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Impacts of Global Warming on different Climate Feedback and related Management

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Abstract:

Global warming is a significant environmental issue caused mostly by increasing emissions of greenhouse gases, specifically carbon dioxide (CO2). The substantial release of CO2, primarily caused by human activities such as the burning of fossil fuels, industrial operations, and agricultural practices, plays a significant role in the Earth's temperature increase by trapping heat in the atmosphere. This paper analyses the mechanisms by which CO2 intensifies global warming and investigates its environmental consequences, specifically focusing on climate feedback networks. Notable feedback mechanisms that contribute to global warming include water vapour, cloud, and ice-albedo feedback. These feedbacks interact with atmospheric conditions in various ways, leading to an intensification of global warming. Efficient methods to reduce the impact of a problem involve the implementation of both governmental actions and developments in technology. These can include steps like setting a price on carbon emissions, adopting renewable energy sources and implementing sustainable transportation solutions. To limit the adverse impacts of global warming, it is crucial to tackle CO2 emissions and adopt pioneering energy and environmental policies.

Keywords: Global warming, climate feedback, carbon dioxide, management

1. Introduction

Global warming, which has been one of the most challenging environmental issues, has raised attention worldwide [1]. The primary factor responsible for the increase in world average temperatures is the escalating levels of greenhouse gases, specifically carbon dioxide [2,3]. Demir et al. revealed that global warming generally results in a shift in temperature and precipitation due to the emission of large amounts of greenhouse gases, further posing harmful impacts on the environment and the Sustainable development of human society [4].

Carbon Dioxide (CO2) is an essential greenhouse gas that effectively absorbs and retains the sun's heat in the Earth's atmosphere for an extended duration compared to other greenhouse gases [5]. As a result, it significantly contributes to the phenomenon of global warming. Therefore, the act of diminishing

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Carbon Dioxide (CO2) is widely recognized as a pivotal measure in combating global warming [6]

And the extra emission of the greenhouse gases, such as CO2, generally comes from anthropogenic activities, including the burning of fossil fuels; emissions released from industries; vehicular emissions and so on [7]. The emission of CO2 plays a crucial role in human-caused climate changes, leading to a great rise in the average temperature of the Earth‘s surface. So, it’s highly urgent to understand the mechanism of how CO2 leads to global warming, and how to address this global environmental issue.

The ongoing growth in carbon dioxide concentrations surpasses nature‘s ability to absorb it, leading to a substantial elevation in the average temperature of the Earth‘s surface. Verma et al. have noted that human activities contribute to an annual increase in atmospheric carbon dioxide levels, surpassing the capacity of natural sinks to absorb it, and it’s crucial to acknowledge that our daily activities have a great influence on climate change and the increase in global surface temperatures, which highly requires our immediate actions to reduce anthropogenic CO2 emission [8].

Unless the impact of global warming can raise the surface temperature, the climate system experiences warming as a result of an excess of Earth‘s energy due to the rise in carbon dioxide levels, which enables the Earth to dissipate excess heat into space through the Planck response [9]. However, this reaction can be altered by additional climate feedback that either amplifies or dampens global warming.

This review study aims to elucidate and analyse the process by which CO2 contributes to global warming, as well as the repercussions of global warming on environmental feedback. In addition, the methods to decrease CO2 levels and alleviate its detrimental effects will be further explained.

2. Factors of climate change

2.1 Sources of Global warming

Over the past few decades, the level of one significant greenhouse gas - carbon dioxide (CO2), has been steadily rising. This increase in CO2 emissions has led to multiple pressing environmental issues such as global warming, extreme weather, and the increase in the sea level [10]. Human activities have intensified global warming by increasing greenhouse gas (GHG) emissions. The cause of the increase in CO2 emissions can be divided into several aspects, including agriculture, and activities of some specific industries, including the energy industry, the transportation industry, and the concrete industry.

Around a quarter of all greenhouse gas emissions worldwide are believed to come from agricultural land [9]. The manipulation of fertilization and irrigation procedures can alter soil conditions, resulting in significant impacts on greenhouse gas emissions. Insufficient irrigation or inadequate precipitation might cause irrigation to result in elevated soil CO2 emissions [10].

What’s more, the global increase in population has led to a significant rise in energy demand in several sectors. In response to this need, numerous countries have incorporated non-renewable energy sources into their national energy portfolios as their primary source, also contributing to the great emission of CO2 [11]. The most energy usually used is fossil fuel, which produces CO2 and pollutants, affecting the environment. What’s more, the transport sector has become the third most significant contributor to carbon dioxide (CO2) emissions[12].

Industries, like the concrete industry, are also defined as a major source of carbon dioxide emissions into the atmosphere. This industry has contributed to the 33% of anthropogenic greenhouse gas emissions [13]. Concrete mixture, which is used most frequently, typically consists of cement, fine particles, coarse aggregates, and water [14]. Cement was identified as the main contributor to CO2 emissions [15]. Specifically, it produces between 0.66 and 0.82 kg of CO2 for every kilogramme of cement manufactured, accounting for approximately 7% of global anthropogenic CO2 emissions [16].

Carbon dioxide sources are not only from agriculture, transportation, and concrete industry, but also from other sectors, like waste management, and animal husbandry. Therefore, it is necessary to analyze its impact and related mechanisms to better predict future climate change and study related countermeasures

2.2 2.2 Impacts of global warming on the climate feedback

Climate change could result in a rise in the frequency and strength of severe weather phenomena, such as the increasing temperature and sea levels, shifted precipitation patterns, more frequent natural disasters, and extreme weather events. Those phenomena, resulting from global warming, have the capacity to significantly disrupt economies, civilizations, and ecosystems on an unprecedented scale [17].

What’s more, the global warming caused by the great emission of CO2, also have a great impact on different climate feedback, which will be discussed further in detail.

Gaining insight into the correlation between carbon dioxide emissions and climatic feedback is crucial for enhancing our ability to forecast and address these occurrences, as well as safeguarding human life and property.

2.2.1 The impacts on the water vapour feedback

The water vapor feedback is an essential concept in climate science, especially when considering global warming. It describes a phenomenon where the Earth's atmosphere becomes warmer as a result the rise in CO2 levels. Furthermore, the increase in temperature tends to lead to higher level of water vapor, which further amplifies the warming impact.

Corroborating the rise in temperature, multiple studies have demonstrated a concurrent increase in global atmospheric water vapor since the 1980s [18].

The global warming, which results in the increase in the average surface temperature, further lead to an increase in atmospheric water vapor. Meanwhile, the increase in the atmosphere's capacity to hold water vapor will further lead to a warmer temperature, based on the Clausius-Clapeyron relation, which in turn, will cause more heat to be trapped, resulting in a substantial downward radiative flux [19]. And this overall process is defined as the positive feedback loop, which has the capability to amplify global warming.

2.2.2 The impacts on the cloud feedback

Cloud feedback refers to the change in the amount of radiation emitted from the top of the atmosphere caused by the reaction of clouds to a rise in temperature. This response is reproduced by global climate models (GCMs) to represent the impact of CO2 forcing. Noda et al. emphasised the significance of comprehending the mechanism of cloud feedback in order to improve our understanding of global warming [19]. They highlighted that the primary source of uncertainty in predicting future climate change lies in cloud feedback.

Regarding cloud feedback, clouds interact with both incoming and outgoing radiation, therefore influencing the overall energy balance of the atmosphere. Furthermore, clouds have the ability to both cool and warm the Earth's surface. This depends on their optical properties and how they are arranged vertically. The cooling effect is referred to as negative feedback, while the warming effect is called positive feedback. Low clouds have the ability to reflect a substantial amount of incoming solar radiation, which leads to a cooling effect known as negative feedback. However, a decrease in low clouds can intensify global warming, serving as a positive feedback.

Changes happening to different cloud types and their phases can further change the cloud feedback, generating positive or negative feedback under global warming. And the global warming generally can impact the fraction of different cloud types and the phases of the mixed-phase low clouds. As for the low cloud, they can reflect a significant amount of incoming solar radiation. Hence, the increase of low cloud will result in negative feedback, dampening global warming. While, high clouds has the ability to trap outgoing infrared radiation. Therefore, the increase of high cloud may lead to positive feedback, amplifying the global warming.

The impact of global warming posed on the cloud feedback is to change the fraction of different types of clouds, especially high and low clouds. Wood and Bretherton have found a significant decline in cloud coverage due to global warming is observed in low clouds, particularly in oceanic regions below approximately 60°latitude. Noda et al. revealed the change of cloud fraction due to global warming. It can be easily found that the net change of high cloud is positive, indicating the net increase of high cloud, while the fraction of low cloud decreases majorly across the ocean [10].

Meanwhile, on a global scale, there is a decline in optically thin high-level clouds and a rise in optically medium and thick high-level clouds in the warming scenarios. This indicates a worldwide increase in the thickness of high clouds. The thickening of high-level clouds is particularly relevant over the Southern Ocean [8].

The increase in the thickness of high clouds can strengthen their ability to trap outgoing infrared radiation, which in turn can intensify global warming.

One potential process for altering the optical characteristics of low clouds due to global warming is the phase transitions of mixed-phase low clouds. Clouds can retain liquid water even at extremely low temperatures, such as -38°C, until they reach a critical threshold where freezing happens uniformly. Mixed-phase clouds are clouds that have temperatures ranging from -38°C to 0°C and contain both liquid water and ice .

As the temperature of the atmosphere rises, there will be a higher proportion of liquid water compared to ice. This means that for a constant amount of water in the clouds, the clouds will become denser and more opaque due to the smaller size of the water droplets. Furthermore, an increased proportion of liquid water is anticipated to reduce the overall effectiveness of precipitation, resulting in a rise in the amount of water in the cloud and a subsequent increase in cloud opacity. Decreased precipitation efficiency can also prolong the lifespan of clouds, resulting in possible negative feedback. However, the phase change mechanism can only occur below freezing temperatures, limiting its presence to middle and high latitudes in low clouds.

To sum up, global warming causes a decrease in low clouds and an increase in high clouds, and the interaction between these two processes impacts the progression of climate change.

2.2.3 The impacts on the ice-albedo feedback

Surface albedo feedback (SAF) refers to the climatic mechanism in which the earth's surface absorbs more (or less) radiative radiation due to a decrease (or increase) in surface albedo The melting and freezing of ice and snow

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during different seasons can result in a fluctuation in surface albedo and feedback.

The ice-albedo feedback, as a branch of the surface albedo feedback, is a significant climatic feedback mechanism that enhances the impacts of global warming. Global warming resulted in the combination of sea ice loss in the oceans and longer snowmelt seasons on land which further led to a reduction in surface albedo. And the reduction in the surface albedo indicated that the surface tended to have higher ability to trap the heat, further leading to the increase in the surface temperature. Polar amplification, a phenomena where the surface temperature rises more in the Arctic than in lower latitudes due to global warming, has been acknowledged since the 1960s driven by the change of Surface Albedo Feedback. To sum up, global warming typically causes a rise in the average temperature, which in turn can contribute to the melting of ice. Subsequently, the Surface albedo feedback will be altered as a result of the ice's disappearance, where the ice has melted and transformed into water, which possesses a low albedo. Consequently, the surface has a greater tendency to absorb heat compared to the surface covered with ice, which contributes to a positive feedback loop that amplifies global warming.

2.3 Management

2.3.1 Policy measures

Carbon pricing mechanisms can be used as an efficient practice to reduce the emission of CO2. As for this mechanism, the carbon emission trading policy (CET) should be adapted, during which companies buy and sell allowances to emit a certain amount of CO2 China has launched the CET policy which greatly reduced the emission of CO2. The carbon trading policy has been proved to has substantially elevated the mean level of environmentally friendly innovation .

The public can utilize sustainable modes of transportation such as walking, cycling, or utilizing public transportation to decrease reliance on private vehicles, so contributing to a reduction in carbon dioxide emission. In addition, implementing carpooling or transitioning to electric vehicles (EVs) can effectively reduce the emissions linked to daily commuting. Implementing basic measures such as switching off lights, utilizing energy-efficient equipment, can effectively decrease the energy demand, thereby leading to a reduction in CO2 emissions. By installing solar panels or choosing green energy sources, individuals can effectively decrease their daily energy consumption.

In addition, individuals can also engage in various actions to save and rehabilitate the forest. Participating in or endorsing local environmental organisations dedicated to preserving forests and other natural carbon sinks can significantly contribute to long-term carbon capture.

2.3.2 Technological solution

Fossil fuel-based energy sources, including coal, oil, and gas, are widely acknowledged as the important contributors to global climate change. Utilization of fossil fuels can have detrimental effects on public health and also contribute to climate issues due to the release of large amounts of carbon dioxide [17]. With the limitations imposed by climate change, it has become imperative for countries to pursue a more environmentally friendly transition in their energy sources in order to ensure sustainable growth [1].

Hence, it's urgent to add some renewable energy, and related technologies into use. Wind and solar technologies can be used as the major energy source, because they cause little pollution into the environment. They are estimated as the energy sources, having the potential to provide approximately 43% of electricity generation globally and significantly reduce global warming [11].

Because the transportation industry, is the third greatest contributor to carbon dioxide emission, it's crucial to make some changes to this sector to reduce the carbon dioxide emission.

The carbon emissions of this industry are impacted by the dependence on road transportation and the inefficient configuration of the transportation network. The intermodal transportation tends to use those transportation with high efficiency, but with lower emission. Thus, using intermodal transportation is a very efficient method to conserve energy and diminish the emission of carbon dioxide, with the lower average carbon intensity compared by trucks .

3. Conclusion

This paper examined a primary catalyst for global warming, namely the great emission of carbon dioxide (CO2). In addition, many sources of carbon dioxide have been further examined. Concurrently, the effects of global warming on various climatic feedback mechanisms and their control were deliberated.

The substantial increase in global CO2 concentrations is a fundamental catalyst for global warming, resulting in substantial alterations in climatic patterns and presenting grave hazards to both natural ecosystems and human societies. The increase in CO2 levels, primarily caused by human activities such as the combustion of fossil fuels, and industrial operations, has worsened global warming by intensifying the greenhouse effect.

Climate feedbacks, including water vapour feedback, cloud feedback, and ice-albedo feedback, emphasise the intricate interactions that intensify global warming. Tackling these difficulties necessitates a comprehensive and diverse strategy. Implementing carbon pricing systems,

such as carbon emission trading, on the policy front can provide incentives for reducing CO2 emissions. Technological progress, namely in renewable energy technology and efficient transportation systems, is essential for decreasing dependence on fossil fuels and minimising emissions. Public involvement in energy conservation and forest preservation also bolsters sustained endeavours to alleviate climate change.

The future of climate change mitigation will rely on effectively incorporating these solutions. Progress in sustainable energy sources, enhanced energy efficiency, and cutting-edge carbon capture methods offer the potential for diminishing CO2 emissions and mitigating the impacts of climate change. Furthermore, continuous investigation into climate feedback processes will be crucial for improving predictive models and guiding policy decisions. To effectively tackle the urgent problem of global warming and guarantee a stable and resilient environment for future generations, it is crucial to have a worldwide dedication to sustainable practices, together with ongoing advancements in technology.

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