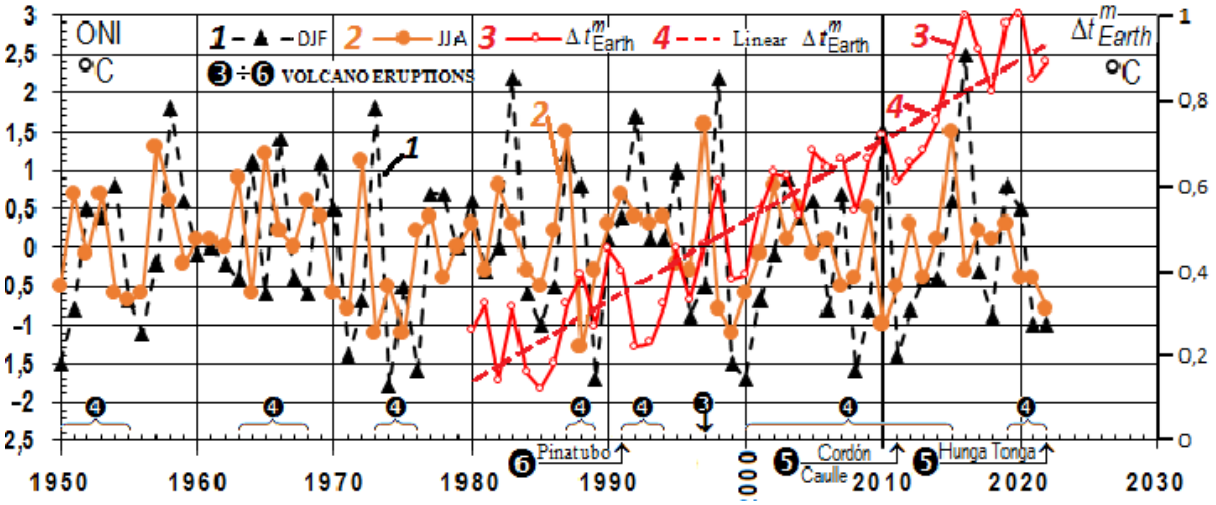

Fig 1. Time change in the intensity of the oceanic Niño index ONI (Oceanic Niño Index)

(1 – winter, 2 - summer), anomalies of the global average temperature of the Earth's surface Δt^{m}_{Earth} (3) and its trend lines (4) and chronology of volcanic eruptions ❸, ❹, ❺, ❻ with volcanic explosiveness index VEI= 3; 4; 5; 6; arrows and braces indicate large volcanoes (VEI≥5) and small (VEI≤4), but with increased eruption frequency

Initial data sources: [6; 7; 8]

Understanding of the possible influences of volcanic activity on the Earth's climate is deepening with new data regarding volcanic eruptions. Thus, the eruption of the relatively large VEI≈5.8 submarine volcano Hunga Tonga-Hunga Ha'apai (hereinafter Hunga) in January 2022 drew attention to the effect of significant warming that can be caused by such volcanoes [9-11].

The Hunga eruption released large amounts of water vapor into the stratosphere, among other volcanic products. The total mass of evaporated water according to satellite and ground-based observations and the results of modeling the atmospheric transport of volcanic masses is estimated in a wide range of 50...146 Teragram. Along with this, the aerosol load in the stratosphere increased 5 times, the influence of which nevertheless did not change the nature of the final effect of volcanic heating [9-11]. For the Earth's climate system, the Hunga eruption and the formation of water vapor determines a large disturbance with a positive energy imbalance of the Earth. This eruption likely increased the net radiation forcing factor. As a result, the likelihood of temporary exceeding

the Paris Agreement norm of 1.5°C has increased over the coming years of the next decade. The corresponding assessment of the significance of the Hung radiation factor is indirectly confirmed by the 2023 summer temperature (JJA-June, July, August - meteorological summer of the Northern Hemisphere) indicator. That is, the indicated fact of reaching a record temperature this year may be evidence of the influence of the Honggu eruption as one of the reasons for the abnormally hot summer. It should be noted that this temperature record was set despite the cooling effect of triple La Niña - a natural regional phenomenon of a cyclical nature with an irregular (up to 7 years) period of change in sea surface temperature in the eastern tropical Pacific Ocean, directly affecting the climatic and weather conditions of most of the tropics and subtropics and indirectly affecting the entire climate system of the earth. Second phase of this phenomenon, La Niña corresponds to a cooling of ocean temperatures.

Conclusions. An analysis of the behavior of the anomaly of the global average temperature of the Earth's surface under the influence of volcanic eruptions was performed. Analyzed the features of volcanic activity and climate change in the format of modern global warming. During this phase of climate change, in most cases the net effect of volcanic emissions is a temporary decrease in the average temperature of the Earth. The issues of deepening the understanding of the possible influence of volcanic activity on the Earth's climate are considered. Evidence is provided of the January 2022 eruption of the relatively large submarine volcano Hunga, which resulted in the effect of a temporary increase in the average temperature of the Earth in 2023, which is associated with the release of large amounts of water vapor among other volcanic products.

References

1. Khalatov A., Fialko N., N., Timchenko M. Energy climate security and energy supply to the building stocks. *Thermophysics and thermal power engineering.* 2023. 48(1). P. 20-27. doi: https://doi.org/10.31472/ttpe.1.2023.3.
2. Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 2023. P. 35-115. doi: https://doi.org/10.59327/IPCC/AR6-9789291691647.
3. Gulev S.K., Thorne P.W., J. Ahn et al. Changing State of the Climate System. *Climate Change 2021: The Physical Science Basis.* Contribution of Working Group I to the Sixth Assessment Report of the IPCC [Masson-Delmotte, V., P. Zhai, A. Pirani et al, (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, USA, 2021. P. 287–422. doi: https://doi.org/10.1017/9781009157896.004.
4. von Schuckmann K., Minière A., Gues F et al. Heat stored in the Earth system 1960–2020: where does the energy go? *Earth Syst. Sci. Data*. 2023. 15. P. 1675–1709. doi: https://doi.org/10.5194/essd-15-1675-2023.
5. Hansen J.E, Lacis A.A. Sun and dust versus greenhouse gases: An assessment of their relative roles in global climate change. *Nature*. 1990. 346. P. 713-719. doi: https://doi.org/10.1038/346713a0.
6. Cold & Warm Episodes by Season. *National Weather Service.* URL: https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php (date of access: 25.11.2023).
7. Rafferty J. P. World's major volcanoes. *Encyclopedia Britannica*. 2023. URL: https://www.britannica.com/topic/worlds-major-volcanoes-2226816 (date of access: 25.11.2023).

8. Lenssen N. & National Center for Atmospheric Research Staff (Eds). The Climate Data Guide: Global surface temperature data: GISTEMP: NASA Goddard Institute for Space Studies (GISS) Surface Temperature Analysis. 2022. URL: https://climatedataguide.ucar.edu/climate-data/global-surface-temperature-data-gistemp-nasa-goddard-institute-space-studies-giss (date of access: 25.11.2023).
9. Jenkins S., Smith C., Allen M. et al. Tonga eruption increases chance of temporary surface temperature anomaly above 1.5 °C. *Nat. Clim. Change.* 2023. 13. P. 127–129. URL: https://www.researchgate.net/publication/367089228_Tonga_eruption_increases_chance_of_temporary_surface_temperature_anomaly_above_15_C (date of access: 25.11.2023).
10. Khaykin S., Podglajen A., Ploeger F. et al. Global perturbation of stratospheric water and aerosol burden by Hunga eruption. *Communications Earth & Environment*. 2022. 3. URL: https://www.nature.com/articles/s43247-022-00652-x (date of access: 25.11.2023).
11. Tymchenko N., Fialko N. Global warming as a critical factor for sustainable development. *International Scientific Journal "Internauka".* 2021. № 13. P. 64-67. doi: https://doi.org/10.25313/2520-2057-2021-13-7536.