

CMIP6 and Climate Change: A Global Analysis of Research and Collaborations on the Water Budget

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Abstract: Global water resources are significantly impacted by climate change, necessitating advanced tools and methodologies for accurate analysis. Although numerous studies have employed the use of Coupled Model Intercomparison Project Phase 6 (CMIP6) models, only a limited number have specifically concentrated on their use in assessing the impacts of climate change on water budgets. This bibliometric analysis utilizes data from the Web of Science Core Collection, covering the period from 2014 to 2024. The analysis was conducted using VOSviewer mapping and visualization software and aims to identify the publication trends and collaborative efforts in CMIP6 research. The analysis reveals a significant growth in CMIP6-related research, with 3,184 publications highlighting the model's extensive adoption in climate science. However, it also reveals a notable gap, with only 64 studies specifically addressing water budget evaluations. Key journals, such as the Journal of Climate and Geophysical findings Letters, played a crucial role in spreading this research. The results also demonstrate significant international collaboration, primarily among developed countries, and emphasize the need for more geographically diverse research partnerships. Moreover, the correlation between research findings and Sustainable Development Goals pertaining to water and climate action illustrates the practical implications of CMIP6 models. The findings of this study offer pathways for future research and collaboration.

Keywords: bibliometric analysis; climate change; CMIP6; sustainable development goals; water budget.

1 Introduction

The Coupled Model Intercomparison Project Phase 6 (CMIP6) is an essential framework for simulating climate scenarios of the past, present, and future, enabling a more profound comprehension of climate changes and their impact on various environmental subsystems (Eyring et al. 2016, O'Neill et al. 2016, Chen et al. 2021). The complex correlation between climate change and water resources requires thorough examination, as changes in the water cycle have a direct impact on hydrological extremes, agriculture, and worldwide water management methods.

CMIP6 data is crucial for understanding the water cycle of the Earth (Jie et al. 2020, Guo et al. 2021). This comprehensive compilation of climate models enables scientists to examine various aspects such as precipitation, evaporation, and runoff (Wang et al. 2022, Balu et al. 2023, Risley and Ammit 2023). Moreover, CMIP6 allows researchers to forecast forthcoming alterations in the

water cycle under various emission scenarios, offering vital insights for the management of water resources and the development of adaptation measures (Shafeeque and Luo 2021). Although CMIP6 is a widely accepted tool, current research aims to enhance the precision of the models and minimize uncertainty in future estimates (Sengupta et al. 2022).

Given the escalating impact of climate change on global water resources, this study aims to provide a bibliometric analysis of global research patterns and collaborations related to CMIP6 with a specific focus on its utilization for water budget evaluations. The significance of this research is emphasized by the growing susceptibility of water resources to climate change, a crucial matter that intersects with various United Nations Sustainable Development Goals (SDGs), particularly those aimed at ensuring clean water and sanitation and taking immediate action to combat climate change and its consequences (Carlsen and Bruggemann 2022).

2 Materials and methods

The methodology used in this study includes a systematic search for articles in the Web of Science Core Collection, including publications from January 2014 to January 2024. The bibliometric analysis of the data obtained from the Web of Science database was performed using VOSviewer mapping and visualization software. This software enables the generation of several network visualizations, including co-authorship, citation, co-citation, and bibliographic coupling networks (Arruda et al. 2022, Badola and Agrawal 2023). These visualizations offer a comprehensive perspective of the scientific landscape. These methods enable the measurement of time trends, identification of articles with high citation rates, detection of authors, journals, institutions, and countries with high productivity, as well as the computation and ranking of scientific output and collaboration (Arruda et al. 2022). The descriptive bibliometric analysis focused on the metrics of journals, authors, and documents to provide a detailed overview of the major data.

Two distinct search queries were utilized: one particularly focusing on "CMIP6" and the other combining "CMIP6 AND Water Budget". The exact two queries were TS=(CMIP6) and (TS=(CMIP6)) AND TS=(water budget), respectively. This approach enables a two-tiered analysis, examining both broad patterns in CMIP6 research and detailed observations of its specific use in water budgets.

3 Results

For the bibliometric analysis of CMIP6-related papers, two separate queries were used to assess the quantity of research and the specific areas of focus. The initial search, specifically focusing on "CMIP6", resulted in a substantial total of 3,184 publications from the Web of Science Core Collection between 2014 and 2024. The second query, which involved the combination of "CMIP6" and "water budget", yielded 64 results.

3.1 Publication Trends

Figure 1 shows a significant growth in the number of publications on CMIP6, indicating a progressive surge in interest and funding toward climate modeling.

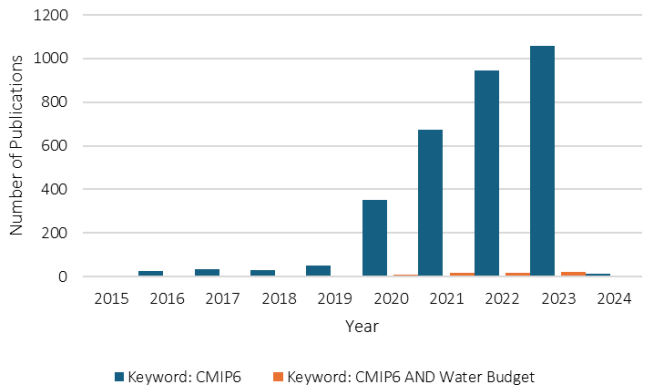


Figure 1. Publication trends over the years 2014–2024.

3.2 Core Journals and Articles

Table 1 lists the journals most active in publishing CMIP6-related research, highlighting their respective impact factors and the volume of contributions.

3.3 Global Collaboration Networks

Figure 3 illustrates the bibliographic coupling between countries, demonstrating a strong network of international collaborations, mainly among developed nations. The colors represent different clusters of research communities based on their geographic and collaborative connections.

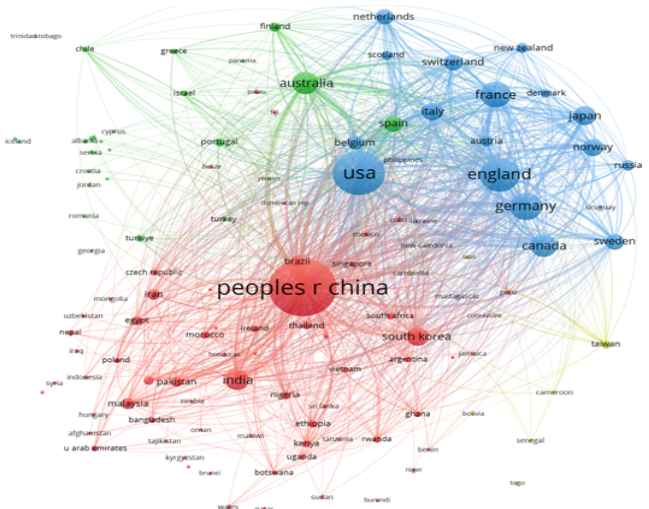


Figure 2. Bibliographic coupling of corresponding author's country.

3.4 Contribution to Sustainable Development Goals

Figure 3 directly correlates the research outputs with specific Sustainable Development Goals, particularly those related to water and climate.

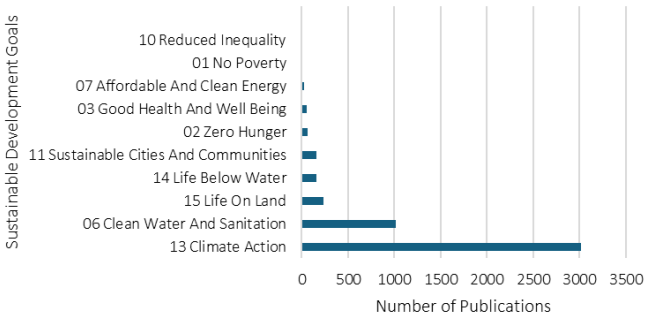


Figure 3. Sustainable Development Goals for the timespan 2014–2024.

4 Discussion

This bibliometric analysis summarized the trends of CMIP6 publications, which offers crucial insights into the utilization of this modeling tool in the context of climate change and its influence on water budgets.

The prominence of journals such as the ‘Journal of Climate’ and ‘Geophysical Research Letters’ in publishing CMIP6-related articles highlights their significant role in spreading advanced research in the field of climate science (Table 1). The high impact factors of these journals indicate their significant influence and their ability to attract and publish high-quality research. Other journals such as the ‘Science of the Total Environment’ and ‘Sustainability’ also play an important role not only for their focus on environmental studies but also for their interdisciplinary approach, integrating diverse aspects of environmental science, including the implications of climate models such as CMIP6.

The bibliographic coupling data shown in Figure 2 demonstrates a strong network of collaborations mostly concentrated in China, North America, and Europe. These regions are the focal point of climate modeling research, characterized by established infrastructures and substantial funding for climate science. Nonetheless, the limited amount of cooperation with academics in Africa, Central Asia, and South America indicates a geographical imbalance in climate research. This disparity could hinder the worldwide applicability of research findings, as areas that are most susceptible to climate impacts may not be well represented in scientific outputs. Previous research has emphasized the significance of inclusive global research collaborations to ensure the effectiveness of climate adaptation methods in various geographical contexts (Eyring et al. 2016, Wang et al. 2022).

Figure 3 demonstrates the connection between CMIP6 research outputs and UN SDGs, highlighting the significant contribution of scientific research in tackling worldwide issues. The focus on ensuring access to clean water and proper sanitation, as well as taking measures to address climate change, emphasizes the capacity of academic

Table 1. Most relevant journals (CMIP6).

Journals	Number of Articles	Impact Factor
Journal of Climate	208	5.38
Geophysical Research Letters	190	5.58
Geoscientific Model Development	133	5.1
Science of the Total Environment	61	10.75
Journal of Advances in Modeling Earth Systems	58	6.80
Atmospheric Chemistry and Physics	54	6.13
Water	54	3.4
Sustainability	42	3.9
Atmospheric and Oceanic Sciences	38	2.3

research to provide valuable insights for policy-making and practical implementation. This relationship is crucial because it highlights the practical consequences of theoretical models and simulations. By matching research objectives with these global goals, the scientific community can focus its efforts on areas of crucial importance, thereby increasing the societal influence of their work. This strategy is substantiated by literature indicating that conducting research in line with Sustainable Development Goals tends to receive wider societal approval and has a greater probability of impacting policy modifications (Sianes et al. 2022).

The results of this bibliometric analysis demonstrate a constantly changing and developing field of climate change research, which has been made possible by CMIP6. The rise in publications during the study period suggests a strong interest and continuous requirement for advanced climate modeling tools to forecast and mitigate climatic impacts. Furthermore, the integration of CMIP6 data into water budget analyses emphasizes the crucial overlap between hydrological and climatological investigations, which are vital for formulating adaptive approaches considering global warming.

5 Conclusions

This bibliometric analysis has revealed the widespread use and influence of CMIP6 in climate change research, revealing both broad adoption and specific applications. Between 2014 and 2024, a substantial amount of literature, consisting of 3,184 publications, has been found, illustrating the extensive application of the model in different areas of climate science. However, when particularly considering the incorporation of CMIP6 into water budget investigations, only 64 papers were found, highlighting a significant gap in the research field. The significant contrast in publication volumes highlights a crucial area for future research—the application of CMIP6 in understanding the hydrological impacts of climate change. The Journal of Climate and Geophysical Research Letters, among other journals, has been recognized as actively promoting the dissemination of CMIP6 research. Furthermore, the analysis of international collaboration networks emphasizes the requirement for broader and more geographically varied research partnerships, which are essential for creating comprehensive and universally

relevant climate solutions. In conclusion, although the CMIP6 has made substantial progress in climate modeling, its specific applications in water budget analysis are underrepresented. This highlights the need for more research and practical investigation in this important field. By broadening our attention to this matter, we may significantly improve our comprehension and control of the impacts of climate change on global water resources. This approach closely aligns with the Sustainable Development Goals that pertain to clean water and climate action. This study establishes a fundamental basis for future efforts, emphasizing the need for a wider range and more extensive incorporation of climate models in hydrological research.

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