

# Global climate change: impacts from polar ice to equatorial heat

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**Abstract.** Climate change is a major environmental emergency during the twenty-first century because it generates large effects throughout ecosystems, together with impacts on human societies and worldwide economies. This investigation examines climate change effects across worldwide polar ice regions, together with equatorial heat zones, by reviewing research trends in these different climatic zones. Scientometric analysis methods were used to examine publications available in Scopus from 2009 to 2025. The research utilized VOSviewer together with Bibliometrix to conduct keyword co-occurrence and citation analyses while identifying research hotspots. Research evidence shows a stronger interest in polar regions because ice melt publications and their effect on sea-level rise have become more prevalent. Climate change research dedicated to socioeconomic analysis continues to expand within tropical regions, because heat stress threatens both biodiversity and human health. Research on climate change has received major backing from the United States, China, and India through their strong international collaboration efforts. This study establishes its importance because it investigates climate change through holistic geographical and thematic examinations. This research demonstrates that scientists have achieved significant advancements in environmental studies on climate change, but investigative work still needs to be done on how climate change impacts social economies and policy formation.

**Keywords:** climate change, global warming, environmental impact, climate policy, scientometric analysis, sustainable development

## 1 Introduction

Climate change is recognized as the most critical threat facing the global community in the twenty first century with significant implications for ecosystems, human health, economies, and societies worldwide [1]. Based on the IPCC report, the global average surface temperature has increased by approximately 1.1°C in comparison to pre-industrial levels,

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with further increases that are anticipated to result in even higher impacts of climatic events such as disasters [2]. The sea level is strongly related to the melting of ice shelves in Antarctica and Greenland. They cause repeated annual changes in the movement of ice sheets, impacting both floating and the ground in the vicinity of marine boundaries [3]. Tides affect the rates of ice shelf melting by hindering turbulent heat transfer across the ice/ocean boundary, which is one of the factors that causes an increase in the melting rates [4].

For instance, tidally mixed regions increase vertical mixing, cause residual circulation in the Amundsen Sea, and promote melting. Tides are particularly important for the interaction of water masses in polar regions with respect to their mixing. Tides in the Arctic Ocean cause a decrease in the volume of sea ice and change the distribution of salinity, making the water column more mixed. This enabled the incorporation of warm Atlantic Waters with colder surface water due to ice melting. Similarly, in the Weddell Sea, both tides entrained variations in the marine carbonate system and the air-sea CO<sub>2</sub> exchange, evading static systems. Past archives also show that polar warming at the same level of variation could result in the dramatic melting of icesheets, making sea levels several meters higher than it is currently [5]. The provisional data suggest that mass loss from Greenland and Antarctica currently contributes about 0.6 mm per year to global sea-level rise which corresponds to 20% of the overall trend [6].

Marine heatwaves have been identified in Australia as a major cause of massive mortality in important habitat-providing organisms, such as corals, kelps, seagrass, and mangroves. These events have brought about coral bleaching and loss of kelp-forests and seagrass beds, with long-term and potentially permanent negative impacts on marine life. Most tropical ectotherms, such as insects and reptiles, are exposed to heat stress because it is difficult for them to adapt to temperature differences. These species, as noted earlier, inhabit regions close to their physiological optima, where even small temperature fluctuations can reduce efficiency and survival [7].

The study also notes that the Arctic region and the Tibetan Plateau are experiencing the increasing effects of heat at a much faster rate than the global average. The Arctic warmed at three times the global mean, whereas the Tibetan Plateau warmed at nearly double the global rate. This warming has diverse impacts, such as reduction of sea ice, melting of glaciers, thawing of permafrost, extreme weather, and global climate systems [8]. The three poles were marked by a feedback mechanism that enhanced the impacts of climate change. For example, melting ice and snow decrease the Earth's albedo, contributing to further warming [8]. These changes have effects not only confined to these ecosystems but also shift atmospheric and oceanic current systems throughout polar climates, affecting weather and climate on a global scale [9].

However, these three poles play a significant role in global climate systems, and their drawbacks stem from extreme climates that are difficult to access. Attempts such as CASEarth Poles have attempted to optimize data acquisition and use for scientific research and sustainable development. These are the production of enhanced remote sensing products and vector data, and atmospheric reanalysis datasets that help in analyzing changes in the environment and their impacts on the entire globe. The present research predominantly involves the study of individual poles; nevertheless, the desirability of research that elaborates on relations among the three poles is rising. More research is crucial for understanding such coordination and coordination changes in these regions and how they impact the global climate system [8].

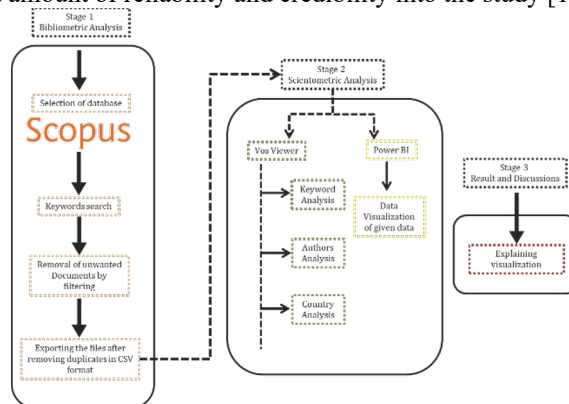
Shifts in these three poles impact hydrological, ecological, and climate systems at the global level. Cohen (2013) explains that these impacts present problems to human societies in areas of resource accessibility, economic predictability and social sustainability [10]. Solving these issues involves the collaboration of climate science with policy and policy

itself, and community resilience approaches. Considering the effects of climate change on the three poles and other regions, there is a need for system-changing policy measures. These are a) ambitious emission reduction, b) protection of ecosystems, and c) equitable distribution of resources. These strategies are important for building climate proof systems and achieving the sustainable development of human societies and ecosystems.

A scientometric analysis shows that, globally, there is a rising trend in scholarly interest in climate change impacts. Over the last decade, many studies have been published using novel approaches, such as deep learning with remote sensing, to track Arctic and Antarctic changes and their importance in achieving global climate stabilization. Studies have also compiled information on various territories to focus on the overlap of climate change impacts from the equator to the poles [11]. The IPCC has highlighted the radical restructuring taking place in polar zones and their impact on climate change across the world [12]. In addition, other studies have investigated how climate change plays out dynamically, such as records of atmospheric circulation changes over polar regions and improving knowledge regarding climate sensitivity. Altogether, these studies explain the increased interest in investigating the effects of climate change on various aspects at different latitudes [13].

## 2 Methodology

A large part of the particularization has focused on the methodology chart because this document is important in scientific metrics studies to present the structure of the work performed. It assists in demystifying procedures and other procedural components, the ability to reproduce the work, and enables understanding of data collection, analysis, visualization, or a combination of the three. A chart of this sort helps readers understand the logical sequence of arguments and is important for making the process transparent; transparency remains a significant issue in the context of reliable scientometric research. The structure of a methodology chart, which displays the workflow, guarantees the presence of important documented steps and permits their replication in other research, putting a significant amount of reliability and credibility into the study [14].



**Fig. 1.** Methodological Framework for Scientometric Analysis of Climate Change Research.

This approach is systematic, offering global coverage in approach to the subject by mapping research trends and impacts as experienced across polar to tropical areas. The identification of search queries is crucial for scientometric research to obtain the desired information in academic databases. They set limits on the study by selecting publications of interest using keywords, thus making the results more relevant.

## Search Query

(TITLE-ABS-KEY ("Polar Ice") OR TITLE-ABS-KEY ("Equatorial Heat") AND TITLE-ABS-KEY ("Climate Change")) AND PUBYEAR > 2009 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE, "English"))

## Research Questions

1. What are the global research trends in climate change studies and how has publication output evolved over time across different regions?
2. Which countries, institutions, and authors contribute most significantly to the body of research on climate change impacts, from polar to equatorial regions?
3. What are the key thematic areas of climate change research and how do they differ across geographic regions, such as polar, temperate, and tropical zones?
4. How does the collaborative network among researchers and institutions influence advancements in climate change mitigation and adaptation strategies?
5. What are the research gaps in addressing the socioeconomic and policy implications of climate change, particularly in data-scarce regions, such as the Arctic, Antarctic, and tropical rainforests?

## 3 Results and discussion

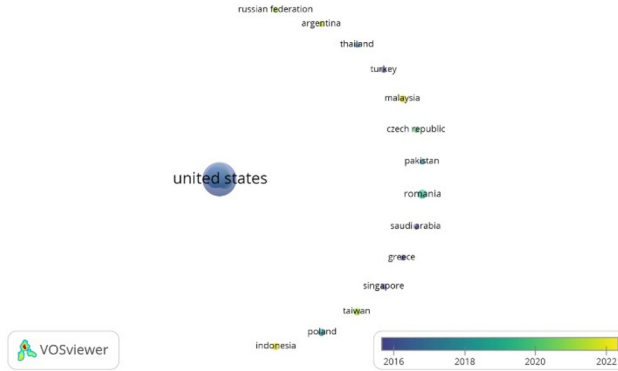
Recent bibliometric analyses have indicated a significant increase in climate change research publications from 2000 to 2024. This trend shows an increasing concern for the global population regarding climate change effects [15]. He suggests that China, India, the United States, the United Kingdom, and Australia are among the pioneers who have been active in research on climate change, especially in identifying measures that should be adopted to combat its impacts of climate change. There have been many studies on the issue of climate change, especially on the effects of global warming, from two extreme poles, for example, the effect of melting ice in the Arctic and the loss of species in tropical zones.



**Fig. 1.** Global distribution of research articles on climate change impact.

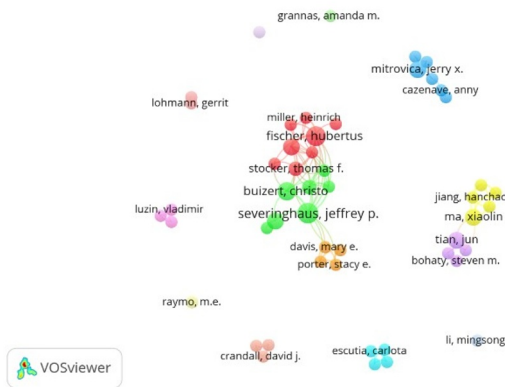
Figure 2 shows the geographical locations of the research articles that formed part of this review. The map uses circular symbols, where the size of the symbol scale is the number of articles published from a specific country, ranging from 7 to 71. Figure 2 captures some of the giant strides made in research contributions from various countries, and the densities are well represented in Western Europe, especially in the Netherlands, Germany, France, Switzerland, and Italy. The United States and Canada are confirmed to be key North

American shareholders, while China and India are the driving forces in Asia. The legend shows the article counts by relative circle areas, the largest circles being equal to 71, and the smallest ones equal to 7. This shows that developed nations have a good representation in climate change research, and most are in the Northern Hemisphere.



**Fig. 1.** Overlay visualization of countries' citations

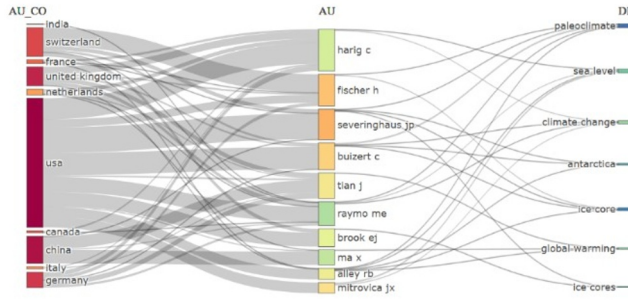
Figure 3 depicts the world's research cooperation and citations of climate change research. The visualization puts the United States in the center as a leading research country with trends from other countries, such as Russia, Argentina, Thailand, Turkey, Malaysia, the Czech Republic, Pakistan, Romania, Saudi Arabia, Greece, Singapore, Taiwan, Poland, and Indonesia around the center. It seems that the size of each country's node corresponds to a measure of the citation impact, or possibly the volume of research arising from each nation, although the USA is by far the largest node. The color gradient timeline bar at the bottom is blue 2016 and yellow 2022, which implies the temporal aspect of citations and research collaborations. As the following VOSviewer-generated picture illustrates, international research cooperation and knowledge exchange of climate change studies within six years.



**Fig. 1.** Co-authorship network analysis of climate change impact

The co-authorship network visualization illustrates the collaborative relationships between the researchers who contributed to this study. In Figure 4, different color nodes present different clusters of authors, and the size of the node can represent the weight of the contribution of that author. The green area depicts Buizert and Severinghaus as the core collaborators while blue area depicts Mitrovića, Cazenave as a separate group working on different issues of the study as the red area shows the Miller, Fischer group and finally there is the yellow area shows Jiang, Ma, and Tian as a part of specialized research group. It





**Fig. 1.** Three-field plot depicting country-author-domain relationships in global climate change research.

This Three-field plot illustrates the collaborative research network in climate change studies, connecting the author countries (AU\_CO), authors (AU), and research domains (DE). The left field illustrates contributing countries, such as the USA, Canada, and Europe, such as Switzerland and France. The middle field shows Researchers Harig C, Fischer H, and Severinghaus JP. The right field on the map presents key subject areas, such as paleoclimate, sea level, climate change, Antarctica, ice core, and global warming. The three circles are color-coded, and the gray connecting lines depict how researchers in different countries are involved in various sectors of climate change research. The width of the bars indicates the amount or connection/proximity between the two elements. This visualization effectively demonstrates the international collaborative nature of climate change research and its diverse focus areas.

**Table 1.** Publication Metrics for Climate Change Research.

Source	h_ind ex	g_ind ex	Total citations	Number of Publications
Proceedings of the National Academy of Sciences of the United States of America	11	12	2195	12
Quaternary Science Reviews	11	13	504	13
Earth And Planetary Science Letters	6	7	647	7
Nature	6	10	1091	10
Journal Of Climate	5	6	267	6
Science	5	6	1834	6
Climate Of the Past	4	4	76	4
Geophysical Research Letters	4	4	258	4
Global And Planetary Change	4	4	232	4
Cryosphere	3	4	291	4

Table 1 provides further detailed information on scientific journals and their roles in the study of climate change. Table 1 presents ten well-known sources, such as Nature and Science, together with their bibliometric values. It is worth stating that all the calculated indices refer to author productivity and citation impact, and their values are 3–11 for *h\_index* and 4–13 for *g\_index*. The total citation count of the sources was as follows: Source No. 76 for Climate of the Past to Source No. 2195 for Proceedings of the National Academy of Sciences. Notably, the ratio of publications for each source correlates well with the *g\_index*; thus, the greater the number of publications per source, the higher is the impact of citations. These data are useful in identifying trends in the most frequently published journals in climate change studies and their broad interdisciplinary nature across the earth sciences, planetary sciences, and climatology subfields.

**Table 1.** The top 10 most-cited papers in climate change research.

Paper	DOI	Total Citations
VICENTE-SERRANO SM, 2013, PROC NATL ACAD SCI U S A	10.1073/pnas.1207068110	1179
WESTERHOLD T, 2020, SCI	10.1126/SCIENCE.ABA6853	1011
SHEPHERD A, 2018, NATURE	10.1038/s41586-018-0179-y	801
STEINHILBER F, 2012, PROC NATL ACAD SCI U S A	10.1073/pnas.1118965109	565
DUTTON A, 2015, SCI	10.1126/science.aaa4019	540
STAMMER D, 2013, ANNU REV MAR SCI	10.1146/annurev-marine-121211-172406	315
HOOD E, 2015, NAT GEOSCI	10.1038/ngeo2331	286
MCGEE D, 2014, EARTH PLAN SCI LETT	10.1016/j.epsl.2013.12.043	252
PAGANI M, 2011, SCIENCE	10.1126/science.1203909	242
PLANE JMC, 2012, CHEM SOC REV	10.1039/c2cs35132c	237

Table 2 presents a comprehensive overview of the influential publications in climate science research. Of the other submissions, Vicente-Serrano's paper published in PNAS in 2013 has been cited 1,179 times, and the paper by Westerhold in Science in 2020 has been cited 1,011 times. The papers cover a wide range of climate research interests and are written for some of the world's best-known scientific journals, such as Nature, Science, and PNAS. More specifically, the number of citations varies from 237 to 1,179, underlining the importance of previous writings. The chronological distribution of papers ranged from 2011 to 2020, and the following publications were found based on the first author, publication year, and journal abbreviations. The Digital Object Identifier (DOI) column generates individual references for every paper contained in this study. This compilation consists of major knowledge on climate change and its impact on the world.



**Fig. 1.** Bibliometric Overview of Climate Change Research (2010-2024)

This bibliometric analysis presents key metrics from climate change research spanning to 2010-2024, encompassing 326 documents from 219 distinct sources. The research field shows good publication trends by involving 1,337 scholars, of which only 66 contributed single-authored research papers. International collaboration is also evident, with 34.97% of papers having at least one international co-author and 4.66 number of co-authors per document on average. It highlights the high level of research impact. The average number of citations for each document is 36.65 per document and an average age of 6.35 years. The field has been growing rather healthy for the year, with a growth rate of 6.02 %. Specific to the author's research interests and work specialization, it features 898 DE Author Keywords and a detailed bibliography list of 18,982 that speaks of a very active interaction with literature. All these metrics portray a robust, collaborative, and productive area in research on climate change.

## 4 Conclusion

Scientometric analysis provides a comprehensive assessment of research trends, geographic distributions, and thematic focus areas in climate change studies. Climate change has emerged as a major global challenge and has received increasing attention from developed countries in the Northern Hemisphere. Despite research ranging from polar to equatorial cryosphere, accommodating such key research questions remains lacking, especially in poorly gauged areas such as the Arctic, Antarctic, and Tibetan Plateau. The use of sophisticated bibliometric techniques, including citation and co-authorship networks, speaks to teamwork in climate change. Based on the analysis of climate change, advances in new technologies such as remote sensing and deep learning are defining new approaches for analyzing climatic patterns. However, relatively little research has been dedicated to policy-related topics and the broad socioeconomic effects of climate change. Several future directions must be highlighted to advance this field, including time integration, interdisciplinary work, and international equal partnerships. If such gaps are addressed, researchers and policymakers can avert the worst impacts of climate change, which are circumstantial. The conclusions drawn from this study are vital for guiding further research, increasing sustainability, and offering solutions to climate change worldwide.

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