

GLOBAL PUBLICATIONS ON HEAT WAVES: A SCIENTOMETRICS ANALYSIS

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Introduction

Climate change is a global concern, adversely affecting planetary and population health. Extreme heat is one of the most significant climate-related causes of death and is projected to cause heat waves globally. A heat wave can be defined as a period during which local excess heat accumulates over a succession of days and nights. The Intergovernmental Panel on Climate Change (IPCC) defines a heat wave as “a period of abnormally hot weather, often defined concerning a relative temperature threshold, lasting from two days to months (IPCC, 2024).” With the increasing effects of climate change, heat waves are placing an enormous burden on health and social systems and

threatening ecological diversity worldwide. Countries in South and Southeast Asia drowned in extraordinary heat in 2024; New data from the Copernicus Climate Change Service (C3S, 2024) reports that April 2024 was the hottest April on record. According to the European Union’s Climate Change Monitoring Service, April 2024 was 1.58°C warmer than the pre-industrial period, or the average temperature from 1850 to 1900. The Hindustan Times looked at the data over 30 years since 1990 and found that more than 1.53 lakh deaths a year were associated with heat waves worldwide, with over a fifth of the share - coming from India (Hindustan Times, 2024).

Heat waves are expected to increase with climate change, posing a significant threat to the human beings health. As heat waves become more frequent due to climate change, adopting preventive measures to maintain health and well-being during extreme heat events will be critical. Therefore, research around heat waves becomes more essential and is more than a primary research fashion. In this regard, the scientific community has contributed extensively to the comprehensive understanding of the Earth’s climate system, mainly by providing various data and projections on heat waves, future climate, and expected global warming impacts and risks (Akompab et al., 2013) intensity and duration as a consequence of climate change. The effects of heat waves on human health

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could be reduced if individuals recognise the risks and adopt healthy behaviours during a heat wave. The purpose of this study was to determine the predictors of risk perception using a heat wave scenario and identify the constructs of the health belief model that could predict adaptive behaviours during a heat wave. A cross-sectional study was conducted during the summer of 2012 among a sample of persons aged between 30 to 69 years in Adelaide. Participants' perceptions were assessed using the health belief model as a conceptual frame. Their knowledge about heat waves and adaptive behaviours during heat waves was also assessed. Logistic regression analyses were performed to determine the predictors of risk perception to a heat wave scenario and adaptive behaviours during a heat wave. of the 267 participants, about half (50.9%. Research on heat waves is an emerging topic in climate change research that is increasingly relevant to the society. This study aims to assess the current status and future of research on heat waves by adopting Scientometric indicators.

Literature Review

As mentioned in the introduction, heat wave research is a trending topic. Therefore, the authors felt it essential to conduct a brief survey of the literature on heat waves and its related topics, i.e. climate change. The Russian heatwave 2010 took many lives and was declared the worst in European history since 1950. In this regard, Russo et al. (2015) ranked the top ten European heatwaves from 1950 to 2014. Their study suggested a proactive vulnerability assessment in Europe to design strategies to reduce the heat wave effects. Sweileh (2020)public health and food security; (3 conducted a bibliometric study on climate change research using SciVerse Scopus from 1980 to 2019. The authors found 4247 publications and distributed them among four themes, i.e., climate change and infectious diseases; climate change, public health and food security; heat waves, mortality, and non-communicable diseases; and climate change, air pollution, allergy, and respiratory health. Further, the study reveals that the USA achieved the top position with 1235 contributions, and the *Australian National University* ranked first.

Using the Berkeley Earth temperature dataset and key heatwave metrics, Perkins-Kirkpatrick and Lewis (2020)frequency and duration, with these trends projected to worsen under enhanced global warming. Understanding regional heatwave trends has critical implications for the biophysical and human systems they impact. Until now a comprehensive assessment of regional observed changes was hindered by the range of metrics employed, underpinning datasets, and time periods examined. Here, using the Berkeley Earth temperature dataset and key heatwave metrics, we systematically examine regional and global observed heatwave trends. In almost all regions, heatwave frequency demonstrates the most rapid and significant change. A measure of cumulative heat shows significant increases almost everywhere since the 1950s, mainly driven by heatwave days. Trends in heatwave frequency, duration and cumulative heat have accelerated since the 1950s, and due to the high influence of variability we recommend regional trends are assessed over multiple decades. Our results provide comparable regional observed heatwave trends, on spatial and temporal scales necessary for understanding

impacts.”,”container-title”:”Nature Communications”,”DOI”:”10.1038/s41467-020-16970-7”,”ISSN”:”2041-1723”,”issue”:”1”,”journalAbbreviation”:”Nat Commun”,”language”:”en”,”page”:”3357”,”source”:”DOI.org (Crossref systematically examine regional and global heatwave trends. The study shows that the trends in heatwaves have accelerated since 1950s, and the authors recommend that regional trends be assessed over multiple decades to gain an in-depth understanding. Marx et al. (2021) analyzed the rapidly growing scientific literature on heat waves. A total of 8,011 related publications were extracted from the Web of Science (WoS) database. The results show that research on heat waves doubled over five years. The authors also present the most severe heat wave events, the cities affected by heat waves, and the ecological and medical impacts they bring. Iancu et al. (2022) studied 74,703 articles published between 1990 and 2022 on climate change, which were extracted from the Web of Science Core Collection. The study found that there was an increase in published research. Further, the study reveals that policies established by the European Union have created synergies between Member States, discovering and developing solutions to help adapt to climate change.

Caka & Caka (2022) conducted a scientometric analysis of climate change-related research in Kosovo. The results indicate a growth in climate change research in Kosovo, with 2014 being the most productive year. Further, the authors suggest that heat wave-related research and policymaking should focus more on climate change adaptation. Domeisen et al. (2022) document the capabilities for heat wave prediction at daily to decadal timescales. The authors felt that knowledge of climate change and its impact allows heat waves to be skillfully predicted daily to weekly and helps to focus on the increased occurrence of humid heat waves, especially in southern Asia. Klingelhofer et al. (2023) heatwaves are placing an enormous burden on health and social systems and threatening ecological diversity around the world. Heatwaves are increasing not only in frequency but also in severity and magnitude. They are causing the deaths of thousands of people. Research is needed on a multidisciplinary, supra-regional, and regional level.

Methods

A detailed evaluation of the research conducted is not yet available. Therefore, this study provides a detailed insight into the publication landscape to identify key players, incentives, and requirements for future scientific efforts that are useful not only for scientists but also to stakeholders and project funders.

Results

The number of publications on heatwaves is increasing, outpacing the trend of research indexed by the Science Citation Index Expanded. However, funding is lagging behind comparatively. Looking at absolute numbers, the USA, Australia, China, and some European countries have been identified as major players in heatwave research. If socio-economic numbers are included, Switzerland and Portugal lead the way. Australia and the UK dominate if the change in heatwave-exposed people is included. Nevertheless, exposure and economic strength of publishing countries were identified as the main drivers of national research interests. Previous heatwaves, in particular, have driven research efforts primarily at the national level.

Conclusion

For an efficient monitoring or early detection system that also includes the economically weak regions, internationally networked efforts are necessary to enable preventive measures and damage limitation

against heatwaves. Regardless of previous regional extreme heat events, research approaches should be focused to the global level.”,”container-title”:”Globalization and Health”,”DOI”:”10.1186/s12992-023-00955-4”,”ISSN”:”1744-8603”,”issue”:”1”,”journalAbbreviation”:”Global Health”,”language”:”en”,”page”:”56”,”source”:”DOI.org (Crossref provide a detailed insight into the publications and project funders related to heat wave research. The findings of the study indicate that the number of publications on heat waves increased with a lag in funding. The USA, Australia, China, and some European countries have been identified as significant players in heat wave research. Further, the study suggests that internationally networked efforts are necessary for an efficient monitoring or early detection system against heat waves. Laino and Iglesias (2023) have made a comprehensive review that comprises the key findings of a systematic scientific literature analysis on climate change’s extreme impacts on coastal cities. The study includes 2321 papers in 470 journals from 1976 to 2021. The study found that geographical diversity in 97 countries and identified the research gaps, which could help find research directions.

Thirukanthan et al. (2023) assessed climate change research trends and future directions. This study is based on publications from the Web of Science Core Collection published between 1977 and 2022. The authors reviewed 2834 papers and 107,502 citations. The findings indicated that the USA was the most significant contributor, followed by China and Brazil. The researchers from the USA and Germany were among the top authors published in this field. Lindawati and Meiryani (2024) quantitatively analyze the global scientific performance of global climate change. The data used for the study was based on 259 papers indexed in the Scopus database. The authors opined that their research could be used by scholars and policymakers to explore future research and to contemplate the existing directions of climate change studies.

Objectives of The Study

1. The main objective of the study is to analyse the research literature on ‘Heat Waves’ published and indexed in the Web of Science database between 2004 and 2023. The other specific objectives are to:
2. study the publications and citations trends at the global level on heat waves;
3. identify the most prolific authors, productive organizations and countries in the field of Heat waves;
4. determine the most preferred journals and research areas to publish in ‘Heat Waves’ Research; and list out the most supportive funding agencies in the field of ‘Heat Waves’ research.

Materials and Methods

The publication records of the published research papers on ‘Heat Waves’ during the period 2004 - 2023 were extracted from the Web of Science database. A total of 2,715 records were found where ‘Heat Wave’ is part of the title or author keywords were extracted in the CSV file format. The publication records were further analyzed using

Excel Spreadsheet, VoSViewer, Biblioshiny, mathematical and statistical formulae for various indicators used.

Analysis and Results

Year-wise distribution of research literature

Table 1 presents the year-wise distribution of the publications, citations received, citations per paper and h-index for the research literature on ‘Heat Waves’ published and indexed in the Web of Science database between 2004 and 2023. Overall, 2,715 publications were extracted and considered for the analysis, which together received 95,837 citations at the rate of 35.30 citations per paper across the period.

The highest number of research papers were published in 2023, i.e. 562 publications; however, the highest number of citations received for research papers published in 2019, i.e. 10,026 citations and the highest h-index of 50, is also recorded for the publications in 2019. The lowest number of publications (10), citations received (643) and the lowest h-index recorded for the research papers published in 2005. Though the number of publications in the year 2004 is only 17 research papers and it is noted that the same year, it has recorded the highest number of 337.00 citations per paper, followed by 2008 (110.00) and 2010 (109.15); the lowest number of citations per paper was recorded for the research papers published in the year 2023, which clearly indicates that for any research paper time is required to get its readers and research impact. Figure 1 shows the chart for year-wise publications and citations received across the study period for infographic representation.

Table 1: Year-wise distribution publications, citations on Heat Waves

PY	TP	TC	CPP	h-index
2004	17	5,729	337.00	10
2005	10	643	64.30	7
2006	20	1,166	58.30	11
2007	25	1,671	66.84	15
2008	38	4,180	110.00	20
2009	27	1,756	65.04	12
2010	53	5,785	109.15	31
2011	45	2,975	66.11	23
2012	48	4,189	87.27	25
2013	49	3,864	78.86	26
2014	97	5,137	52.96	43
2015	83	5,300	63.86	36
2016	105	6,544	62.32	42
2017	137	7,165	52.30	48
2018	173	9,216	53.27	47

2019	234	10,026	42.85	50
2020	262	7,924	30.24	48
2021	341	6,733	19.74	39
2022	389	3,876	9.96	27
2023	562	1,958	3.48	16
Total	2,715	95,837	35.30	-

PY: Publication Years; TP: Total Publications; TC: Total Citations; CPP: Citations per Paper

Distribution of research output by document types

Overall, 2,715 research papers on ‘Heat Waves’ have been published in 13 different document types. The maximum number of researchers preferred to publish their research as a Journal Article, i.e. 84.70%, followed by the Review Articles (4.09%) and Meeting Abstracts (3.33%). According to the citations received, Articles have attracted the highest, i.e. 84,987 citations, followed by Review Articles (9,553), Proceeding Papers (1,607) and Book Chapters (1,525). Although only three book chapters were published during the study period, Book Chapters achieved the highest 508.33 citations per paper, followed by Review Articles (84.54) and Proceeding papers (66.96). Figure 2 presents the infographic presentations of the document types preferred by the researchers on ‘Heat Waves’.

Table 2: Distribution of research output by document types

Document Types	TP	%TP	TC	%TC	CPP	H-Index
Article	2341	84.70	84,987	85.84	36.30	122
Review Article	113	4.09	9,553	9.65	84.54	44
Meeting Abstract	92	3.33	51	0.05	0.55	4
Editorial Material	83	3.00	931	0.94	11.22	13
News Item	34	1.23	111	0.11	3.26	4
Letter	27	0.98	175	0.18	6.48	6
Proceeding Paper	24	0.87	1,607	1.62	66.96	16
Early Access	21	0.76	34	0.03	1.62	3
Correction	17	0.62	9	0.01	0.53	1
Book Review	7	0.25	2	0.00	0.29	1
Book Chapters	3	0.11	1,525	1.54	508.33	3
Reprint	1	0.04	18	0.02	18.00	1
Retracted Publication	1	0.04	4	0.00	4.00	1

TP: Total Publications; %TP=Percentage among Total Publication; TC: Total Citations; %TC=Percentage among Total Citations; CPP: Citations per Paper

Highly productive countries

The authors from 115 countries have published 2,715 research papers on ‘Heat Waves’; table 3 presents the list of top 10 highly productive countries. The USA (670) has published the highest number of research papers, followed by China (503) and

Australia (409). The USA has received the highest, i.e. 36,564 citations, followed by Australia (21,821) and England (16,998). However, according to the citations per paper, Switzerland leads the table with 103.42 CPP, followed by England (69.66) and Canada (58.24). Similarly, according to the h-index, the USA has led the table with 83 h-index, followed by Australia (71) and England (59). Figure 3 shows a collaborative network map of countries involved in the research publications on ‘Heat Waves’.

Table 3: Top 10 highly productive countries

Countries	TP	TC	CPP	H-Index
USA	670	36,564	54.57	83
China	503	13,348	26.54	55
Australia	409	21,821	53.35	71
England	244	16,998	69.66	59
Germany	213	9,900	46.48	46
Italy	199	8,713	43.78	47
Spain	189	8,762	46.36	43
France	164	6,254	38.13	38
Canada	116	6,756	58.24	36
Switzerland	105	10,859	103.42	39

TP: Total Publications; TC: Total Citations; CPP: Citations per Paper

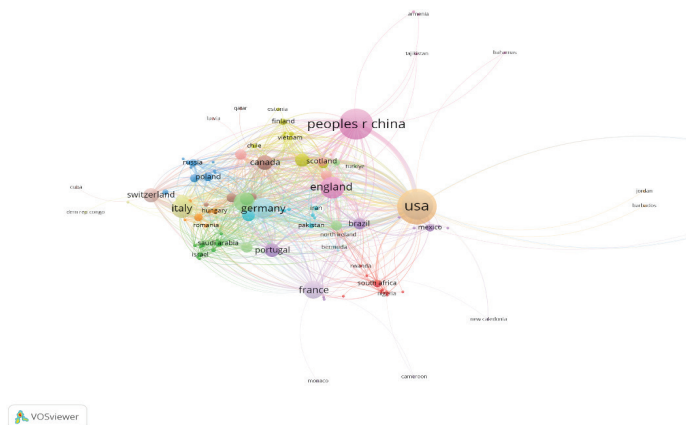


Figure 1: Co-authorship map of highly productive countries

Most productive Organizations

Authors affiliated with 2,688 organizations collaborated to publish 2,715 research papers on ‘Heat Waves’. Table 4 presents the list of the top 10 organizations with maximum contributions. Chinese Academy of Sciences has contributed the highest number of 144 research papers, followed by the University of California System (99) and Centre National De La Recherche Scientifique-CNRS (94). However, the University

Most productive authors

A total of 9,011 authors have participated in the publications of 2,715 research papers on ‘Heat Waves’ with an average of 3.32 authors per paper. Among the 9,011 authors, 157 have published 197 single-authored research papers. The Table 5 presents the top 10 most productive authors. The Cristina Linares of Instituto de Salud Carlos III, Madrid, Spain, has contributed the highest number, i.e. (37) research papers, followed by the Peng Bi of the University of Adelaide, Adelaide, Australia (32) and the Jose Diaz of Universitat de Vic-Universitat Central de Catalunya, Vic, Spain (27). Among the top 10 productive authors, Thomas Wernberg of the University of Western Australia has received the highest (4,841) citations, followed by Eric C. J. Oliver (4,834) and Neil J. Holbrook (4711). According to the citations per paper, Neil J. Holbrook of the University of Tasmania has achieved (254.42) CPP, followed by Neil J. Holbrook (235.55) and Thomas Wernberg (210.48). Cristina Linares of Instituto de Salud Carlos III and Sarah E. Perkins-Kirkpatrick of the University of New South Wales Sydney have achieved the highest 19 h-index. Among the top 10 most productive authors, five were from Australia, two were from Spain and China, and one was from Italy. Figure 5 shows a collaborative network map of authors contributing to the ‘Heat Waves’ literature.

Table 5: Top 10 Most Productive Authors

Authors	Affiliation	Country	TP	TC	CPP	H-Index
Cristina Linares	Instituto de Salud Carlos III	Madrid, Spain	37	1,013	27.38	19
Peng Bi	University of Adelaide	Adelaide, Australia	32	1,742	54.44	18
Jose Diaz	Universitat de Vic - Universitat Central de Catalunya (UVic-UCC)	Vic, Spain	27	1,219	45.15	15
Sarah E. Perkins-Kirkpatrick	University of New South Wales Sydney	Sydney, Australia	23	3,751	163.09	19
Thomas Wernberg	University of Western Australia	Crawley, Australia	23	4,841	210.48	15
Neil J. Holbrook	University of Tasmania	Tasmania, Australia	20	4,711	235.55	14
Paola Michelozzi	Regional Health Service	Rome, Italy	20	1,013	50.65	7
Eric C. J. Oliver	University of Tasmania	Tasmania, Australia	19	4,834	254.42	18
Shilu Tong	Chinese Center for Disease Control & Prevention	Beijing, China	19	999	52.58	14
Ming Luo	Sun Yat Sen University	Guangzhou, China	18	686	38.11	13

TP: Total Publications; TC: Total Citations; CPP: Citations per Paper

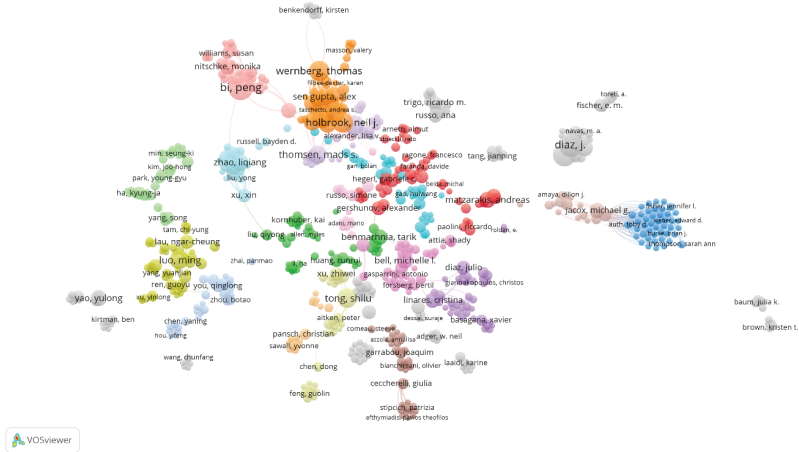


Figure 3: Co-authorship map of highly productive authors

Highly preferred Journals

Out of 659 publication sources, 656 were journals. The highest number of research papers were published in the journal, i.e. *Science of the Total Environment* (90), followed by *Environmental Research Letters* (85) and *Climate Dynamics* (80). Among the top 10 highly preferred journals, *Environmental Research Letters* has received the highest 5,576 citations, followed by *Climate Dynamics* (3,227) and *Journal of Climate* (3,208). *Environmental Research Letters* has achieved the highest, i.e. 65.60 citations per paper, followed by *Journal of Climate* (59.41) and *Climate Dynamics* (40.34). Similarly, *Environmental Research Letters* has received the highest 36 h-index. Among the top 10 journals, two were published by Elsevier and MDPI. Nine journals were listed in the Journal Citations Reports-2022, and *Science of the Total Environment* has received the highest 9.8 impact factor, followed by the *Environmental Research* (8.3) and the *Environmental Research Letters* (6.7). Figure 8 presents a Co-citation Network map of the journals published research papers on ‘Heat Waves’.

Table 6: Top 10 highly preferred journals

Journal Titles	Publisher	IF(2022)	TP	TC	CPP	H-Index
Science of the Total Environment	Elsevier	9.8	90	2,521	28.01	28
Environmental Research Letters	IOP Publishing Ltd	6.7	85	5,576	65.60	36
Climate Dynamics	Springer	4.6	80	3,227	40.34	30
Geophysical Research Letters	Amer Geophysical Union	5.2	79	3,085	38.56	29
Frontiers in Marine Science	Frontiers Media SA	3.7	77	1,554	20.18	21
International Journal of Climatology	Wiley	3.9	69	1,925	27.90	24

Marine Freshwater Biology	203	3,454	17.01	30
Engineering	134	2,722	20.31	31
Construction Building Technology	88	2,494	28.34	29
Oceanography	82	2,896	35.32	21
Water Resources	80	1,358	16.98	21

TP: Total Publications; TC: Total Citations; CPP: Citations per Paper

Distribution of research output by funding agency

Out of 2,715 research papers on the ‘Heat Waves’ considered for the study, 1,912 research papers received funding from one or more funding agencies. Out of 881 funding agencies, the top 10 funding agencies, as per the number of publications, were listed in Table 8. The National Natural Science Foundation of China (NSFC) have funded the highest (310) research papers, followed by the National Science Foundation-NSF (171) and the Australian Research Council (146). Among the top 10, research papers funded by the Australian Research Council have attracted the highest, i.e. 10,978 citations, followed by UK Research Innovation-UKRI (10,664) and National Science Foundation-NSF (10,416). Natural Environment Research Council-NERC led the ranking according to the citations per paper with 126.94 CPP, followed by UK Research Innovation-UKRI (100.60) and Australian Research Council (75.19). Australian Research Council funded research papers have achieved the highest 48 h-index.

Table 8: Distribution of Research Output by Funding Agency

Funding Agency	TP	TC	CPP	H-Index
National Natural Science Foundation of China NSFC	310	8,087	26.09	46
National Science Foundation NSF	171	10,416	60.91	46
Australian Research Council	146	10,978	75.19	48
European Union EU	127	9,417	74.15	45
UK Research Innovation UKRI	106	10,664	100.60	42
Fundacao Para A Ciencia E A Tecnologia FCT	64	1,802	28.16	25
Natural Environment Research Council NERC	63	7,997	126.94	31
Spanish Government	61	2,556	41.90	26
United States Department of Energy DOE	57	3,817	66.96	32
Natural Sciences and Engineering Research Council of Canada NSERC	50	2,339	46.78	26

TP: Total Publications; TC: Total Citations; CPP: Citations per Paper

Conclusion

The present study analysed 2,715 research papers on ‘Heat Waves’ as indexed in the WoS databases from 2004 to 2023. The study found vicissitudes growth in the number of publications across the study period; however, a continues growth is observed since 2016. More than 84% of the research papers were published in the journals as ‘Articles’,

however recorded three book chapters have recorded highest citations per paper across all the document types. The USA was highly productive country across 115 countries and the Chinese Academy of Sciences was adjudged as the highly productive organization among the 2,688 organisations involved in the research publications. Among the 9,011 authors participated in the research publications under study, Cristina Linares of Instituto de Salud Carlos III, Madrid, Spain found to be the most productive organization. Among the 656 journals, *Science of the Total Environment* has published highest number of articles. The National Natural Science Foundation of China has funded highest number of research papers published on 'Heat Waves'.

Heat Waves are becoming more common and more intense all around the world. According to a recent study by Luo et al. (2024), an average of 98 heat waves per year between 2016 and 2020 lasted an average of 12 days. The study also found a substantial change in contiguous heatwaves have been identified from 1979 to 2020, with longer persistence, longer travelling distance, and slower propagation. Thus, the current study helps researchers and scientist to identify the major research evidences and trends among the research literature published on 'Heat Waves'. The findings may also useful to the climate research community, health care research community, ecologists, environmental consultants and policy makers for evidence-based planning for reduction of intense heat-waves in coming days.

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