

A Review of Research on Extreme Heat Events in China

Weiwei Ren

Xi'an International Studies University, Xi'an, China

ABSTRACT

Based on the current research literature on extreme high temperature events in China, this paper reviews the spatial and temporal characteristics of extreme high temperature events, causes of extreme high temperature events, identification methods of extreme high temperature events, and impacts of extreme high temperature events in China, and points out the problems existing in the research on extreme high temperature events in China.

KEYWORDS

Heat Events; Spatial and Temporal Characteristics; Identification Methods; Impacts.

1. INTRODUCTION

With global climate change and the intensification of human activities, extreme high temperature phenomena occur frequently around the world. According to the IPCC special report on the impacts of global warming of 1.5°C, it is estimated that the global average temperature rises by about 0.2±0.1°C per decade, and that the world has already experienced a cumulative increase of about 1°C[6]. The trend of extreme high temperature climate change in the China region is almost relatively consistent with the trend of extreme high temperature change worldwide. Relevant studies show that since as early as the 1960s, the number of days, frequency, intensity and range of high-temperature heat waves in China have shown an enhancing trend^{[1],[2]}. Especially in the 1990s, regional high-intensity heat events were frequent in China, especially in the Yangtze River Basin^{[3],[4]}. In recent years, according to the latest research by the National Climate Centre, the frequency of extreme summer heat events in China will increase significantly in the future^[5]. By around 2025, at least 50 per cent of summers are likely to be characterised by prolonged high-temperature heatwave processes, and in the worst possible scenario, by the end of the century, the frequency of extreme heat events in the country will be five times higher than at present. And extreme heat may lead to human heat stroke, pyrexia and other diseases, affect crop growth and yield, exacerbate the urban heat island effect, and trigger the occurrence of forest fires and other disasters. Extreme weather events involve a number of disciplinary fields, including meteorology, geography, environmental science, economics, etc. In recent years, the heat of research on extreme heat events has also been rising in recent years. In this paper, through a literature review of the spatial and temporal characteristics of extreme high temperature events in China, the analysis of causes, identification methods, and the impact of extreme high temperature events, we can gain a deeper understanding of the laws and characteristics of extreme high temperature events, and provide reference help for the next research on extreme high temperature events.

2. ANALYSIS OF THE CAUSES OF EXTREME HEAT EVENTS

The causes of extreme heat events are complex and varied, and different scholars have come to different conclusions due to the different research perspectives and methods adopted to treat this issue. By reviewing the relevant literature, it can be found that the causes of high-temperature events are natural factors and man-made factors and the combined effect of the two. Cui Tong et al.^[6] found that global warming is the background for the occurrence of high-temperature events, and atmospheric circulation anomalies are the direct cause of high-temperature events, by using the daily temperature data in China and NCEP reanalysis data. Sun Jianqi et al.^[7] based on the index of the number of days of extreme high temperature events to study the relationship between extreme climate events and atmospheric circulation in China, they found that due to the location in the air and the height of the anomalies of the atmospheric circulation factor is one of the causes of the occurrence of extreme high temperature events in the northern region of China, and when the higher the height of the potential, the more the number of days of extreme high temperature events, and vice versa, the lower the number of days of extreme high temperature events. However, for the southern region of China, the atmospheric circulation factors that cause extreme weather events to occur abnormally, in addition to the above reasons, there are also cold and warm advection in the lower atmosphere. The Sixth Assessment Report (AR6) of the United Nations Intergovernmental Panel on Climate Change (IPCC) states that the increase in temperature on a global scale is due to the increase in the concentration of greenhouse gases (GHGs) in the atmosphere and through the thermodynamic effect, and that this phenomenon has led to an increase in the frequency and intensity of extreme warm weather events[8]. Li Zongheng et al.^[9] used daily maximum air temperature data from 1960 to 2011 years from meteorological stations in Jianghuai area and regressed the standardised summer extreme high temperature indices with the potential height field, vertical velocity field, and wind field, respectively, as a way of explaining the connection between extreme high temperature events and atmospheric circulation. Shi Jun^[10] et al. studied the extreme high temperature phenomenon in North China from time and space, and explored the causes and characteristics of the extreme high temperature events produced by it using qualitative and quantitative research methods such as power spectrum analysis, Mann Kendall test method, etc., and the results showed that the causes of the extreme high temperature events occurring in the East China region are related to the area of the subglacial high of the western Pacific Ocean in the summer and the intensity index, SST, typhoons and the role of urbanisation. Yang Xuchao^[11] and other researchers focus on the impact of urbanisation on extreme heat events, and point out that the urban heat island effect exacerbates the probability and intensity of extreme heat events, especially in the context of China's aging population, which poses a great challenge to people's health. They also pointed out that research on the impact of urbanisation on high temperatures and the development of people's physical and mental health still needs to be studied in depth.

3. SPATIAL AND TEMPORAL CHARACTERISTICS OF EXTREME HEAT EVENTS

The spatial and temporal characteristics of extreme heat events vary across regions and time scales. Globally, the frequency and intensity of extreme heat events seem to be increasing, which is consistent with the trend of global warming[12]. However, the influencing factors are more complex when specific to different regions and time scales. To accurately understand and predict the spatial and temporal characteristics of extreme heat events in a specific region, it is necessary to comprehensively consider a wide range of factors, including climatic patterns, local environmental conditions, urbanisation processes, and so on. Through multidisciplinary cross-disciplinary research, we are expected to gain a deeper understanding of these complex systems and provide a scientific basis for responding to extreme heat events. In China, the research on the spatial and temporal characteristics of extreme heat events started relatively early, and the related research results are

relatively abundant. Since the 1960s, extreme climate events in China have shown obvious regional and seasonal characteristics^{[16][17]}. Wang Yan jiao, Ren Fumin et al.^[13] In exploring the spatial and temporal characteristics of regional persistent high-temperature events in China, we defined and extracted the regional persistent high-temperature events from the aspects of high-temperature intensity, duration, area and continuity, and systematically analysed and researched the spatial and temporal characteristics of the persistent extreme high-temperature events in China in the past 50 a. The results show that, from the spatial distribution, the regional persistent high-temperature events in China are more and more common in China. The results show that, in terms of spatial distribution, the regions with higher frequency and intensity of regional persistent high temperature events are located in the northwestern and southeastern regions of China. In terms of temporal distribution, the annual frequency, duration, area affected and intensity of regional persistent extreme heat events in China have all shown a significant increase over the past 50 years. Wang Pengxiang et al.^[14] defined the extreme high temperature thresholds using the percentile method based on the daily maximum temperature data of meteorological stations in Northwest China from 1960 to 2004, and then analysed and counted the frequency of extreme high temperature events at each station in Northwest China. The results show that the five regions in Northwest China with high frequency of extreme heat events are northern Qinghai, northern border region, southern border region, eastern Northwest China, and Tibetan Plateau region, and the cyclic fluctuation of every twelve to fourteen years is obvious in these five regions. Qi, Q. et al^[15] used statistical methods such as the percentile method, the least squares method, and the non-parametric Kendall-tau method to analyse the climate trends, and also used time-lag correlation analyses to explore the spatial and temporal patterns of changes in the extreme characteristics of the temperature and the trend characteristics in eastern China. The conclusions on the spatial and temporal variations of extreme weather events show that the frequency of extreme heat events in China showed a decreasing trend before the 1990s and an increasing trend after 1990. In addition, the long-term trend of the intensity of extreme heat events is not obvious, especially in the Huanghuaihai region, which shows a decreasing trend. In addition, scholars have analysed that the subtropical high pressure, the Southern Oscillation (SO) and the Northern Oscillation (NO) are the main causes of extreme climate change in eastern China. Yang Yang, Zhao Na et al.^[18] used Mann-Kendall mutation test, sliding t-test, spatial autocorrelation and standard deviation ellipse to study the spatial and temporal evolution pattern of extreme high temperature events in China from 1980 to 2018. The results show that the number of summer days, hot night days, warm night days and warm day days in China have shown a significant upward trend over the past 40 years. Li Z et al.^[19] analysed the spatial and temporal distribution of extreme temperature time and its trends in the Loess Plateau during the period of 1961-2007 using day-by-day temperature data from more than fifty stations on the Loess Plateau, and the results showed that the spatial and temporal differences in extreme temperature events on the Loess Plateau were obvious, with a gradient from the southeast to the northwest, and that the frequency of extreme high temperature events in the region showed an increasing trend. The frequency of extreme heat events in this region tends to increase.

4. IDENTIFICATION OF EXTREME HEAT EVENTS

Although scholars in related fields have been studying extreme heat events extensively, domestic and foreign scholars have not yet given a unified answer to the definition of extreme heat. Currently, there are two main definitions of extreme high temperature, namely temperature indicator and temperature threshold^[20]. In the research about temperature indicators, some scholars use the maximum temperature as an indicator^[21], these scholars use the maximum daytime temperature as a basis, and think that the daytime time is more in line with people's daily activities. There are also scholars who use the average temperature as an indicator^[22], arguing that the use of a whole day is more compatible with temperature exposure. In addition, scholars' studies on temperature thresholds are divided into absolute and relative thresholds. The first one is the absolute threshold: the criteria on high temperature heat wave issued by China Meteorological Department are: high temperature day is

defined as a day-by-day maximum temperature greater than 35°C, three consecutive days with maximum temperature greater than or equal to 35°C, i.e., a single-station persistent high temperature event[23][24] . The second one is the relative threshold: i.e. the 90th, 95th and 99th percentiles of the daily maximum temperature[25] are used for high temperature studies.

In terms of specific research analyses on extreme heat events, the research tools used by different scholars are slightly different. Jiang Tong et al.[26] used the IAD (i.e., intensity-area-impact-duration) method to define extreme weather events in three dimensions. The IAD method is used to study the relationship between the intensity of a regional extreme weather event and the disturbed area under a certain period of time, and then vividly presents regional extreme events in the form of an envelope. visualise the changes in regional extreme events. This method provides reference value for experts in the selection of future economic development paths and measures that should be taken to cope with climate change. In addition, when scholars in China study extreme heat events, they usually only consider surface air temperature as the only factor to carry out research[21][27] . However, with global climate change, more and more uncertainties need to be taken into account, so more and more scholars also take surface humidity into account[28] .

5. IMPACT OF EXTREME HEAT EVENTS

Extreme heat events are situations in which temperatures rise abnormally above the normal range. They are usually accompanied by features such as increased humidity, high body temperatures, and deterioration of air quality, with significant impacts on human life and health, among others[29] . Extreme heat events have a wide range of impacts on human beings and the environment, mainly involving impacts on human health, energy consumption, agriculture and ecological areas. Firstly, in terms of the impact on people's health, extreme heat events have the most significant impact on human health. High temperatures can make the human body feel uncomfortable and trigger conditions such as heat stroke, heat exhaustion, heat cramps, etc., which may even lead to death in severe cases. For the elderly, children, pregnant women and the physically weak, high temperatures are more likely to cause health problems, especially for the elderly, high temperatures are more prone to cause sudden outbreaks of cardio-cerebral and cerebrovascular diseases and respiratory diseases, which poses a greater challenge to the survival of the elderly,[30][31] . The second is that extreme hot weather can lead to increased energy demand. People need more electricity to cool their houses and drive equipment such as air conditioners, which can put a strain on the electrical system and may even lead to power shortages and blackouts^[32] . Again, extreme heat can have an impact on agriculture and ecosystems. High temperatures can lead to increased transpiration, causing plants to lose too much water and die^[33][34] . Also, high temperatures can affect the survival and reproduction of animals, disrupting the ecological balance[35] . Finally, extreme hot weather can also have an economic impact. For example, crops will be reduced due to high temperatures, affecting agricultural income; tourism will also be affected by hot weather; and high temperatures will also affect the productivity of industries such as construction and manufacturing[36] . As for the research direction of our scholars on the impacts of extreme heat events, most of the scholars' studies mainly tend to focus on the impacts on crops.

6. CONCLUSION

Extreme heat events in the context of global warming has become more and more attention of researchers, and the research results are also quite a lot. China's research on extreme heat events started relatively late, and there is still a certain gap between the results achieved compared with foreign countries, but in recent years, the relevant research results have been increasing trend. At present, the research results published by Chinese scholars, due to the vast geographical scope of our country, the characteristics of extreme high temperature events occurring in different regions are

different, in the content of the study above the analysis of extreme high temperature events focusing on the spatial and temporal characteristics of the event. Regarding the analysis of the causes of extreme weather events, most scholars attribute them to the role of atmospheric circulation and global warming, and a considerable number of scholars attribute them to the urban heat island effect. In the identification of extreme heat events, most of the research is based on single station and single grid point extreme threshold or fixed range of station threshold for spatial and temporal characteristics analysis, but ignored the extreme climate events have regional, so some scholars use the IAD method, which is very helpful for the identification of regional extreme heat events. The impact of extreme high temperature events is multifaceted, and the research content of our scholars is mostly focused on the impact of extreme high temperature events on crops. At present, the number of research results on the prediction of extreme heat events is relatively small. Predicting the frequency and intensity of extreme heat events has a guiding significance for production and life, and can provide a basis for preventing the negative impacts of extreme heat, so related scholars should also conduct in-depth research on the prediction of extreme heat.

REFERENCES

- [1] YE Dianxiu, YIN Jifu, CHEN Zhenghong, et al. Spatial and temporal characteristics of summer heat waves in China from 1961 to 2010[J]. Progress in Climate Change Research, 2013, 9(1) :15-20.
- [2] Yin H, Sun Y. Characteristics of extreme temperature and precipitation in China in 2017 based on ETCCDI indices [J]. Adv Climate Change Res, 2018, 9(4) :218-226.
- [3] SHEN Haojun, YOU Qinglong, WANG Pengling, et al. Characterisation of changes in high-temperature heat waves in China from 1961 to 2014[J]. Meteorological Science, 2018, 38(1) :28-36.
- [4] LIANG Xiaoni, LEI Jun, LUO Yuezheng, et al. Characteristics of extreme temperature and precipitation index changes in Hangzhou from 1955-2014[J]. Meteorological and Environmental Science, 2016, 39(3) :68-74.
- [5] Sun Y. Hu T. Zhang X. Substantial increase in heat wave risks in China in a future warmer world[J]. Earth's Future, 2018, 6(11) : 1528-1538.
- [6] Cui Tong, Sun Linhai, Zhang Chi et al. A preliminary study on the characteristics and causes of extreme heat events in China in the summer of 2022[J]. Meteorological and Environmental Science, 2023, 46(03):1-8.
- [7] SUN Jianqi, WANG Huijun, YUAN Wei. Interdecadal variability of extreme heat events in China and its connection with atmospheric circulation[J]. Climate and Environment Research, 2011, 16(02):199-208.
- [8] Zhou Botao, Qian Jin. Interpretation of the IPCC AR6 report: Changes in extreme weather and climate events[J]. Progress in Climate Change Research, 2021, 17(6):713-718.
- [9] Li Zongheng, Li Chongyin, Song Jie et al. Characteristics and causes of extreme high temperature days in summer in the Jianghuai region in 1960~ 2011[J]. Climate and Environment Research, 2015, 20(05):511-522.
- [10] SHI Jun, DING Yihui, CUI Linli. Characteristics and causes of extreme high temperature in East China[J]. Atmospheric Science, 2009, 33(02):347-358.
- [11] YANG Xuchao, CHEN Baode, HU Kejia. Progress of research on the impact of urbanisation on extreme heat events[J]. Advances in Geosciences, 2015, 34(10):1219-1228.
- [12] Zhou C, Wang K, Qi D, et al. Attribution of a record-breaking heatwave event in summer 2017 over the Yangtze River Delta[J]. Bull Amer Meteor Soc, 2019, 100(1) :97-103.
- [13] Wang Yanjiao, Ren Fumin, Yan Feng. Characteristics of spatial and temporal variations of regional persistent high temperature events in China[J]. Geoscience, 2013, 33(03):314-321.
- [14] WANG Pengxiang, YANG Jinhu. Extreme heat events in Northwest China over the past 45a and their response to regional warming[J]. Desert China, 2007(04):649-655.
- [15] QI Qinghua, CAI Rongshuo, GUO Strait. Temperature extremes and their climatic characteristics in eastern China[J]. Geoscience, 2019, 39(08):1340-1350.
- [16] Qin Dahe. National Assessment Report on Risk Management and Adaptation to Extreme Climate Events and Disasters in China[M]. Beijing: Science Press, 2015.
- [17] Preparation Committee for the Third National Assessment Report on Climate Change. Third National Assessment Report on Climate Change [M]. Beijing: Science Press, 2015.
- [18] Yang Yang, Zhao Na, Yue Tianxiang. Evolutionary characteristics of spatial and temporal patterns of extreme heat events in China from 1980 to 2018[J]. Geoscience, 2022, 42(03):536-547.

- [19] LI Zhi,ZHENG Fanli,LIU Wenzhao. Temporal and spatial variations of extreme temperature events on the Loess Plateau[J]. Journal of Natural Hazards,2011,20(06):6-12.
- [20] Zhang Haiyan. Population Exposure to High Temperature and Health Risk Prediction in China in the 21st Century[D]. Northwest Normal University,2023.
- [21] WANG Wen, HU Yanjun, XU Chuanyi. Characteristics of spatial and temporal variations of heat wave events in the Huaihe River Basin from 1961-2018[J]. Geoscience, 2021, 41(5): 911-921.
- [22] WANG Fang, ZHANG Jintao, GE Quansheng, et al. "Risk prediction of extreme heat waves in the 21st century along the Belt and Road[J]. Science Bulletin, 2021, 66(23): 3045-3058.
- [23] Gao Rong, Wang Ling, Gao Ge. Trends in the number of high-temperature days in China from 1956 to 2006[J]. Progress in Climate Change Research,2008(03): 177-181.
- [24] LI Qingxiang, HUANG Jiayou. Discussion on the threshold of extreme heat events in China[J]. Journal of Applied Meteorology, 2011(22): 12-18.
- [25] PAN Xiaohua,ZHAI Panmao. Selection and analysis of temperature extremes[J]. Meteorology, 2002, 28(10): 28-31.
- [26] JIANG Tong,WANG Yanjun,ZHAI Jianqing et al. Risk study of socio-economic impacts of extreme weather events: theory, methodology and practice[J]. Journal of Reading River,2018,10(01):90-105+147.
- [27] Jiao Wenhui,Zhang Bo, Ma Bin et al. Analysis of spatial and temporal variations of extreme temperatures and influencing factors in northern China in the last 58 a[J]. Arid Zone Geography,2020,43(05):1220-1230.
- [28] Russo S, Sillmann J, Sterl A. Humid heat waves at different warming levels[J]. Scientific Reports, 2017, 7(1): 7477.
- [29] Ren FM,Gao H,Liu LL et al. A review of research progress on monitoring and prediction of extreme weather and climate events and their applications[J]. Meteorology,2014,40(07):860-874.
- [30] LUO Xuerong,CHEN Zhenghong,GONG Xue et al. Impacts of summer high-temperature heat waves on mortality of Wuhan residents[C]// Chinese Meteorological Society. Proceedings of the 27th Annual Meeting of the Chinese Meteorological Society on Climate Environmental Change and Human Health. Hubei Meteorological Science and Technology Service Centre;Wuhan Disease Control Centre;.,2010:5.
- [31] Cui W, Huang YQ. Effects of extreme temperature events on human health and countermeasures[J]. Popular Science and Technology,2010,(06):116-117.
- [32] Gao Ya. Extreme heat "grills" the global economy[N]. First Financial Daily, 2023-07-17(A05).
- [33] GUO Xingxu. Research on the impact of extreme weather events on agricultural production in Hubei[J]. Rural Economy and Technology,2018,29(13):197-198.
- [34] ZHANG Yin,LIN Jingfeng. Impact of persistent hot weather on urban greening trees[J]. Jiangsu Forestry Science and Technology,2013,40(06):31-34.
- [35] MA Chunsen,MA Gang,ZHAO Fei. Impact of climate warming on wheat aphids[J]. Journal of Applied Entomology,2014,51(06):1435-1443.
- [36] WU Pingping,YAN Hailong,WU Pei Pei et al. Impact of extreme temperature events on production and life in Weichang County and countermeasures[J].Xinjiang Agricultural Reclamation Science and Technology,2018,41(03):47-48.