

The Principle of Climate Cycle Variations

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Keypoints

- Climate has changed periodically over the past few million years and is not solely dependent on carbon dioxide concentrations on Earth.
- There is a consistent correspondence between millennial-scale climate cycles over the past 10,000 years and North Atlantic Bond Events.
- The mechanism of Bond Events is the cyclical result of negative feedback interactions between oceanic warm currents and changes in polar ice sheets.

Abstract

The current trajectory of global climate change presents increasing uncertainties. This paper employs satellite observation data from NASA to analyze the dynamic processes of changes from a holistic perspective. We identify evidence for a correlation between climate change and the periodicity of Bond Events. This correlation reveals potential causal principles behind changes in the Holocene millennial climate cycles and 100,000-year ice age cycles on Earth. We assert that the increase in greenhouse gas concentration is not the primary cause of the current phase of climate warming. We propose that ocean currents and monsoons are primary factors in global warming. A deeper understanding of Earth's cyclical climate variations may open avenues for developing technologies to influence climate, potentially mitigating future environmental crises for life and human civilization.

Keywords: Climate Cyclical Variations, Natural Climate Variability, North Atlantic Current, Bond Events, NASA Scientific Visualization Studio (SVS), Atlantic Meridional Overturning Circulation (AMOC), Artificial Climate Influence

1. Introduction

1.1. Global Warming

In recent years, the Earth's surface temperatures, particularly during summer, have shown a marked increase. While the Earth's climate has demonstrably undergone cyclical changes over millions of years, the underlying principles driving these variations remain a subject of ongoing scientific investigation. The current climate crisis appears to be entering a phase characterized by unprecedented changes and increasing uncertainty. This raises a fundamental question: are the observed changes indicative of a system spiraling beyond control, or do they represent a phase within a "normal" but as-yet-uncharacterized natural cycle?

The GISTEMP is NASA's global temperature analysis tool, with

data extending back to 1880. According to NASA's GISTEMP analysis, the global average temperature has increased by approximately 2°C since 1880. NASA's Scientific Visualization Studio has produced an animation depicting global surface temperature variations since 1880. The upper panel of Figure 1 shows a five-year (2016–2020) spatial map of global temperature anomalies [1]. Temperatures higher than normal are shown in red, while those lower than normal are shown in blue. Normal temperatures represent the average over the 30-year baseline period from 1951 to 1980. Two key phenomena emerge from this data:

- (1) The Northern Hemisphere exhibits a significantly greater temperature increase compared to the Southern Hemisphere, with

the Arctic Circle experiencing the most pronounced warming, roughly twice that of the Southern Hemisphere;

(2) Notably, since 1880, there have been persistent cooling centers in the North Atlantic Ocean south of Greenland, in the

North Pacific near Alaska, and around Antarctica, a pattern that directly contrasts with the overall global warming trend. These two primary conclusions will serve as the basis for subsequent analysis in this article.

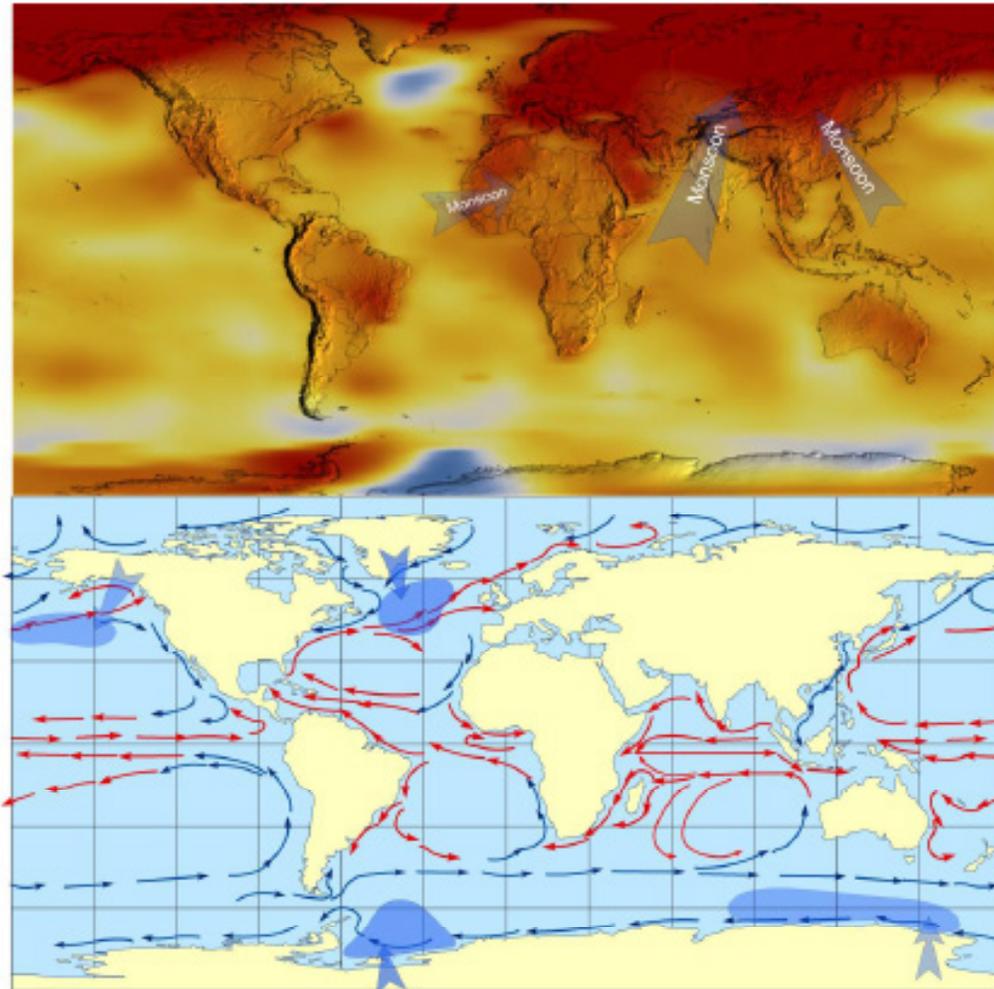


Figure 1: Global Temperature Anomalies from 2016 to 2020 According to NASA's SVS (top) and a Schematic Diagram (Bottom) Illustrating Major Global Ocean Currents and Areas of Observed Cooling. Indicative Arrow Lines for Ocean Currents Were Added by the Author.

1.2 Ocean Currents and Monsoons as Primary Factors in Global Warming, Not Carbon Dioxide

Some scholars have attributed global warming to the increase in carbon dioxide emissions from human activities. However, a detailed analysis of the varying extents of warming in different global regions suggests that the primary causes of changes in the Earth's surface temperature are variations in ocean currents and atmospheric circulation, rather than the impact of carbon dioxide. NASA's Scientific Visualization Studio data on global temperature changes clearly shows that the Arctic Circle and European regions have experienced significantly greater temperature increases compared to other parts of the world. What could be the reason? This calls for consideration of the impact of the North Atlantic Current on warming in Arctic regions.

In the Northern Hemisphere, the Gulf Stream–North Atlantic

Current plays a crucial role in influencing Earth's climate. It transports a significant amount of heat from the equatorial region to the northern Atlantic. Its main flow then carries this warmth through the relatively narrow passage between Greenland and the Scandinavian Peninsula into the largely enclosed Arctic Ocean, contributing to warming in the Arctic. Due to this concentrated heat input into the Arctic Circle, the warming observed there is substantially greater than in other regions. The warming in Europe is less than that in the Arctic Circle but greater than that in other regions, with an increase of approximately 1–2 degrees Celsius. This can be attributed to the westerlies, which carry a portion of the North Atlantic Current's heat onto the European continent, acting as a major driving force for the warming there.

Aside from Europe, the northeastern corner of Africa, including Morocco and Algeria, has experienced greater warming than other regions of the African continent, likely due to the influence of southward-flowing tributaries of the North Atlantic Current along the Iberian Peninsula. In the North Pacific, the Japan–North Pacific Current, under the influence of westerlies, flows toward the west coast of North America. A portion of it moves north, forming the Alaskan Current, which contributes to the warming of the polar regions and the Northern Hemisphere.

The more pronounced warming along the west coast of North America and Alaska is a clear consequence of the influence of the North Pacific-Alaska Current. The warming of the northern part of the Asian continent and the Arabian Peninsula is influenced not only by warm currents but also by the southwest monsoon, which carries moisture and heat from the Indian Ocean. The monsoon from the Atlantic also contributes to warming in the West Africa region. However, compared to the influence of warm currents on temperature increases, the impact of monsoons is secondary. The combination of heat from warm currents and monsoon winds has caused continental Asia and the Arabian Peninsula to warm more than much of the Southern Hemisphere and North America. From the schematic and comparison in Figure 1, the main warming areas can be explained by the heat generated by ocean currents and monsoons.

In the Southern Hemisphere, the extent of warming in the eastern part of Australia is significantly greater than that in the western part, clearly due to the influence of the East Australian Current. In the Atlantic, part of the South Equatorial Current, guided by the terrain of Brazil, flows south to form the Brazil Current. The extent of warming in Brazil is significantly greater than that in other regions of the South American continent. However, due to the vast oceanic area of the Southern Hemisphere, the flow of warm currents there is not strong. Under the influence of westerlies, heat is relatively evenly dispersed throughout the Southern Hemisphere. Moreover, due to the strong westerly winds and oceanic current circulation around Antarctica, the heat carried by warm currents from the equatorial region has difficulty reaching the central areas of the Antarctic continent. Because the warm currents in the Southern Hemisphere are weak and scattered, the average extent of warming in the Southern Hemisphere is approximately 1 degree Celsius lower than that in the Northern Hemisphere.

Therefore, the entire Earth's temperature anomalies are closely related to monsoons and warm currents. The surface ocean currents and monsoons bring large amounts of heat and moisture from the Earth's equator to areas along their paths and to polar regions, causing an increase in surface temperatures and precipitation in these areas, thus driving up the Earth's average temperature. The changes in ocean currents and atmospheric circulation patterns can effectively explain the regional differences in warming anomalies across the Earth. The increased concentration of carbon dioxide is relatively evenly dispersed in the air with atmospheric circulation, making it unable to cause regional differences in surface warming, and even less likely to match these regions. NASA's Scientific

Visualization Studio provides data visualization of the distribution of global carbon dioxide (CO₂) concentration from September 2002 to May 2022, which proves that the carbon dioxide concentration is evenly distributed globally [2].

When comparing the distributions of warm currents and increased carbon dioxide concentrations with the regional differences in global warming, the conclusion is clear: the main reason for Earth's warming is not the increase in carbon dioxide concentrations. Numerical simulations of carbon dioxide warming contain too many simplistic artificial assumptions and ignore the complexity of natural cycles, making them unreliable. Increases in carbon dioxide concentrations caused by human activities have a negligible impact on rising Earth temperatures. In contrast, due to the warming of the Earth, the water cycle has intensified, and land vegetation, along with ocean phytoplankton, has increased, leading to the consumption of a significant portion of the increased carbon dioxide through photosynthesis. These observational data challenge the idea that increasing carbon dioxide concentrations are the primary cause of global warming. In fact, the massive emission of carbon dioxide by human activities only began after the Industrial Revolution, less than 300 years ago. Prior to this, the Earth had already gone through approximately 8-10 climate change cycles over the last 10,000 years, with a typical amplitude of approximately 2 degrees Celsius, and for most of that time, the climate was much warmer than it is today. Over the past million years, the Earth has repeatedly experienced ice age climate changes in 100,000-year cycles, with swings of up to 10 degrees Celsius. Even before the appearance of humans, these cycles of Earth's climate change were already present. Clearly, these preindustrial warming periods cannot be attributed to increases in carbon dioxide concentrations.

1.3 Warm Currents as the Main Cause of Polar Ice Cap Melting, Not Climate Warming

Despite the overall increase in global average temperatures, visualization animations from NASA's Scientific Visualization Studio (1880–2020) have identified several distinct oceanic cooling regions at the northern and southern extremities of the Atlantic and Pacific Oceans, as well as around Antarctica. What causes these cooling areas?

While the peripheral areas of Greenland's and Antarctica's ice caps are shrinking in response to global climate warming, the central regions of these ice sheets are experiencing an increase in thickness. Images created from GRACE and GRACE-FO data show changes in polar land ice mass since 2002 [3]. The rate of ice melt from Greenland is approximately twice that of Antarctica, a trend that aligns with the observation that Arctic warming is roughly twice as pronounced as warming around Antarctica. Regions of significant ice loss in Greenland coincide with the North Atlantic-West Greenland Warm Current, while the areas of substantial ice loss in Antarctica correspond with the Brazil and East Australian Warm Currents. This supports NASA's observation that the warming of nearby seawater plays a key role in contemporary ice mass loss. Concurrently, NASA and JPL/Caltech imagery reveals light blue areas in Antarctica and Greenland, indicating regions of increasing

snowfall and ice mass accumulation that appear to be less influenced by warm ocean currents. This also implies that a significant portion of the ice mass loss in polar regions due to warm currents originates from annual snowfall, which offsets a considerable amount of the rise in sea level. During the summer melt season, while some polar ice and snow melt occurs, these regions experience renewed ice and snow accumulation during autumn and winter, with meltwater from new snowfall contributing to the following summer's melt. NASA research shows that while the Arctic ice cap area shows a declining trend in summer, recent summer warming has had little impact on the extent of winter ice and snow cover [4]. If polar glacier melting were due to warming temperatures, the melting would be relatively uniform, and regions with increasing ice mass would not occur. This leads to two significant conclusions: (1) The primary cause of polar ice cap melting is warm currents, not temperature increases. (2) The opposite has happened: climate warming has led to an intensification of Earth's water cycle, which has resulted in increased polar snowfall, particularly in areas less affected by warm currents.

1.4 Bond Events and Holocene Climatic Periodicity Principles

NASA's global temperature anomaly visualizations clearly show extensive areas of cooler, light blue ocean at the southern tip of Greenland and the northern part of West Antarctica - effectively at both ends of the Atlantic Ocean. This cooling is causally related to the melting of glaciers in Greenland and Antarctica. The massive influx of freshwater from melting glaciers into both ends of the Atlantic Ocean, which is less dense than seawater, does not readily sink to the ocean floor. As a result, large pools of cold glacial meltwater accumulate south of Greenland, creating physical barriers and cooling effects on the surface currents of the North Atlantic. This, in turn, weakens the compensating flows, reduces heat transfer, and mitigates the erosion and melting of Greenland's glaciers by the mainstream North Atlantic Current as it flows toward the Arctic Ocean. Consequently, the entire Atlantic circulation system slows, as illustrated in Figure 2. The obstructed North Atlantic Current may redirect a portion of its flow southward along the western side of the Iberian Peninsula, intensifying the warming and humidification of the North African region.

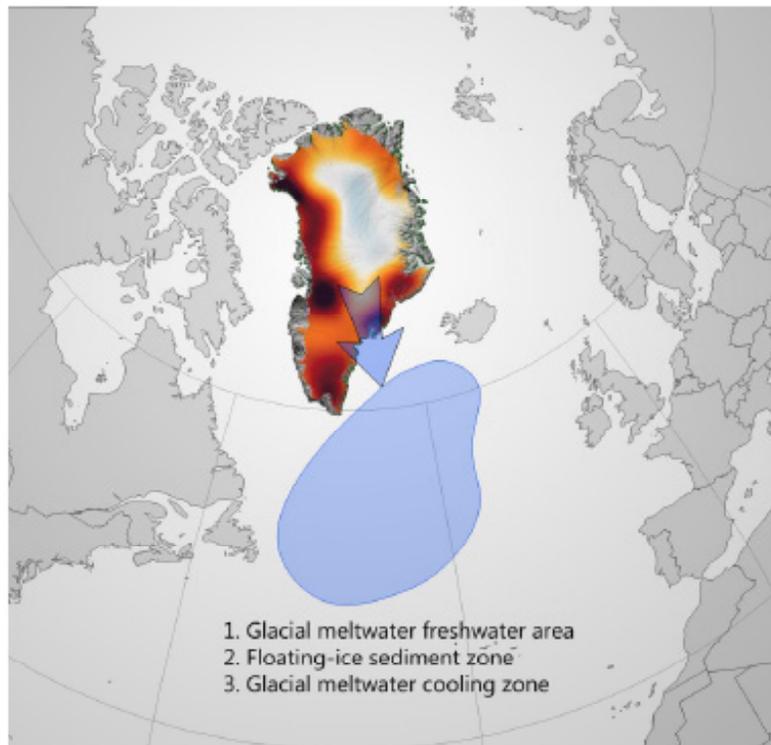


Figure 2: Greenland Ice Sheet Mass Losses Between 2002 and 2023 from NASA and JPL/Caltech, and a Schematic Diagram of Greenland Glacier Meltwater Entering the North Atlantic to form a Cooling Area.

Similarly, the glaciers on the margins of West Antarctica, which are north of the southern end of the Atlantic Ocean, are affected by the Brazil Warm Current flowing southward along the eastern coast of South America. The freshwater areas formed by melting glaciers create obstacles for the circulation of the West Wind Drift around Antarctica and further impede the erosion and melting of Antarctic glaciers by the Brazil Warm Current. This also weakens the Benguela Cold Current, which flows equatorward along the

southwest coast of Africa. With the weakening of compensatory currents, the flow of the Atlantic Equatorial Warm Current is further reduced. This leads to further blockage and slowing of the entire Atlantic Ocean circulation system, thereby diminishing the Atlantic Equatorial Warm Current's transfer of heat toward the Gulf Stream and the North Atlantic Current.

At the northern and southern ends of the Pacific, we also find similar regions of oceanic cooling and the same mechanisms at work. At

the northern end of the Pacific coast, the influence of the relatively weak Alaskan Warm Current leads to the melting of some glaciers in the Alaskan region, creating a meltwater cooling area south of the Aleutian Islands. This introduces physical barriers and cooling effects to the eastward flow of the North Pacific Warm Current and the northward movement of the Alaskan Warm Current. In the Pacific waters south of Australia, influenced by the relatively weak East Australian Warm Current and warm currents from the southern Indian Ocean, a meltwater cooling area is formed by the melting of adjacent Antarctic glaciers. These cooling areas also reduce the erosion and melting of glaciers by warm currents. The schematic diagrams are shown in Figure 1 for illustration.

With global warming intensifying the water cycle and increasing annual snowfall in polar regions, the volume of glacial meltwater and ice fragments in the Atlantic near southern Greenland and northern West Antarctica has increased, enhancing resistance to and cooling effects on warm currents. When the meager heat input from the weakened North Atlantic Warm Current into the Arctic Ocean is counteracted by winter cooling, the Arctic's warming trend may reach a tipping point and begin to cool, potentially reversing climate change and leading to a global cooling trend and negative feedback loop. When warm currents weaken and the polar climate cools, glaciers in Greenland and Antarctica begin to reform. Once no new meltwater enters the Atlantic, the freshwater areas in the ocean gradually dissipate. The blocked North Atlantic Warm Current will resume its flow, and ocean currents will become active again under wind influence, strengthening the warm currents. As global warm currents act together, they transport large amounts of heat and moisture back to polar regions, particularly the Arctic Circle, initiating warming and glacier melting and thus entering the next climatic cycle. This phenomenon can be expressed by the phrase 'misfortune may be an actual blessing, and a blessing may lead to misfortune,' reflecting the traditional Chinese philosophy of mutual genesis within Yin and Yang (Yang within Yin and Yin within Yang).

Recent studies have indeed suggested a weakening of the AMOC (Atlantic Meridional Overturning Circulation) [5]. This is believed to be primarily due to the influx of freshwater from melting Greenland ice sheets and increased precipitation, which dilutes the ocean's salinity. A weakened AMOC can have significant climate impacts. The weakening of the AMOC is consistent with the reasoning in this article and can be used as evidence to support its theory.

This represents the internal mechanism of the Holocene climatic cycle, with a periodicity of approximately 800 to 1500 years and global temperature changes within a range of 1 to 3 degrees Celsius.

The initial discovery of Bond events, which have a periodicity of approximately 1500 years, was based on cyclical traces of deep-sea ice-rafted debris in the North Atlantic (Bond et al., 1997). However, Bond hypothesized that this could be due to changes in solar energy output affecting hydrometeorological changes at the ocean surface [6]. The formation of North Atlantic deep-sea ice-rafted debris, which serves as a cyclical tracer for Bond events, results precisely from periodic climate warming causing the Greenland ice sheet to melt and collapse into fragments that drift into the North Atlantic. The evidence for Bond events can be cross-verified with NASA's visual data, proving that the Bond event cycle and the Holocene climate change cycle share the same internal mechanism.

NASA's website reports observations that the melting areas of the Greenland and Antarctic ice sheets are influenced by oceanic warm currents but does not reveal the mechanism of chain reactions between the poles and the equator or the periodic causality related to climatic changes. Instead, the focus remains on emphasizing increased carbon dioxide concentrations as the cause of climate warming. Currently, current findings proving that Holocene climate periodic changes result from Earth's intrinsic operational mechanisms of ocean and air currents should be considered, demonstrating that global warming is not caused by increased carbon dioxide concentrations.

1.5 Principles of Earth's 100,000-Year Climatic Period

Further inquiry is needed into how the Bond event cycle or the millennial Holocene climate change cycle will develop and how long it will continue. Earth has experienced at least eight Bond event cycles over the past 12,000 years. The North Atlantic ice-rafted debris index exhibits a declining trend over time within these periodic oscillations [7]. This implies that during the next warm phase, there will very likely be less floating ice in the North Atlantic than in the current warm phase.

Similarly, Robert A. Rohde used publicly available data to construct temperature change curves for the Holocene and Ice Age. The black line in the middle-right panel of Figure 3 represents the average of eight records of local temperature changes, showing an enlarged view of the climate change curve for the last 12,000 years of the 450,000-year Holocene. The temperature change cycle is positively correlated with the Bond event ice-rafted debris index and shows a decreasing trend. Currently, the global climate is in a warming phase known as 'Bond event 0' or the end of the Little Ice Age. According to Zhu Kezhen's research on China's climate over the past 5,000 years, the rebound temperatures reflected in the Chinese region during the last three Bond events show a decreasing trend [8].

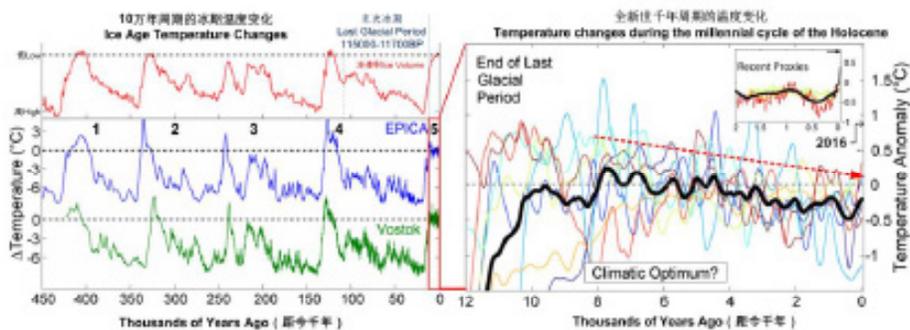


Figure 3: Left: Temperature and Ice Volume Changes Associated with Recent Glacial and Interglacial Periods. Right: Local Temperature Variability During the Holocene Period. (Image source: Wikimedia Commons, by Robert A. Rohde. The Red Trend Arrow was Added by the Author.)

Hence, the sequential reduction in the Bond event ice-rafted debris index and the stepwise decrease in average global temperature during Holocene climate cycles are not coincidental. The underlying principle is that glaciers that expanded during the last cooling cycle are more likely to melt and collapse under warm current influence in the next warming phase, making it easier to block ocean warm currents and leading to earlier climate cooling. This made it difficult for rebound warming temperatures to surpass previous cycle peaks, conforming to the law of oscillatory decay.

The three curves on the left panel of Figure 3 display changes in Antarctic temperatures over the last 450,000 years and their comparison to global ice volume changes. The two lower curves show local temperature changes at two locations in Antarctica, with a maximum amplitude of approximately 10 degrees Celsius [9]. These curves exhibit synchronized sawtooth-wave periodic patterns at approximately 100,000-year intervals. The temperature change curves show a relatively rapid warming process at the start of each cycle, lasting approximately 10,000 years. After each rapid temperature increase in the 100,000-year cycle, there was a period of approximately 90,000 years during which global temperature decreased within a relatively low oscillation amplitude. When global temperature decreases by approximately 10 degrees Celsius, glaciers reach their maximum extent, and then temperature suddenly and sharply increases by approximately 10 degrees Celsius. The internal mechanism may still relate to energy transfer between the equator and the poles.

The top curve on the left panel of Figure 3 reflects the synchronous relationship between global ice volume and temperature: the lower the average temperature, the greater the ice volume (curve dips indicate greater ice volume). When glaciers reach their maximum extent, the flow of the North Atlantic Warm Current almost completely ceases or overturns. Heat accumulates at the equator, and once a critical point is reached, a stark contrast develops between equatorial warm currents and high-latitude polar glaciers. The significant thermal difference rapidly melts the ice at the 'fire and ice' boundary, similar to volcanic eruptions or earthquakes. The pathway for the North Atlantic Current into the Arctic Ocean reopens, and heat from the equatorial region is transported back to the Arctic

Ocean by the North Atlantic Warm Current, initiating the next 100,000-year climate cycle. After the 10,000-year rapid warming phase, there are approximately 90,000 years with an average of 8-10 small-amplitude climate change cycles every 10,000 years - these are the Bond event cycles.

Over the last 450,000 years, Earth has experienced four complete 100,000-year climate change cycles. In the past, every 100,000-year cycle showed irregular periodic temperature changes similar to Bond events, with large fluctuations. These could also have been affected by a combination of volcanic eruptions, plate tectonics, and other unknown factors. This topic warrants further observation and research.

We are now in the early stage of the fifth 100,000-year cycle, in which temperature changes during Holocene Bond events have remained roughly within a 3-degree Celsius range. Compared to the relatively larger fluctuations in the previous four 100,000-year cycles, the temperature changes during this round of Bond events have been relatively stable, nurturing the development of human civilization throughout the Holocene without major climate-related interruptions. According to the millennial-scale pattern of the most recent Bond events, the current climate change cycle remains in a rising, high-temperature phase, which may be followed by several hundred years of relatively stable decline before the next cycle begins. Considering that approximately one-fifth of the current 100,000-year climate cycle has passed, humans must prepare for severe climate cooling that may occur within the next 20,000 to 80,000 years.

1.6 Future Climate Outlook

Understanding the complex interplay of natural cycles, including Earth's orbit, tilt, and precession, alongside human activities, contributes to a comprehensive and nuanced understanding of climate dynamics. The lessons from past climatic events, such as Bond events, not only provide insights into natural variability but also offer a cautionary tale about the limits and thresholds within which Earth's climate operates. With the aid of NASA's comprehensive satellite observations, this article sheds light on the mechanisms of periodic climate change.

Holocene climate changes have significantly interacted with the trajectory of human activities and civilization. To some extent, Holocene climate change cycles have shaped the development of human civilization over the past ten thousand years and have shown regional seesaw effects [10]. The narrative of civilizations rising and falling with the ebb and flow of climatic conditions serves as a reminder of our own civilization's fragility.

These findings underscore the importance of advancing our understanding of climatic mechanisms and developing capabilities to respond to and perhaps guide climatic trends in favorable directions. As we navigate the current interglacial period - the Holocene, which has allowed human societies to flourish - it is imperative to consider the long-term trajectory of climate change. The integration of paleoclimatic data, contemporary observations, and future projections forms the bedrock of our preparedness for coming climate challenges.

The concept of geoengineering, which encompasses methods to deliberately alter Earth's climate system, is an area of active research and debate. It involves potential interventions such as carbon dioxide removal, solar radiation management, or even direct manipulation of oceanic currents. Based on current and future technological developments, it is believed that future humans will have sufficient wisdom and capability to eliminate factors causing severe cooling in the North Atlantic. By artificially controlling and adjusting the heat transferred by the North Atlantic Warm Current to the Arctic Circle, it may be possible to influence and regulate Earth's climate, thereby avoiding civilization-threatening disasters caused by drastic climate changes.

While the prospects of controlling such vast and intricate systems may seem daunting, ongoing research in climate science and innovative engineering holds promise. This future vision would require substantial technological advancements and global cooperation. The goal would be to maintain warm current stability and ensure balanced energy distribution across the planet, which could mitigate potential ice age formation and support a sustainable environment for human civilization.

In conclusion, the prospect of proactively managing Earth's climate is ambitious and presents both risks and opportunities. It requires not only technological innovation but also collective will to ensure interventions are governed by a commitment to promote the well-being of all Earth's inhabitants and preserve the delicate balance of our climate system for future generations.

2. Open Research

2.1 Data Availability Statement

All data referenced in this article are derived from publicly available sources. Datasets and methodologies are accessible as follows:

2.1.1 NASA Global Surface Temperature Data (2021–2024)

Full surface temperature datasets and calculation methodologies: NASA GISS Surface Temperature Analysis (GISTEMP)
<https://data.giss.nasa.gov/gistemp>

2.1.2. NASA Scientific Visualization Studio (SVS)

Global temperature anomaly visualizations:

Global Temperature Anomalies Series

<https://svs.gsfc.nasa.gov/search/?series=Global%20Temperature%20Anomalies>

3. Robert A. Rohde (2009) – Global Warming Art Project

Ice Age and Holocene temperature reconstructions (public domain):

Ice Age Temperature:

Wikimedia Commons

https://commons.wikimedia.org/wiki/File:Ice_Age_Temperature.png

Holocene Temperature Variations:

Wikimedia Commons

https://commons.wikimedia.org/wiki/File:Holocene_Temperature_Variations.png

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