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Extreme Short-Term Heavy Precipitation Hazard Zoning Study in Linyi City

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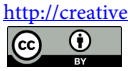

Abstract

Based on the hour-by-hour precipitation data from national and regional-level surface meteorological automatic stations in Linyi from 2011 to 2020, the statistics of short-term heavy precipitation show the following characteristics:(1) Short-term heavy precipitation in Linyi shows obvious interannual and intermonthly variations, and its frequency is on the rise after 2015, with the extreme short-term heavy precipitation showing high frequency and high intensity. (2) During the June-September flood season, July is the month with the highest frequency of short-term heavy precipitation, followed by August, with the ratio of short-term heavy precipitation to heavy rainfall reaching 82.2% in August. (3) There is a clear pattern of daily changes in short-term heavy precipitation, with the high incidence concentrated in the late afternoon to evening and early morning. (4) The high-frequency areas of short-term heavy precipitation in Linyi include Hedong District, south-central Yinan County, southern Mengyin County, northwestern Jounan County, southeastern Yishui County, northern Tancheng County, and southeastern Linshu County in Linyi City.

Keywords

Short-Term Heavy Precipitation, Heavy Rainfall, Spatial and Temporal Distribution, Cyclic Variation

1. Introduction

Hort-duration heavy precipitation is a kind of strong convective weather, which usually occurs in summer in China. Short-duration heavy precipitation is prone

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to cause urban flooding, small and medium-sized river water level surge, flooding of farmland, and even geologic disasters such as landslides and mudslides, which poses an important threat to the safety of people's lives and property (An et al., 2021; Bi et al., 2019; Wang et al., 2015). This kind of weather process is characterized by strong suddenness, concentrated precipitation time and strong localization. At present, many scholars use hourly precipitation data to analyze its spatial and temporal distribution characteristics (Fan et al., 2018; Hou et al., 2020; Shi et al., 2020). For example, Cai Xinling (Cai et al., 2014) analyzed the spatial and temporal changes of precipitation hours, hourly rainfall intensity, extreme precipitation hours and extreme precipitation intensity during the flood season by using hourly precipitation data from 23 meteorological stations in Shanxi Province from 1961 to 2011; Tang Chuanshi (Tang et al., 2018) analyzed the spatial and temporal distribution of heavy precipitation by using hourly precipitation data from 83 national meteorological stations in Jiangxi Province in order to explore the relationship between local short-term heavy precipitation and heavy rain; Yang Xuebin (Yang et al., 2018) used hourly precipitation data from 83 national meteorological stations to analyze the spatial and temporal distribution of heavy precipitation. They analyzed the spatial and temporal distribution characteristics of short ephemeral heavy precipitation in Shandong Province by using the 10-year hourly precipitation data from 123 national meteorological observation stations during the flood season; Meng Zhenxiong (Meng et al., 2019) analyzed the spatial and temporal characteristics of short ephemeral heavy precipitation from the national automatic meteorological stations and the regional automatic stations, and used the Eurocentric reanalysis data to analyze the weather situation of short ephemeral heavy precipitation; Zhou Fang (Zhou et al., 2018) analyzed the temporal and spatial distribution of localized short-duration heavy precipitation by using the hour-by-hour precipitation data of the flood season in the past years at 89 measuring stations in Jiangxi Province, and based on the method of weather science, the localized short-duration heavy precipitation was classified by the weather science, and the temporal and spatial distribution characteristics of different types of short-duration heavy precipitation were statistically analyzed.

With the accelerated development of socialization and the needs of the times, the public has put forward higher requirements for the accuracy and timeliness of weather forecasts, and it is more and more important to improve the accuracy of catastrophic weather at the township level, especially the accurate warning of catastrophic weather (Zheng et al., 2013). In Linyi City, catastrophic weather such as heavy rainfall, short-term heavy precipitation, hail, thunderstorms and gusty winds bring certain losses to the society and economy every year, and the requirements for fine forecasting are more urgent for special industries such as logistics, industry and specialty agriculture in the region. This paper mainly utilizes the national ground observatory data from 1979-2020 and the regional station data of Linyi since the last 10 years from 2011-2020 to study the occurrence, development pattern and spatial and temporal distribution of heavy rainfall and extreme short

duration heavy precipitation weather in our city, so as to provide technical support for carrying out the research on catastrophic weather and research and development of forecast and early warning technology.

2. Information and Methodology

2.1. Short-Term Heavy Precipitation Classification

Referring to the operational regulations, precipitation ≥20 mm in 1 hour is defined as short-term heavy precipitation. In this paper, the day-by-day hourly precipitation data of national stations and regional stations from 2011 to 2020 are selected, and the hourly rainfall intensity data greater than or equal to 20mm are extracted as short-term heavy precipitation data for analysis. The short-term heavy precipitation was classified into three grades: 20 - 30 mm/h, 30 - 50 mm/h, and ≥50 mm/h. Statistically, from June to September from 2011 to 2020, among 144 national automatic meteorological observation stations in Linyi, as long as there are more than five stations with more than one hour of precipitation ≥50 mm, or more than one station with more than one hour of precipitation ≥100 mm, it is considered as an extreme If the eligible stations last for two days or more but the influencing system is the same system, it will be categorized as the same extreme short-term heavy precipitation process.

2.2. Main Precipitation Indicators

The main precipitation indicators used in this paper are: precipitation frequency, precipitation intensity and precipitation amount. Precipitation frequency refers to the number of times of short-term heavy precipitation in a certain period of time, precipitation intensity refers to the hourly precipitation during the period of time, and the precipitation amount is selected as 24-hour precipitation and 1-hour precipitation. This paper analyzes the annual, monthly and daily time change characteristics of short-term heavy precipitation by the frequency of short-term heavy precipitation, and analyzes the spatial change characteristics of short-term heavy precipitation by the frequency of precipitation and different levels of precipitation intensity.

3. Characteristics of Spatial and Temporal Variations of Short Duration Heavy Precipitation

3.1. Characteristics of Short-Term Heavy Precipitation Time Distribution

In the past 10 years, short-term heavy precipitation in Linyi City has obvious inter-annual variation characteristics, of which, the most frequent year of short-term heavy precipitation from 2011 to 2020 is 2013, with a frequency of 908 times, which is also the year with the most frequency of ≥50 mm level short-term heavy precipitation. The least is 2015, with a frequency of 100 times. From the increasing trend, the frequency of ≥50 mm short duration heavy precipitation showed an increasing trend after 2015.

The frequency of short-term heavy precipitation during the flood season can be seen from the all-weather frequency chart, June to September all-weather different times may occur short-term heavy precipitation, and has a certain daily change characteristics. Among them, the frequency is higher in the late afternoon and early evening, and the frequency of 20 - 30 mm/h level of heavy precipitation at 18 - 19 hours is the highest in the whole day, which is up to 184 times, while the frequency of 30 - 50 mm/h and ≥50 mm/h levels of heavy precipitation at 14 - 15 hours is the highest in the whole day, which is up to 91 times and 125 times. This is due to the high temperature of the subsurface in the late afternoon to evening, good thermal conditions, increased unstable energy, the most active atmospheric convection. The second most frequent time period was 07 - 08 hours, when the frequency of 20 to <30 mm/h level of short-term heavy precipitation reached 147 times, and the early morning time period was less affected by the thermal instability conditions, which was likely to be more related to the development of rapids and other related weather systems (Figure 1).

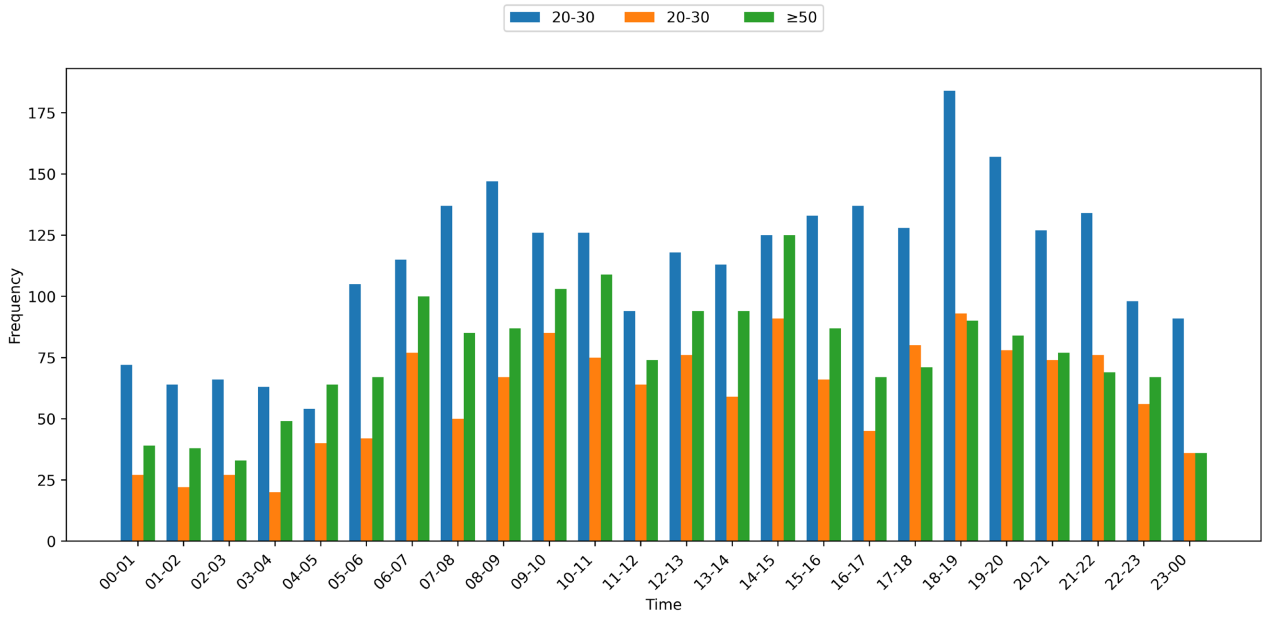

Figure 1. Frequency of graded short duration heavy precipitation during all-weather hours from June to September.

From the monthly statistical analysis of the frequency of occurrence of heavy precipitation throughout the day, it can be found that the June heavy precipitation occurs mainly during the daytime, in which the main peak area appeared in 10 - 11 hours, the secondary peak area appeared in 07 - 08 hours, while July and August heavy precipitation peak mainly in the afternoon to the first half of the night, this is due to the June into the prune rainy period, the heavy precipitation along with the north-south swing of the prune rain belt and the change of the heavy precipitation appeared in the morning by the heat Unstable conditions have less impact, it is likely to be more related to the development of the weather system in question, while July-August out of the plum is often under the control of the subtropical

high pressure, high temperatures in the late afternoon to the evening before, the atmospheric instability of energy focusing, when there is a certain triggering conditions, it will produce strong convective weather.

3.2. Characteristics of Spatial Distribution of Short-Term Heavy Precipitation

Linyi City is located in the northern part of the Huaihe River Basin and the southeastern part of Shandong Province, with many hills and mountains in the northern part of the city and plains in the southern part of the city. Annual precipitation spatial and temporal distribution is uneven, most areas of Linyi City rainstorms in April, the earliest rainstorms appeared in Lanling, Linshu for April 4, 2006, followed by the most frequent occurrence of the first day of the May 4, 2003 appeared. The end date is generally November 18, 2020 and October 14, 1987; the maximum rainstorm extreme value in Yinan County is 339.4mm, which occurred on August 14, 2020, and the minimum value in Junan is 146.8mm, which occurred on August 5, 1993, respectively.

The spatial distribution maps of the total number of days of short-duration heavy precipitation (**Figure 2(a)**) and the total frequency of short-duration heavy precipitation (**Figure 2(b)**) from 2011 to 2020 show that the spatial distribution of short-duration heavy precipitation is uneven, with the highest frequency occurring in the Hedong District of Linyi City, the south-central part of Yinan County, the southern part of Mengyin County and the northwestern part of Jounan County, and the southeastern part of Lancing County, and the lower frequency occurring in Fei County and Linshu County, which may be due to the topography having a certain correlation, due to the fact that the hilly and mountainous northern part has more windward slopes tend to lift water vapor, triggering small- and medium-scale convective systems that produce higher precipitation efficiency.

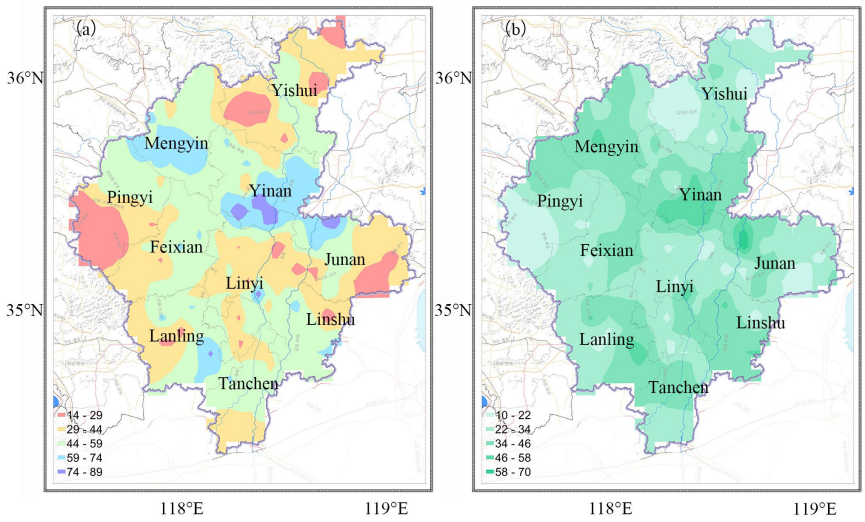

Figure 2. Spatial distribution of total number of days (a) and total frequency of short duration heavy precipitation (b) from 2011 to 2020.

3.3. Characteristics of Spatial Distribution of Different Levels of Short Duration Strong Water

According to the precipitation intensity, the short-term heavy precipitation is divided into three levels: 20 - 30 mm/h, 30 - 50 mm/h, and ≥50 mm/h, and the characteristics of the occurrence of different levels of short-term heavy precipitation in different counties and districts of the city of Linyi are counted separately (Figure 3). It can be seen that 20 - 30 mm/h accounts for the most, which is close to the spatial distribution of the total frequency of short-term heavy precipitation, in which the Hedong District of Linyi, the middle and southern part of Yinan County, the southern part of Mengyin County and the northwestern part of Jounan County, the southeastern part of Lancing County, the northern part of Tancheng County, and the southeastern part of Linshu County are the most frequent areas. 30 - 50 mm/h short-term heavy precipitation is distributed, and the distribution of the south-central part of the Hedong District, the southern part of Mengyin County, the eastern part of Yinan County, and the eastern part of Lancing County are the most frequent areas, and eastern Yinan County, and eastern Laning County have the highest frequency of occurrence. In the distribution map of ≥50 mm/h rated short duration heavy precipitation, northeast of Junan County has the highest frequency.

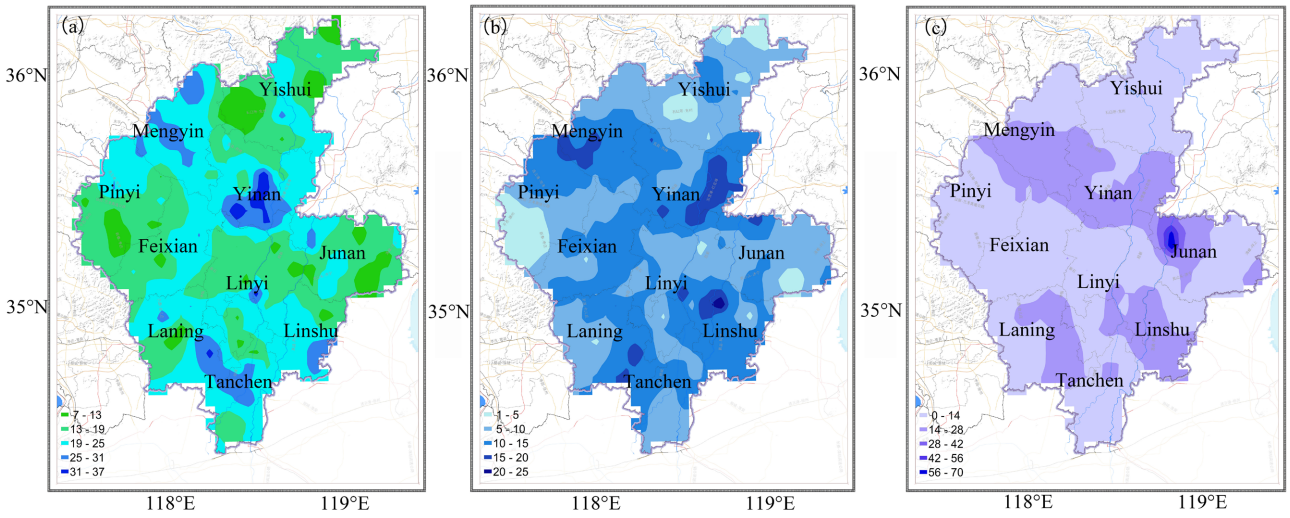

Figure 3. Spatial zoning maps of different levels of short duration heavy precipitation ((a): 20 - 30 mm/h, (b): 30 - 50 mm/h, (c): ≥50 mm/h).

4. Percentage of Short Duration Heavy Precipitation Affecting Heavy Rainfall

Heavy rainfall is one of the major meteorological disasters during the flood season, with an annual average of 29.3% of the total annual precipitation in the city of Linyi from 1962 to 2020, and between 25.1% (Yinan County) and 31.6% (Linyi City) of the total annual precipitation at each station. However, prolonged persistent heavy rainfall and short-calendar-time extreme heavy rainfall may lead to

dam collapse of reservoirs, house collapse, urban flooding, drowning, electrocution, and mudslides and landslides, which, if not adequately guarded against, can result in significant casualties and property damage.

Heavy rainfall is closely related to short-term heavy precipitation. When the short-term heavy precipitation reaches more than 50 millimeters in one hour, it is extreme short-term heavy precipitation. The risk of disaster is obviously increased, and it is very easy to cause urban flooding, waterlogging of farmland, etc. Therefore, it is very meaningful to analyze the relationship between short-term heavy precipitation and heavy rainfall. In order to further analyze the relationship between short duration heavy precipitation and heavy rainfall, for a certain station at a certain time of short duration heavy precipitation, if the day of the station is a heavy rainfall day, the short duration heavy precipitation is considered to cause heavy rainfall on that day.

Figure 4 shows the percentage of days with heavy rainfall caused by short-duration heavy precipitation in different months during the 2011-2020 flood season at each station. From the temporal distribution, the probability of heavy rainfall caused by short-duration heavy precipitation varies greatly in each month, with the highest percentage (82.2%) in August, followed by the second highest percentage (71.8%) in June and the second highest percentage (62.3%) in July, and the lowest percentage (47.5%) in September. In terms of spatial distribution, the highest average percentage (87.1%) is found at the station in Mengyin County and the lowest (43.3%) at the station in Pingyi County during the period of 2011-2020, and the short-term heavy precipitation at each station is more likely to cause heavy rainfall in August and September due to the high number of typhoons.

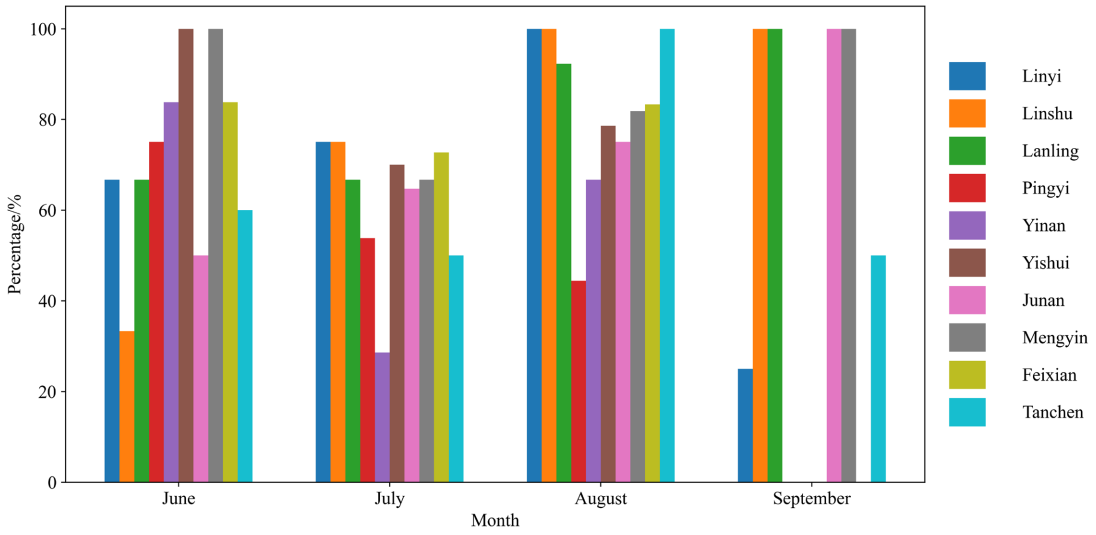

Figure 4. Percentage of short duration heavy precipitation affecting heavy rainfall on the same day from June to September in each county and district.

5. Conclusion and Discussion

In this paper, the spatial and temporal distribution of short-term heavy precipita-

tion in each district and town was analyzed by using the hour-by-hour precipitation data from the national and regional stations from 2011 to 2020, and the following conclusions were drawn.

(1) The short-term heavy precipitation has obvious time-varying characteristics. From the growth trend, the frequency of short-term heavy precipitation of ≥50 mm or more showed a growth trend after 2015, and the highest value of the frequency of short-term heavy precipitation occurred in 2013, and the lowest value occurred in 2015. During the June-September flood season, the frequency of short-term heavy precipitation peaked in July, and the trough was in September, during which the hourly heavy precipitation was mostly maintained at 20 - 30 mm, followed by 30 - 50 mm; during the whole-day period, the short-term heavy precipitation mainly occurred in the late afternoon to the early evening, and the daily changes showed a single-peak distribution.

(2) The spatial distribution of short-duration heavy precipitation varies widely. 20 - 30 mm/h is the largest proportion, close to the spatial distribution of the total frequency of short-duration heavy precipitation, with Hedong District of Linyi City, south-central Yinan County, southern part of Mengyin County and northwestern part of Junan County, southeastern part of Luling County, northern part of Tancheng City, and southeastern part of Linshu City being the most frequent areas. 30 - 50 mm/h class of short-duration heavy precipitation is shown in the map of the distribution of short-duration heavy precipitation. Linyi City, south-central Hedong District, southern part of Mengyin County, eastern part of Yinan, and eastern part of Laning had the highest frequency of occurrence. In the distribution map of ≥50 mm/h-rated short-term heavy precipitation, the highest frequency was observed in northeastern Junan County.

Short-duration heavy precipitation is closely related to heavy rainfall, with a lower percentage of short-duration heavy precipitation causing heavy rainfall on the same day in September, and a significantly higher percentage in June-August, with short-duration heavy precipitation very likely to cause heavy rainfall in August, and with a higher average percentage at the station in Mengyin County (87.1%), and the lowest at the station in Pingyi County (43.3%) during the period of 2011-2020 in terms of the spatial distribution, with short-duration heavy precipitation more likely to cause heavy rainfall at the stations in August and September due to the higher frequency of typhoons. Heavy precipitation is more likely to cause heavy rainfall weather in August and September, and this variation difference is closely related to summer convective weather.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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