Research Progress of Urban Heat Wave Environment

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Abstract. High temperature heat wave is one of the disasters with higher frequency and greater impact in extreme weather. This article starts with the definition, disaster and health, influencing factors, prevention and control of high temperature heat wave. The results show that: (1) The current situation of high-temperature heat waves is obvious. After 2000, my country’s high-temperature heat waves showed a rapid growth trend. The high-temperature heat waves lasted for a long time and the highest temperature exceeded the historical extreme. (2) High temperature and heat waves have a major impact on human health, and at least they may induce heatstroke and other symptoms, and may cause death. And high temperature not only directly harms human health, but also indirectly affects the human body from the environment, such as inducing malaria. (3) Currently, the research on the influencing factors of high temperature heat wave generally conducts quantitative and qualitative research on the thermal environment from the on-site environmental assessment, high temperature heat wave model, and thermal simulation. (4) At present, my country’s prevention and control of high-temperature heat waves started relatively late, and the construction of developed countries such as Japan, the United States, and Germany, which are more comprehensive in prevention and control, is less complete.

1. Introduction

With the global climate change, extreme weather has become more and more frequent in recent years, which has a significant impact on people's physical and mental health. According to the global Risk Report from 2017 to 2020, extreme weather has now become the first risk facing human survival. Among all types of extreme weather, extreme high temperature heat waves have the highest probability of occurrence, the largest impact range, and the strongest risk hazard. Although extreme weather is unevenly distributed in space, if there is no proper response policy when a disaster occurs, it is not only for disasters. The destruction of the physical space of the location will also have a significant impact on the local society and economy, such as the Chicago heat wave in 1997 and the European heat wave in 2003[1].

The definition of high temperature has two main categories, single-element and multi-element. Single element refers to the division based on temperature. The international standard of the World Meteorological Organization (WMO) defines the heat wave: the maximum daily temperature is above 32°C and lasts for more than 3 days. The China Meteorological Administration defines a high-temperature heat wave as: a daily maximum temperature of 35°C is defined as a high-temperature day,
and a high-temperature day with more than 3 consecutive days is called a high-temperature heat wave[2]. Multiple factors combine various indicators. For example, the United States and Canada often judge the high temperature index based on indicators that affect the human body such as temperature, relative humidity, and wind speed[3]. The Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) in 2013 pointed out that the temperature has increased significantly in the past few decades. The average global surface temperature rose by 0.85°C from 1880 to 2012. The development situation will rise by 0.3°C-0.7°C from 2016 to 2021, and the temperature will continue to rise by 0.3°C-4.8°C until the end of the 21st century[4]. In 2016, the team of Professor Zhang Ren from the PLA University of Science and Technology studied 753 weather stations in China from 1983 to 2012 and found that China’s temperature has fluctuated and increased since 2000. The frequency of high temperatures in the past decade has increased significantly compared with the past, which is much higher than the historical average. In 2010, there were 11,342 high-temperature weather at the highest peak in 2010, and the high-temperature average was twice that of the 1980s[5]. In 2013, 8 provinces (cities) including Jiangnan, Jianghuai, Jianghan and Chongqing had an average high temperature of 31.6°C, which was nearly double the previous average of 15.1°C[6]. In the summer of 2018, there was a severe fever in the northern hemisphere. From July 14 to August 25, China’s Central Meteorological Observatory issued a high temperature warning for 33 consecutive days, the longest high temperature warning since 2010, with 57 meteorological observatories. The highest temperature on the release day broke the historical extreme value[7]. In 2020, El Niño is likely to cause a warm winter, and southern China’s summers are hot for a shorter period of time. The statistics of the highest temperature in Shanghai from July to August in 2020 (Figure 1) found that there are more than 38 days with temperatures above 32°C and over 35 days on the 19th.°C, the heat wave phenomenon is still obvious.

![Figure 1. The daily maximum temperature in Shanghai from July to August 2020.](image)

2. The harm of high temperature heat wave to human body
According to research, the most suitable temperature for the human body is between 15-25°C. When the temperature exceeds the suitable value, every 1°C increase, the risk of death increases by 1.03 times[8]. When a person is exposed to high temperatures, heat-related diseases can occur, and their body cannot be sufficiently cooled by sweating. Symptoms range from mild swelling, rash, or cramps to heat stroke that can be fatal. High temperature heat waves will cause the body's own temperature regulation organs to be extremely overloaded, causing damage to the original functions of the organs and destruction of inter-organ tissues, thereby inducing diseases or causing aggravation of diseases and causing deaths. The mortality rate of people during high temperature heat waves is compared with other people. The time period has increased significantly. Cardiovascular and cerebrovascular diseases, heatstroke and other heat-related diseases are the more common causes of death; in addition, high temperature heat waves can also cause water and electrolyte disturbances, kidney failure, urinary tract infections and other diseases[9].
Table 1. Statistics of different countries

| Country    | Date            | Case                                                                 |
|------------|-----------------|----------------------------------------------------------------------|
| France     | Year 2003       | 14,802 people died during the 20-day heat wave. Approximately one-third of the deaths were recorded directly from heat stroke. |
| United Kingdom | Year 2003     | The highest record in 130 years. From August 4th to 13th, 2045 people died of heat in just 9 days. From 2001 to 2010, approximately 28,000 people in 20 U. S. states were hospitalized for high temperature related diseases. In 2004, there were an average of 1.1 cases of related diseases per 100,000 people. In 2006, there were 2.5 cases of related diseases per 100,000 people. The average incidence in 2010 was 1.8 cases. The death rate is even higher. From 1979 to 2014, the death rate caused by direct exposure to high temperature (or a potential cause of death) hovered at 0.5 to 1 per million people, and there was an increasing trend in certain time periods. Since 1979, about 9,000 Americans have died from heat-related causes, and about a quarter of heat-related deaths are directly related to cardiovascular and cerebrovascular diseases. |
| United States | 1979 to 2014 | In the 33 years from 1975 to 2007, the number of deaths due to heat waves was 5877, with an average of 178 per year. After 1995, the number of deaths due to heat waves was significantly higher than before 1994. Akita Prefecture had the highest death rate, followed by Luer Island and Gunma, lower in Hokkaido, Kanagawa and Nagano. In 1983, the number of deaths due to the high temperature and heat wave was about 17 times that in 1982, in 1988 it was about 100 times that in 1987, and in 1998 it was about 190 times that in 1998. In 1998, the death toll was the highest at 1,658 people. There were 33 heat waves, and they all set new highs at the end of the 20th century. In April, May, June and July 2012, India experienced severe heat waves. The total number of deaths reached 575. |
| Japan      | 1975 to 2007    | The risk of non-accidental deaths caused by heat waves in China is relatively high. Only between 2006 and 2011, the number of deaths caused by heat wave exposure in Northeast China accounted for 2.35% of the number of deaths in the region, ranking first in the country with 1520 people; followed by North China. In the region, the attributable heat wave exposure resulted in a total of 861 cases with a mortality rate of 1.79%; then in Central China and East China, the attributable mortality rate was 1.79% and 1.64%, respectively, and the attributable death rate was 1933 and 2140; finally, the Southwest and East China regions. In South China, the attributable mortality rate is 1.27% and 0.24%, and the number of deaths is 1470 and 194. The data in Northwest China is not clear due to statistical problems[10]. High temperature disasters not only directly harm human health, but also indirectly affect the human body from the environment; for example, rising temperature provides favorable conditions for the parasitism, reproduction and transmission of vectors and pathogens, and enhances their ability to treat diseases, thereby harming them. Human health research shows that whenever the global temperature rises by 1℃, the potential pollution hazard of dengue fever will increase by 3.1%-4.7%, and the global incidence of malaria will increase greatly, posing a major challenge to the field of public health[11]. High temperature and heat waves can also cause the destruction of water bodies, |
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the imbalance of ecological balance, and the melting of permafrost glaciers, which will have a significant impact on human survival.

3. Research on the influencing factors of heat wave disasters

The analysis and research on the factors affecting high temperature heat waves are generally divided into three categories: site environmental assessment, model research, and thermal simulation. On-site environmental assessment generally involves directly scoring the factors affecting heat at the survey site and setting weights to obtain the evaluation score, and dividing the evaluation interval to compare different locations. Model research generally involves obtaining heat wave-related data through the Internet or on-site to construct analysis models for analysis and comparison. Thermal simulation generally uses simulation software to model or visualize the analysis area, and to compare the gap before and after the analysis by changing the parameters of the influencing factors.

3.1. On-site environmental assessment of high temperature heat wave

At present, there are three commonly used methods of on-site environmental evaluation: POE evaluation method, Defil method evaluation and AHP analytic hierarchy process.

(1) POE evaluation method: The evaluation takes the feelings of local residents as the main body as the starting point to obtain complete evaluation data of the thermal environment in the life system to analyze the comprehensive index of the built thermal environment[12-13]. Evaluation ideas: 1. Survey/understand the situation, complete through visits, conversations and document review. 2. The research method setting (determine the question to be investigated, the object, the method, the content to be tested, the index, etc.) is completed through the investigation. 3. Data collection (user's subjective perception of the physical environment, objective measurement of the physical environment, such as temperature, humidity, light, sound, working area, traffic distance) survey users determine the objective physical environment to determine the number of survey objects to obtain. 4. Data analysis (using data analysis method).

(2) Fadfair method: also called the expert investigation method. It was founded and implemented by the American Rand Corporation in 1946. On the basis of setting the research question, firstly solicit expert opinions on the question, sort it out, summarize and count it; then anonymously feedback the statistical results of the previous round to the experts for the second round of opinion collection, summary and statistics And feedback, iteratively until the consensus of the experts is obtained, and the opinion is used as the evaluation standard[14].

AHP Analytic Hierarchy Process: Proposed by the American operations researcher Professor T.L. Saaty in the 1970s, it is a combination of quantitative and qualitative analysis methods. It is a scientific system engineering decision-making method. Its main idea is to divide complex problems into various constituent factors, and establish a hierarchical structure model for these factors according to the dominant relationship. Through the pairwise comparison of the factors at each level, the relative importance is judged, and finally the judgment matrix is constructed to calculate the weight of each (level) index. In the actual problem, the problem is divided into various levels, weights are assigned to the measured target, and the results are obtained by constructing the judgment matrix formula in the computer to compare the results. The AHP analytic hierarchy process is used in multiple fields to evaluate and analyze complex problems. Get evaluation results[15].

3.2. High temperature heat wave model

He Xiaodong et al. constructed a gridded urban canopy parameter model to use the current and predicted weather conditions, field observations and kilometer-scale simulations to study the behavior of local-scale urban heat islands during a heat wave in Beijing. This is currently the most common heat wave research model[16]. Sun Yijie’s team analyzed the characteristics of drought and heat waves in the Loess Plateau from 1960 to 2016 with the help of high temperature thresholds and standardized precipitation indicators, and used superimposed statistical analysis methods to find the trend of simultaneous drought and heat wave events[17]. From the perspective of geography, Xue
Qian and others used spatial assessment as an entry point to formulate three assessment frameworks (stress-state-response vulnerability assessment, socio-economic system vulnerability assessment, and man-natural coupling vulnerability assessment) to analyze high temperature heat waves. Chen Kai et al. took the single high temperature and heat wave event in Beijing as the research object and formulated three new vulnerability assessment frameworks (natural disaster-oriented vulnerability evaluation, socioeconomic-oriented vulnerability evaluation, and comprehensively-oriented vulnerability evaluation), and identified the spatial distribution of the vulnerability of high-temperature heat waves in central Beijing. Seung-Ki Min and others used high-resolution large-scale regional climate models (RCM) and global climate models (GCM) to quantify the contribution of humans to the duration of the longest summer heat wave in South Korea in 2018. They compared the real world and the counterfactual world (no human influences).

3.3. Thermal simulation
Thermal simulation mainly analyzes the thermal environment under different conditions by constructing a 3D model and changing parameters. At present, the more common simulation software is ENVI-met and PHOENICS two microclimate simulation software. ENVI-met is a three-dimensional non-stationary microclimate model, including a simple one-dimensional soil model, radiation transfer model and vegetation model. The software was developed by Professor M. Bruse of University of University. ENVI-met can carry out qualitative and quantitative research on urban thermal environment by accurately controlling all atmospheric parameters combined with GIS and remote sensing technology. PHOENICS is a CFD (computational fluid dynamics) software. It is the world's first commercial software for calculating fluid and heat transfer developed by CHAM in 1981. It can be directly imported from SketchUp, AutoCAD, Rhino and Revit, thus the modeling process is simplified and the research efficiency is improved. By changing the parameters, the range of sunlight exposure, wind environment and heat flow can be obtained.

4. Prevention and control of heat wave disasters at home and abroad
Japan responded to the high temperature heat wave earlier. In 1991, Tokyo promulgated the urban greening law and officially started to deal with the high temperature heat wave from the regulations. The main measures: 1. Strengthen urban greening and improve the nature of the underlying surface of the city. 2. Strengthen the observation and forecast system. 3. Reasonable planning Urban building layout to improve the urban ecological environment. 4. Reduce urban man-made heat emissions. 5. Utilize urban water bodies, expand urban water surface area, and effectively use water resources. 6. Develop new pavement materials. 7. Build underground pipe cooling systems. 8. Use natural wind The sea breeze cools the heat island; the main measures in the United States are: 1. Planting trees and vegetation on the roof. 2. Painting the buildings with white paint. 3. Changing the pavement to bright colors to alleviate the urban heat island effect. 4. Controlling the urban population; Germany was the first in the world to develop green roofs and the technology is leading in the world, the roof greening rate is more than 14%, and the pavement reconstruction has been carried out since the 1980s. At present, 90% of the roads in the cities of the country are permeable pavements. The prevention and control of high temperature heat waves in my country started late, and there are few written records that can be found. At present, the main measures are to increase roof gardens, increase urban green area, improve urban wind environment, increase urban air duct planning, reduce urban man-made heat emissions, and build urban high temperature warning mechanisms. Enhance the public's awareness of the prevention and control of urban heat waves, etc. Style and spacing

5. Footnotes
A large number of scholars in my country began to pay attention to urban thermal environment and heat wave disasters only after 2010. Judging from the papers published after 2020, my country’s current research papers on heat wave disasters rank second only to the United States, but my country
has published a large number of papers. But the center has low intermediary and low quality, and has less influence. The future research on heat waves in my country should not be limited to evaluating the heat waves of the city as a whole or urban agglomerations from the macro perspective of the city. It is also possible to start from the meso and micro perspectives of a certain area or several locations in the city, which is more conducive for city managers to formulate different heat wave prevention and control standards for different types of land in accordance with local conditions, and to deal with high temperature heat waves scientifically and effectively.

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