ATLANTIS PRESS
Advances in Engineering Research, volume 125
International Conference on Material Science, Energy and Environmental Engineering (MSEEE 2017)

The analysis of "urban rain island effect" in Jingjinji District of China

Yingdong Yu[1, 2, a], Jiahong Liu[1, 2, b], Sheng Yan[1, 2] and Zhiyong Yang[1, 2, c]
[1] State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin, Beijing 100038, China;
[2] China Institute of Water Resources and Hydropower Research, Beijing 100038, China.
[a]yuyingd@iwhr.com, [b]liujh@iwhr.com, [c]yangzy@iwhr.com

Keywords: rain island effect, urban, Jingjinji district, China.

Abstract. In the context of rapid urban expansion and accelerated urbanization, the urban rain island effect begin to have the urban rain island effect. The rainfall character in the city proper is different from that in suburban district in many regions. In this study, 25 meteorological stations are selected for exploring the rain island effect of three major cities in Jinjinji district. The results indicate that the rain island effect is different in the three major cities. The rain island effect and dry island effect is more obvious in Beijing and Tianjin. The effect is also different under high flow year and low flow year.

1. Introduction

With the acceleration of urbanization process, the urban climate has changed in many regions. The study of Urban Rain Island belongs to the category of urban climate research. The study of the urban climate can be traced back to the early nineteenth Century. Great progress has been made in the field of urban climate research in recent years. Many scholars have summarized and reviewed city climate research achievements in different stages of world. Arnfield[1] summarized and reviewed the city climate in the last 20 years. In the global climate warming trend, some observations and model studies show that urbanization will increase the amount of precipitation in the urban area and downwind direction. Huff [2] indicates that the occurrence frequency of monthly and seasonal precipitation was significantly higher over the city and leeward direction than that in adjacent area in the city of Saint Louis. The distribution of precipitation is most obvious especially in summer. It shows an increasing trend with the acceleration of urbanization process. Changwon [3] had make a research in the Saint Louis region of United States, the results show that the summer precipitation increased by 5%-25% in this region. It is mainly concentrated in urban areas or urban downwind direction of about 50-75km. Jaurequi et al [4] found that the frequency and intensity of showers in Mexico City have increased in recent decades. According to the reanalysis data of TRMM in Atlanta from 1998-2000, Shepherd [5] indicates that the precipitation in downwind 30-60km direction is greater than that in the city center. Baik [6] applied numerical models to simulate the effect of urban heat island on precipitation. The results show that there was a high water center in the leeward area of the city. Some experts also done much work in the field of urban rainfall in China [7-8]. Li Tianjie [9] analyze the influence of urbanization on Precipitation in Shanghai. The results show that the urbanization effect should have a certain effect of precipitation enhancement. Chen [10] also found that precipitation has shown an increasing trend with the development of urban agglomerations in the Yangtze River Delta.

Although many researchers have analyze the "Urban Rain Island Effect" in China and abroad. The investigation of "Rain Island" in Jingjinji District is few. It is necessary for analyze the characteristics of extreme precipitation in major cities. In this study, three major cities are selected for investigating the "Urban Rain Island Effect".

2. Methods

2.1 Study area

The Jing-Jin-Ji district lies in northern China (113°27'36"-119°50'53"E, 36°2'8"-42°37'19"N), which comprises a total area of 21.8 km^2. Jing, Jin, and Ji are the widely known abbreviations for Beijing, Tianjin, and Hebei provinces in China, and they are usually collectively referred to as Jing-Jin-Ji district because of their close socio-economic ties. In this study, three major cities are chosen for analyzing the difference of rainfall in the urban and suburban area. Three cities include Beijing, Tianjin and Shijiazhuang. Around three cities, 25 meteorological stations are selected for calculating the area rainfall of three cities. The location of the study area are shown in Figure 1.

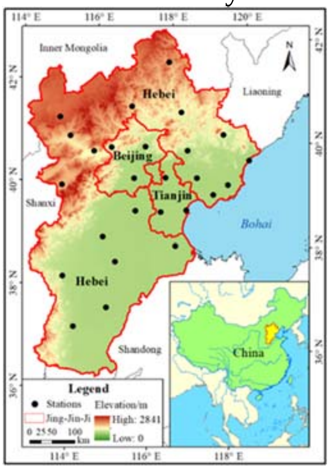

Fig.1 Location of the study area and meteorological stations

2.2 Methods

In this study, the area rainfall is calculated by the IDW (Inverse Distance Weighted) method. The spatial buffer analysis method is adopted for analyzing the yearly rainfall depth of different buffer area.

2.2.1 Area rainfall calculation

The inverse distance interpolation algorithm is one of the most commonly used rainfall interpolation methods. It indicates that the reference stations nearest to the non-sampling point make the biggest contribution. The contribution is inversely proportional to the distance. The relationship can be indicate by the following formula:

$$p_k = \sum_{i=1}^{n} w_{ik}\, p_i / \sum_{i=1}^{n} w_{ik}$$

In the formula, p_i repsents the site rainfall; w_{ik} repsents the weight of the site i relative to the site k, d_i repsents the distance of site i and site k; n respensts the number of related rainfall stations; p_k respsents the grid data vlues.

Select the city proper as the center, the annual rainfall data within 150km of the site is distributed to the empty distance within 100km of the urban area by the inverse distance weighted method. To the city as the center, respectively, around the 150km site within the annual rainfall data using the inverse square distance distribution method to distance less than 100km between the empty city, 36 City 1961 -2010 annual rainfall spatial distribution map. The spatial distribution of rainfall in three cities in 1961 -2010 was obtained.

2.2.2 Spatial analysis buffer method

Based on the ArcGIS software, the site of the urban area was extracted from the land use map in 1980 as a city. Based on city map, 21 buffer area are obtained by expanding outward in 5km distance to the city proper. Take Beijing as an example, the distribution of 21 buffer area are shown in Figure 2. According to the calculation results of surface rainfall, the annual rainfall depth of 21 buffers is calculated. The variation trend of precipitation depth with distance is obtained.

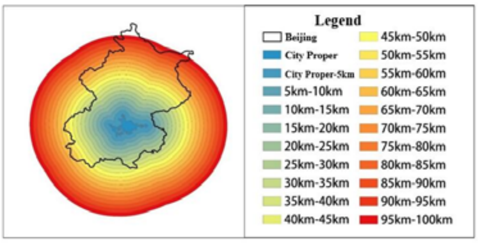

Fig.2 Distribution map of the buffer zone of Beijing City

2.2.3 Selection of hydrological period

Based on the average annual rainfall, the three four kinds of hydrological year are divided by the statistical ranking method and setting three threshold values. The four typical hydrological years are the high flow year, partial high flow year, partial low flow year and low flow year. The variation trend and characteristics of precipitation depth versus distance were studied respectively in different precipitation years.

3. Analysis of “Urban Rain Island Effect”

3.1 Temporal and Spatial rainfall characteristics of rainfall in different buffer area

The three large cities in Jingjinji district are selected as typical research area. Analyzing the impact of urban rain island on the distribution of urban rainfall under four different scenarios. It mainly considers the change of rainfall depth when the urban area increases outwards. In this study, the time series of research data is 1961-2010. According to the land use change, the time series is divided into three parts (1961-1980; 1981-2000; 2001-2010).

3.1.1 Beijing

The total rainfall varies greatly in Beijing. The total annual rainfall presents a decreasing trend in high flow year, partial high flow year and partial low flow year. In the 2001-2010 year period, the total amount of rainfall in dry season is larger than that in other period. According to the curve change in Figure 3, we can see that the influence area of the dry and rain island in Beijing is about 0-40km away from the city proper. Among them, the urban rain island effect is obvious in 1961-1980 and 1981-2000 period under partial high flow and partial low flow scenarios. The urban rain island effect is also remarkable in 2001-2010 under low flow scenarios.

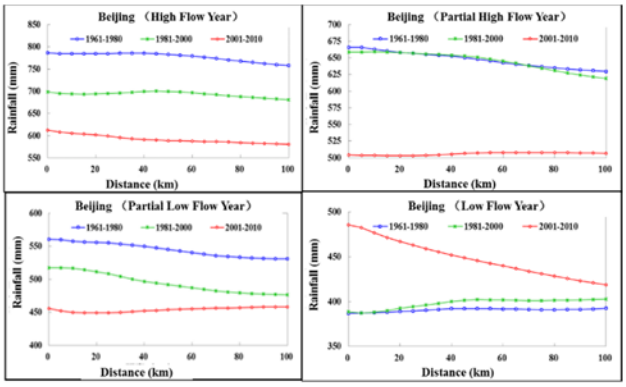

Fig.3 Rainfall distribution map around Beijing

3.1.2 Tianjin

The average yearly rainfall in Tianjin during 1961-2000 decreased under high flow year, partial high flow year and partial low flow year. During the three periods, the average annual rainfall in 2000-2010 decrease 220 mm compared with that in 1961-1980. Based on the curve change in Figure 4, we can see that the influence area of the dry and rain island in Tianjin is about 0-5km away from the city proper. Among them, the urban rain island effect is obvious in 2001-2010 period under partial high flow year, partial low flow year and low flow year. The urban dry island effect is also remarkable in 1981-2000 under partial high flow and partial low flow scenarios. Under low flow scenarios of 1981-2000, the urban rain island is notable in Tianjin.

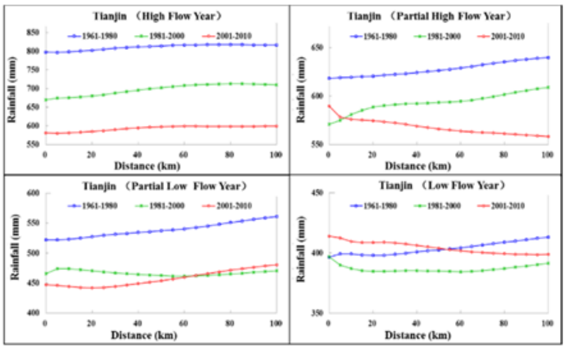

Fig.4 Rainfall distribution map around Tianjin

3.1.3 Shijiazhuang

The total amount of rainfall in Shijiazhuang varies greatly during three periods under high flow scenarios. It shows a decreasing state with time. The annual rainfall had little change in other three scenarios. According to the curve change in the Figure 5, it can be seen that the influence area of the dry and rain island in Shijiazhuang is about 0-25km away from the city proper. Among them, there is no urban rain island effect or dry island effect during 1961-2000. The urban rain island effect is obvious during 2001-2010 under high flow year. The dry island effect is remarkable during 2001-2010 under low flow year.

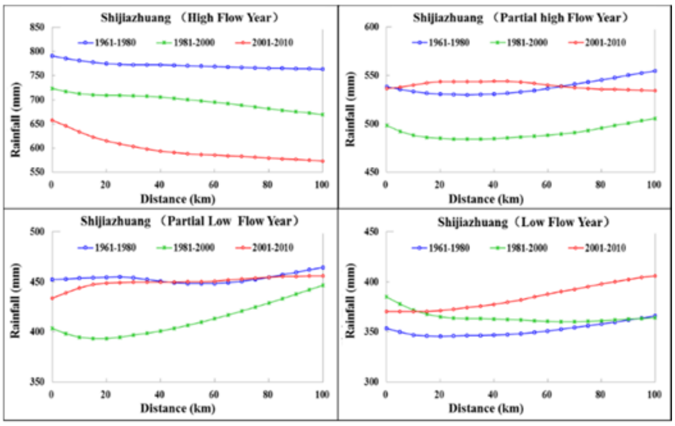

Fig.5 Rainfall distribution map around Shijiazhuang

4. Conclusion

The aim of this study was to explore the rain island effect and dry island effect in Jingjinji District of China. For this purpose, 25 stations are selected for indicating the urban island effect of three major cities in this region. The research results can be summarized as follows:

The effect of Rain Island on urban precipitation is different from region to region in Jingjinji district. The influence range of Rain Island and Dry Island varies greatly during three cities.

The rain island effect and dry island effect is more obvious in Beijing and Tianjin. The starting time of Rain Island effect is earlier than other two major cities. The rain island and dry island effect is only obvious in recent ten years.

References

[1]. A.J. Arnfield. Street design and urban canyon solar access. Energy & Buildings. Vol. 14 (1990), p. 117-131.

[2]. F A Huff. The effect of natural rainfall variability in verification of rain modification experiments. Water Resources Research. Vol. 2(1967), p. 791-801.

[3]. SA Changnon. Rainfall Changes in Summer Caused by St. Louis. Science. Vol. 205(1979), p. 402-408.

[4]. E Jauregui. Rainfall fluctuations and tropical storm activity in Mexico. Erdkunde. Vol. 49(1995), p. 39-48.

[5]. J M Shepherd. A review of current investigations of urban-Induced rainfall and recommendations for the future. Earth Interactions, Vol.9(2004)：1-27.

[6]. J Baik， M Choi. Spatio-temporal variability of remotely sensed precipitation data from COMS and TRMM: Case study of Korean peninsula in East Asia. Vol. 56(2015), p. 1125-1138.

[7]. ZHOU Zu-gang,JIANG Yong-qiang,ZHANG Gao-ying,ZHANG Wen-jun,WANG Cheng-lin. Numerical Simulation on a Heavy Rainfall Event over Jiangxi Province. Meteorological and Environmental Research, Vol.12 (2012), p:8-12.

[8]. LV Xiao-hua,DAI Jin,YANG Ke,ZHU He-xiang. Comparative Analysis of Two Rainstorms in the Southwest of Hunan Province. Meteorological and Environmental Research, Vol.12 (2012), p: 20-28.

[9]. Li Tianjie. The influence of urbanization on Precipitation in Shanghai. Hydrology, Vol.3 (1995):34-41.

[10]. CHEN Jing. Genetic Analysis of a Heavy Rainstorm on June 29, 2006 in Henan Province. Meteorological and Environmental Research, Vol.12 (2012), p: 37-41.