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Temporal and Spatial Characteristics and Intraseasonal Variations of Summer Precipitation Contribution Rates in the Haihe River Basin

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Abstract: The summer precipitation in the Haihe River Basin not only exhibits significant interdecadal and interannual variations, but also shows obvious intraseasonal variation characteristics in its spatial distribution. Based on the daily precipitation data of 148 meteorological stations over the Haihe River Basin from 1961 to 2015, the authors calculated the contribution of single station precipitation to the Haihe River Basin total annual amount during summer, June, July and August. Concurrently, according to the locations of the stations within the various river systems of the Haihe River Basin, we calculated the annual proportion of summer precipitation from nine river systems relative to the total amount of the Haihe River Basin using the regional statistical average method. Then the summer precipitation contribution rates dataset over Haihe River Basin (1961–2015) was developed. The dataset includes: (1) the contribution of precipitation to total annual amount at 148 stations in the Haihe River Basin during the summer, June, July and August from 1961 to 2015; (2) the contribution of precipitation to total annual amount in the nine river systems in the Haihe River Basin during the summer from 1961 to 2015. The dataset is archived in one excel file with data size of 175 KB.

Keywords: Haihe River Basin; summer precipitation; contribution rate of precipitation; intraseasonal change

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The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2024.06.07.V1 or https://cstr.escience.org.cn/CSTR:20146.11. 2024.06.07.V1.

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1 Introduction

The Haihe River Basin is located in North China, with a dense population, playing a pivotal role in China's economic and social development. The water resources in this region are relatively scarce[1], and the annual precipitation is highly concentrated in the summer. Thus, the amount and distribution of summer precipitation have an extremely important impact on the local climate, agricultural and industrial production[2]. Additionally, the Haihe River Basin is located on the northern edge of the East Asian summer monsoon activities. The summer precipitation not only exhibits significant interannual and interdecadal variability on the temporal scale[3,4], but also shows significant regional differences in drought and flood conditions, with a very uneven distribution of precipitation within the basin[5,6].

Previous studies on the temporal and spatial variations of summer precipitation in the Haihe River Basin have been extensive[7–10], and most of these studies directly used precipitation data, with few analyzing from the perspective of precipitation contribution rates. This paper calculated the contribution of single station precipitation to the Haihe River Basin's total annual amount during summer, June, July and August. Concurrently, according to the locations of the stations within the various river systems of the Haihe River Basin, the annual proportion of summer precipitation from nine river systems relative to the total amount of the basin was calculated by using the regional statistical average method. The study analyzes the distribution characteristics and intraseasonal variations of the major contributing precipitation regions in the Haihe River Basin from 1961 to 2015. This provides an important foundation and climatic background for understanding the temporal and spatial patterns of summer droughts and floods in this basin, and for improving summer precipitation forecasting techniques.

2 Metadata of the Dataset

The metadata of the Summer precipitation contribution rates dataset over Haihe River Basin (1961–2010)[11] is summarized in Table 1. It includes the dataset full name, short name, authors, year of the dataset, temporal resolution, spatial resolution, data format, data size, data files, data publisher, and data sharing policy, etc.

3 Methods

Using daily observation data from over 2,400 meteorological stations provided by the National Meteorological Information Center, daily precipitation data from 148 complete observation stations located in the Haihe River Basin were selected (Figure 1). The study period covers the summer months (June to August) from 1961 to 2015.

3.1 Algorithm

3.1.1 Contribution Rate of Station Precipitation

The contribution rate of station precipitation is the proportion of the precipitation at a single station during a specific period to the total amount in the study area (in this article, the study area is the Haihe River Basin, hereinafter referred to as the same) during the same period[13]. The equation is as follows:

$$C_{si} = \frac{P_{si}}{P_w} \times 100\% \quad (i = 1, 2, 3, \ldots\ldots, 148) \tag{1}$$

where, C_{si} represents the contribution rate of precipitation at the *i*-th station, P_{si} represents the *i*-th station precipitation during a specific period, and P_w represents the total

Table 1 Metadata summary of the summer precipitation contribution rates dataset over Haihe River Basin (1961–2015)

Items	Description
Dataset full name	Summer precipitation contribution rates dataset over Haihe River Basin (1961–2015)
Dataset short name	SummerPrecipContribution_HaiheRB_1961-2015
Authors	He, L. Y. L-4778-2016, China Meteorological Administration Basin Heavy Rainfall Key Laboratory/Hubei Key Laboratory for Heavy Rain Monitoring and Warning Research, Institute of Heavy Rain, ChinaMeteorological Administration; Tianjin Climate Center, heliyehly@163.com Hao, L. S. Tianjin Climate Center, hls54515@163.com Cheng, S. J. Tianjin Climate Center, chengshj08@lzu.edu.cn Ma, N. Tianjin Climate Center, amsmaning@126.com
Geographical region	Haihe River Basin, China
Year	1961–2015
Temporal resolution	Year
Spatial resolution	Station, River System
Data format	.xlsx
Data size	175 KB
Data files	(1) contribution of precipitation to total annual amount at 148 stations in the Haihe River Basin during the summer from 1961 to 2015; (2) contribution of precipitation to total annual amount at 148 stations in the Haihe River Basin during June, July and August from 1961 to 2015; (3) contribution of precipitation to total annual amount in the nine river systems in the Haihe River Basin during the summer from 1961 to 2015
Foundations	China Meteorological Administration Basin Heavy Rainfall Key Laboratory (2023BHR-Y05); Haihe River Basin Meteorological Technology Innovation Fund (HHXM202408); Ministry of Science and Technology of P. R. China (2018YFA0606302, GYHY201506001-1)
Computing environment	NCAR Command Language (NCL); Fortran; Microsoft Excel
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	(1) *Data* are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use *Data* subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute *Data* subject to written permission from the GCdataPR Editorial Office and the issuance of a *Data* redistribution license; and (4) If *Data* are used to compile new datasets, the 'ten percent principal' should be followed such that *Data* records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[14]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS, GEOSS, PubScholar, CKRSC

precipitation in the Haihe River Basin during the same period as P_{si}.

3.1.2 Contribution Rate of River System Precipitation

The contribution rate of river system precipitation refers to the proportion of the average precipitation in each river system during a specific period to the total amount in the study area during the same period[14,15]. The eaqution is as follows:

$$C_{rj} = \frac{P_{rj}}{P_w} \times 100\% \quad (j = 1, 2, 3, \ldots\ldots, 9) \tag{2}$$

$$P_{rj} = \frac{1}{n}\sum_{i=1}^{n} P_{si} \tag{3}$$

where, C_{rj} represents the precipitation contribution rate of the *j*-th river system, P_{rj} represents the average precipitation of the *j*-th river system during a specific period, P_w

represents the total precipitation of the Haihe River Basin during the same period as P_{rj}, P_{si} represents the precipitation of the *i*-th station located in the *j*-th river system, and *n* represents the total number of stations located in the *j*-th river system.

By applying the above method, it is possible to more clearly reflect the contribution of precipitation from different regions or different river systems to the total basin amount during different periods.

3.2 Data Processing

(1) Using the daily precipitation data of 148 meteorological stations in the Haihe River Basin, the annual precipitation for each station in summer, June, July, and August was calculated from 1961 to 2015.

(2) According to the Equation 1, the precipitation contribution rates of the annual summer and monthly (June to August) periods were calculated for 148 stations in this basin.

(3) Based on the distribution of meteorological stations within the nine river systems in the Haihe River Basin (Figure 1), the annual summer precipitation contribution rates for each river system were calculated using the Equations 2 and 3.

(4) The aforementioned calculation results were used to derive the dataset of summer precipitation contribution rates over the Haihe River Basin from 1961 to 2015.

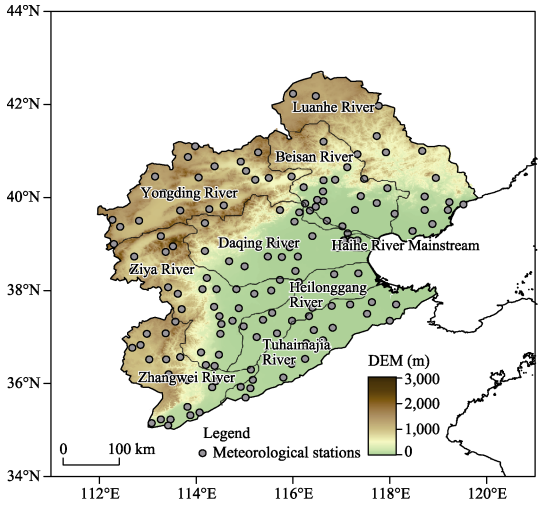


Figure 1 Distribution map of meteorological stations and river systems in the Haihe River Basin[6]

4 Data Results and Validation

4.1 Data Composition

The dataset of summer precipitation contribution rates over the Haihe River Basin from 1961 to 2015[11] includes: (1) contribution of precipitation to total annual amount at 148 stations in the Haihe River Basin during the summer from 1961 to 2015; (2) contribution of precipitation to total annual amount at 148 stations in the Haihe River Basin during June, July and August from 1961 to 2015; (3) contribution of precipitation to total annual amount in the nine river systems in the Haihe River Basin during the summer from 1961 to 2015. The dataset is archived in one excel file with data size of 175 KB.

4.2 Data Results

4.2.1 Spatial Distribution and Intraseasonal Variations of Summer Precipitation Contribution Rates in the Haihe River Basin

From the distribution of summer precipitation contribution rates in the Haihe River Basin (Figure 3), it can be observed that the contribution rates gradually decrease from east to west. The high value areas are located in the northeastern part of the basin, specifically in the lower reaches of the Luanhe River and the Beisan River. The low value areas are found on the western side of the basin, primarily in the Yongding River.

To further study the intraseasonal variation characteristics of summer precipitation contribution rates in the Haihe River Basin, an analysis was conducted on the spatial distribution

of the high value areas of precipitation contribution rates for each month of summer at various stations[6], as shown in Figure 4. It can be seen that in June, the main contribution area of precipitation is located in the northeastern part of the basin. In July, it shifts to the eastern and southern parts of the basin. By August, the main contribution area not only includes the eastern part of the basin but also sees the July southern contribution area move northward to the central part of the basin, forming a northeast-southwest oriented high value belt. Consistently, throughout the three summer months, the main contribution areas of precipitation always include the high value center in the northea stern part of the Haihe River Basin.

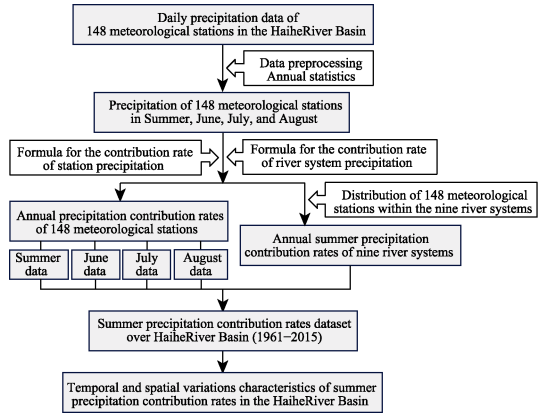


Figure 2 Flowchart for the dataset development

4.2.2 Temporal Variations of Summer Precipitation Contribution Rates in the Haihe River Basin

Based on the statistics of summer precipitation contribution rates for the nine river systems in the Haihe River Basin, the time series from 1961 to 2015 for each river system is presented in Figure 5. It can be observed that the summer precipitation contribution rates of each river system exhibit significant interannual variability. From the interannual average results, the Luanhe River and Beisan River have the highest average precipitation contribution rates, both exceeding 12.5%. They are followed by the Tuhaimajia River and the Haihe River Mainstream, with average precipitation contribution rates both above 11.5%. The Yongding River has the lowest average precipitation contribution rate, at only 8.0%, making it the only river system with an average precipitation contribution rate below 10% in the Haihe River Basin.

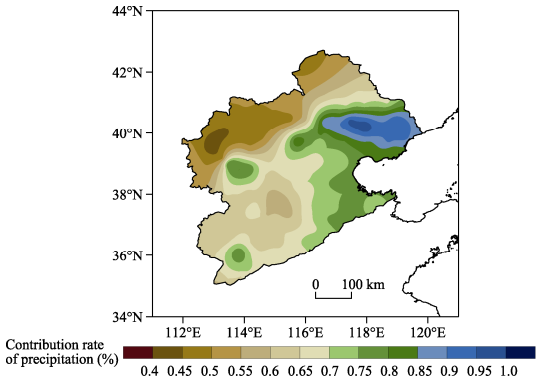


Figure 3 Distribution map of precipitation contribution rates at 148 stations in the Haihe River Basin during the summer from 1961 to 2015

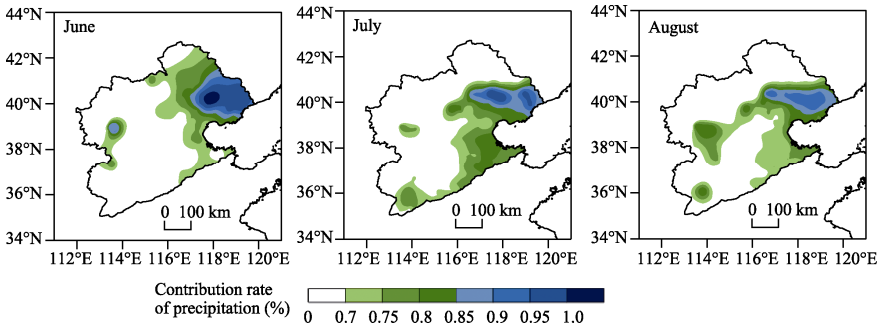
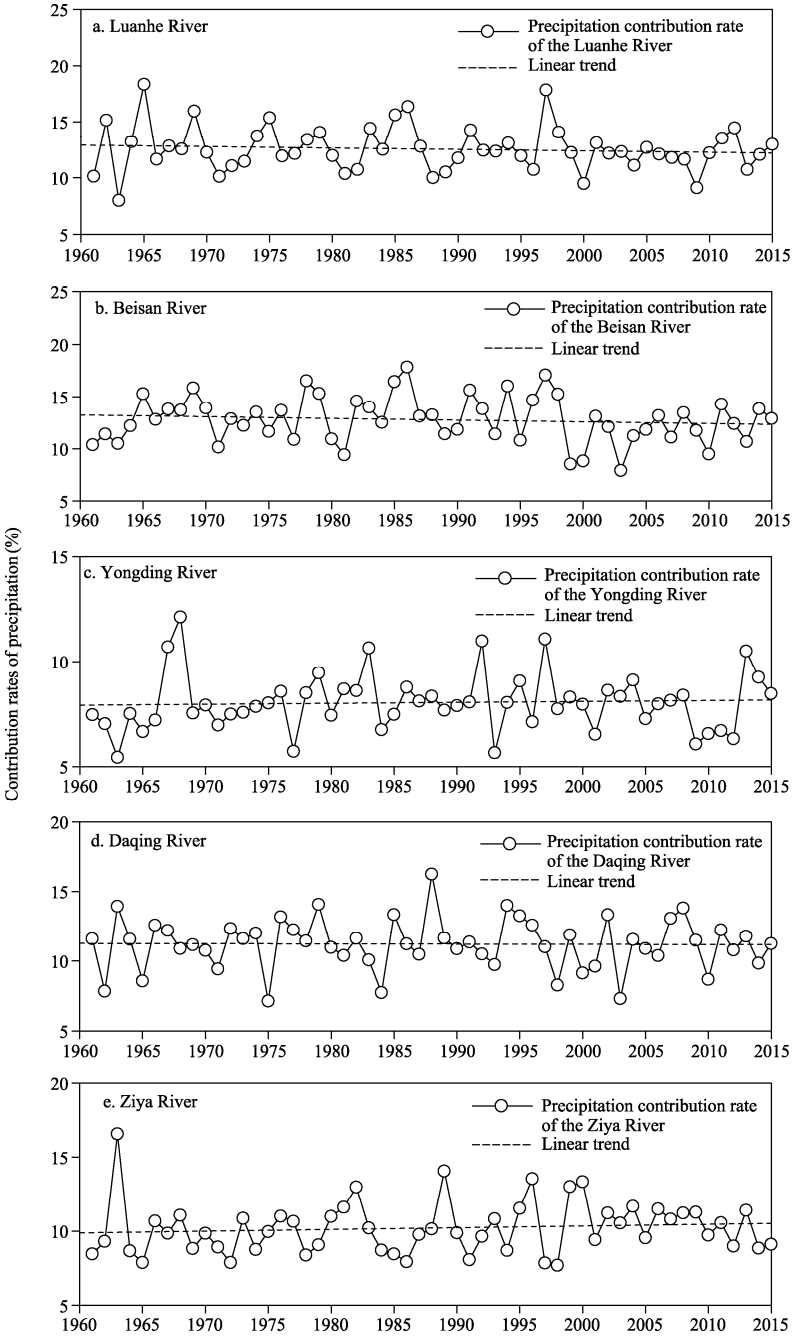


Figure 4 Distribution maps of high value areas of monthly precipitation contribution rates in the Haihe River Basin during the summer from 1961 to 2015

On the decadal scale, the summer precipitation contribution rates in the Luanhe River, Beisan River, Daqing River, Heilonggang River, and the Haihe River Mainstream within the basin show a decreasing trend, with the Haihe River Mainstream exhibiting a more pronounced decline. In contrast, the summer precipitation contribution rates in the Yongding River, Ziya River, Zhangwei River, and Tuhaimajia River show an increasing trend, particularly in the southern part of the basin where the Zhangwei River and Tuhaimajia River exhibit a more significant upward trend.



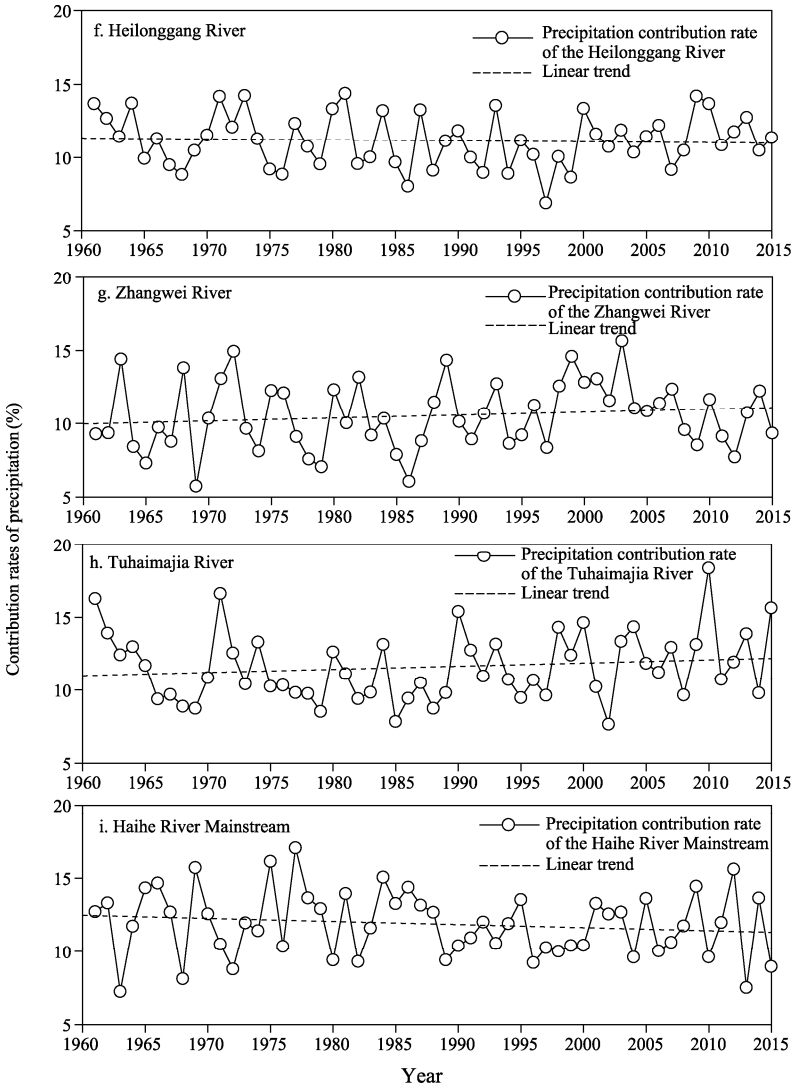


Figure 5 The time series of precipitation contribution rates for nine river systems in the Haihe River Basin during the summer from 1961 to 2015

5 Discussion and Conclusion

The Haihe River Basin is both a climate vulnerable area prone to drought and flooding and a region with relatively scarce water resources. Precipitation is one of the important sources of surface water and shallow groundwater recharge in this basin. 60%–70% of the annual precipitation in the Haihe River Basin comes from summer precipitation. By calculating the annual precipitation contribution rates of stations and river systems within the Haihe River Basin during the summer, June, July and August from 1961 to 2015, this study investigates the evolution patterns of summer precipitation in the Haihe River Basin from the perspective of precipitation contribution rates. It analyzes the temporal and spatial characteristics and intraseasonal variations of the areas that mainly contribute to summer precipitation in this basin. The results show that the high value center of summer precipitation contribution rates is primarily located in the northeastern part of the basin, particularly in the downstream

areas of the Luanhe River and the Beisan River. This high value center remains stable throughout the summer months and is a key area of focus for summer precipitation research and flood prevention efforts. The summer precipitation contribution rates data for the Haihe River Basin developed in this study provides a crucial data foundation for understanding the temporal and spatial distribution unevenness of drought and flood within this basin. The data calculation methods and analysis conclusions also offer references for future research on summer precipitation in the Haihe River Basin

Author Contributions

He, L. Y. and Hao, L. S. designed the algorithms of dataset. He, L. Y., Cheng, S. J. and Ma, N. contributed to the data processing and analysis. He, L. Y. wrote the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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