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Research Article

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A study on temporal and spatial change characteristics of precipitation concentration degree (PCD) and precipitation concentration period (PCP) in Wenchuan Earthquake areas

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ABSTRACT

Based on the long sequences daily precipitation data observed at 12 stations (Beichuan, Lixian, Maoxian, Mianzhu, Pingwu, Qingchuan, Shifang, Wenchuan, Jiangyou, Anxian, Pengzhou) in the earthquake areas of Wenchuan during the period 1966-2012, these was had systematic diagnostic analysis on the precipitation type, geographical distribution, interannual variability, quasi-periodic and mutation characteristics, distribution characteristics of different intensity precipitation days and precipitation, distribution characteristics of precipitation-concentration degree (PCD) and precipitation-concentration period (PCP), characteristics of precipitation concentrated in wet and dry years, and the impact on landslides, debeis flows and other geological disaster in earthquake areas. These studies have important theoretical and practical application significance for prevention project of geological disaster triggered by heavy rains in the earthquake areas.

Keywords: Wenchuan Earthquake; Geological Disaster; Precipitation-concentration Degree (PCD); Precipitation-concentration Period (PCP); Heavy Precipitation

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INTRODUCTION

After the violent Wenchuan earthquake occurred on May 12, 2008 in Sichuan Province, geological activities become more frequent in Sichuan region, especially in the surrounding region of Chengdu. There were multiple numbers of landslide, debris flow and other geological disasters that have caused great impact [1-3] , such as a serious debris flow disaster occurred in Beichuan earthquake areas on Sep.24, 2008, in which 42 people were dead or missing [4]; a serious debris flow disaster occurred on Aug.07, 2010 in Zhouqu County of Ganshu Province (sharing border with Sichuan), leading to 1463 dead and 302 missing; the serious debris flow disasters occurred on Aug. 12-14, 2010 in Qingping Village of Mianzhu City, Yingxiu Township of Wenchuan County and Longchi Township of Dujiangyan City [5]; and a serious high-level landslide induced by mountain torrents occurred on July 10, 2013 in Dujiangyan City, resulting in 45 death and 116 missing. In addition to influence of special geological environment of Longmeng Mountain fault zone, heavy precipitation and concentrated precipitation were also important inducement of the occurrence of these serious geological disasters [6]. Therefore, it is of vital importance to carry out studies on patterns of precipitation changes, especially on precipitation concentration degree (PCD) in disaster-prone regions. Such studies will be having important theoretical and practical application significance in prevention and control of geological disasters in earthquake affected region.

2 DATA AND METHOD

2.1 Study Area and Data

Observation data of daily precipitation in the past 47 years from 1966 to 2012 as recorded by 12 meteorological stations are chosen for the study of this article. These stations (including Beichuan, Lixian, Maoxian, Mianzhu, Pingwu, Qingchuan, Shifang, Wenchuan, Jiangyou, Anxian, Pengzhou and Dujiangyan) are located in Wenchuan

Earthquake Areas where a great earthquake occurred on May 12, 2008. Analyses have been made on climatological distribution characteristics of amount precipitation and number of rain days as well as the features of precipitation concentration degree (PCD) and precipitation concentration period (PCP) in the earthquake areas by way of Morlet wavelet analysis method [7], M-K mutation analysis method [7] and PCD analysis method. The study is able to offer important theoretical support to and has practical application significance in engineering projects for prevention and control of geological disasters induced by heavy precipitation in earthquake areas.

2.2 Calculation Methods of PCD and PCP

Vector quantity theory is utilized to define time-allocation characteristic parameter, thus achieving quantitative description of PCD and PCP. Specific methods [8] are given below:

For presentation of annual allocation of precipitation in an area, precipitation of each pentad or each season expressed as a percentage of annual precipitation can be adopted and indicated by way of isoline. Time-allocation characteristic parameter of precipitation recorded by a single meteorological station is defined by utilizing vector quantity analysis theory, in which value of precipitation of one pentad is taken as the length of the vector quantity and the corresponding pentad is taken as the direction of the vector quantity. In this way, the two parameters of PCD and PCP can be defined.

$$CN_{\mathrm{i}} = \frac{\sqrt{R_{xi}^2 + R_{yi}^2}}{R_i} \quad (1)$$

$$D_i = \arctan\left(R_{xi} / R_{yi}\right) \quad (2)$$

Wherein, CNi and Di respectively represent PCD and PCP in study period.

$$R_{xi} = \sum_{j=1}^{N} r_{ij} \times \sin\ \theta_j \quad (3)$$

$$R_{yi} = \sum_{j=1}^{N} r_{ij} \times \cos\ \theta_j \quad (4)$$

Wherein, Ri is the total precipitation recorded by a certain meteorological station in the “i”th year of the study period; rij is the precipitation in the “j”th pentad of the “i”th year of the study period; “i" represents a particular year and “j” is the sequence of pentad in study period. “θ” represents directional angle corresponding to the “j”th pentad (directional angle in the entire study period is 360°. One year is taken as a circumference and each pentad is evenly distributed). It is obvious that formula (1) is able to reflect concentration degree of total precipitation in each pentad in the study period. Value of PCD rests between 0.0 and 1.0. The closer of PCD value to 1.0, it indicates that the higher the total precipitation is concentrated in a certain pentad; On the contrary, the closer of PCD value to 0, it indicates that precipitation is distributed more evenly in each pentad. Directional angle of resultant vector is calculated by formula (2), result of which expresses the angle indicated by center of gravity after composition of vector quantity, representing the period in which maximum precipitation in a pentad in one year occurs. Therefore, PCD and PCP shall be applied for studying spatial and temporal distribution characteristics of precipitation. PCD of each pentad within study period can be expressed by concise data, showing the period expressed by center of gravity after composition of precipitation [9-10].

3 CLIMATOLOGICAL DISTRIBUTION CHARACTERISTICS OF PRECIPITATION IN WENCHUAN EARTHQUAKE AREAS

3.1 Distribution Characteristics of Annual Precipitation in Wenchuan Earthquake Areas

Fig.1 shows the geographic distribution of climatological mean of annual precipitation in the past 47 years in Wenchuan Earthquake Areas. Precipitation distribution is approximately higher in the east part and lower in the west. Centers of large value of precipitation in northeastern area locate mainly in Beichuan, Anxian and Jiangyou. Beichuan has the highest annual precipitation and climatological mean of which is up to 1300mm. Climatological mean at Anxian and Jiangyou stations also exceeds 1000mm. Another large-value center locates at Dujiangyan Station in southeastern area, where climatological mean of annual precipitation is up to 1173.0mm. Located in high mountain region, Wenchuan, Lixian and Maoxian are in a low-value zone. Climatological mean of annual precipitation observed in these areas is less than 540mm. Center of low value of precipitation is located at Maoxian, having a value of 472.8mm only. Apparently, serious debris flow in Beichuan, serious debris flow in Qingping Village and Yingxiu

Township, serious high-level landslide triggered by mountain torrents in Dujiangyan and other geological disasters as mentioned above occurred in large-value centers of precipitation.

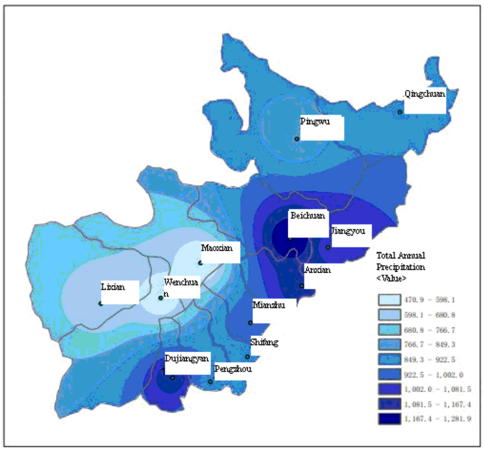


Fig.1: Climatological Distribution Characteristics of Precipitation in the Past 47 Years in Wenchuan Earthquake Areas

3.2 Multi-scale Periodical Characteristics of Annual Precipitation in Wenchuan Earthquake Areas

Fig.2 is the real-part diagram of Morlet wavelet transformation coefficient and wavelet variance diagram of overall annual precipitation of 12 meteorological observation stations in Wenchuan Earthquake Areas, from which it can be seen that mean annual precipitation of Wenchuan Earthquake Areas has quasi-periodical oscillation feature of multiple time scales. Such oscillations are mainly long-period oscillation with a cycle of 10-13 years and short-period oscillation with a cycle of 4-6 years as well as 3 years. Periodical oscillation with a cycle of 10-13 years was remarkable during the period of 1966-1985, and periodical oscillation with a cycle of 16-19 years was obvious in the period of 1985-2012; Oscillation in short cycles were relatively more complicated. In the period of 1966-1990, the cycle was 6-8 years, and in the period after 1990, the cycle was divided into a medium-to-long cycle of 6-10 years and a short cycle of 4-5 years. The two medium-cycle oscillations existed steadily in the period of 1990-2010. It can be seen from wavelet variance diagram that wavelet with a 3-year cycle has stronger energy. That's to say, the cycle of about 3 years is the most conspicuous.

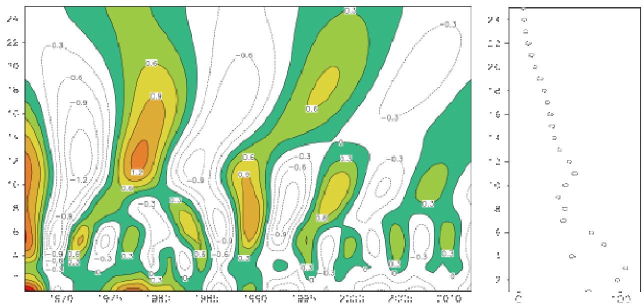


Fig. 2: Real-part Diagram of Morlet Wavelet Transformation Coefficient (Left) and Wavelet Variance Diagram (Right) of Annual Precipitation in Wenchuan Earthquake Areas

Fig.3 is a real-part diagram of precipitation in different seasons of spring, summer, autumn and winter in Wenchuan Earthquake Areas; Fig.3a shows the periodic oscillation of precipitation in spring, cycles of which are mainly of 6-8 years –, a cycle of 8 years before 1985 and a cycle of 6 years after 1985; Fig.3b shows the periodic variation of precipitation in summer, cycles of which are mainly of 13 years, 6-10 years, 3 years as well as a weaker cycle of 4-6 years; It reveals generally a periodical feature of a long cycle of 10-16 years before 1985 and a medium cycle of 8 years between 1985-2012; Fig.3c presents the periodic variation of precipitation in autumn, with a long cycle of 10-18 years and a short cycle of 4-6 years of which existing side by side during the entire period; Fig.3d shows periodic variation of precipitation in winter, with a cycle of 6-10 years and a cycle of 3 years of which coexisting in the whole period. Cycle of 10-12 years was apparent prior to 1985, cycle of 4-8 years was notable after 1985 and short cycle of 3 years was conspicuous in the entire period. It can be seen from the above that apparent multi-scale periodic oscillation feature exists in both of the total annual precipitation and the seasonal precipitation, and it reveals the fact that notable multi-scale concentration period exists in both of the total annual precipitation and the seasonal precipitation. It is of positive significance to understand and grasp this feature in forecasting and early warning of geological disasters.

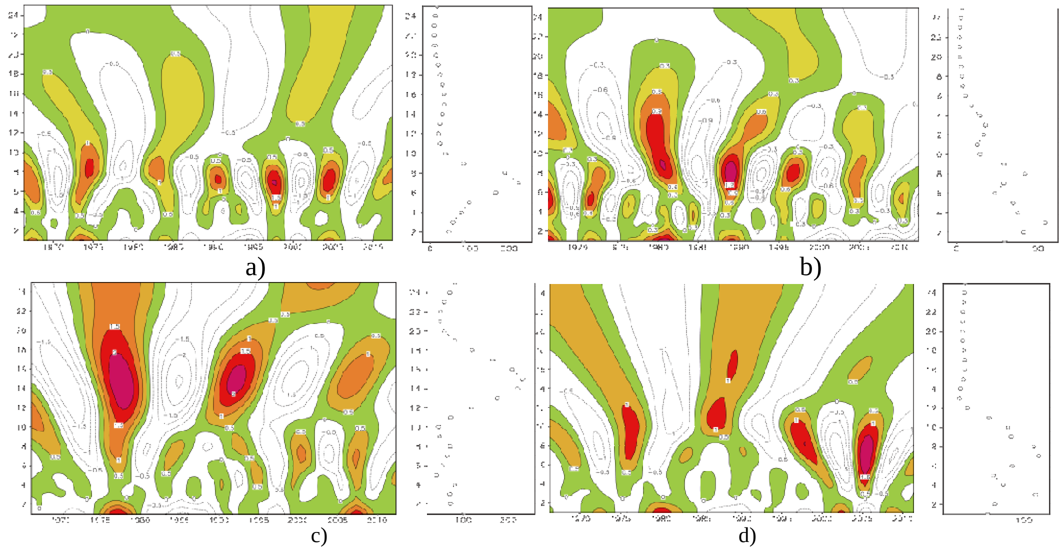


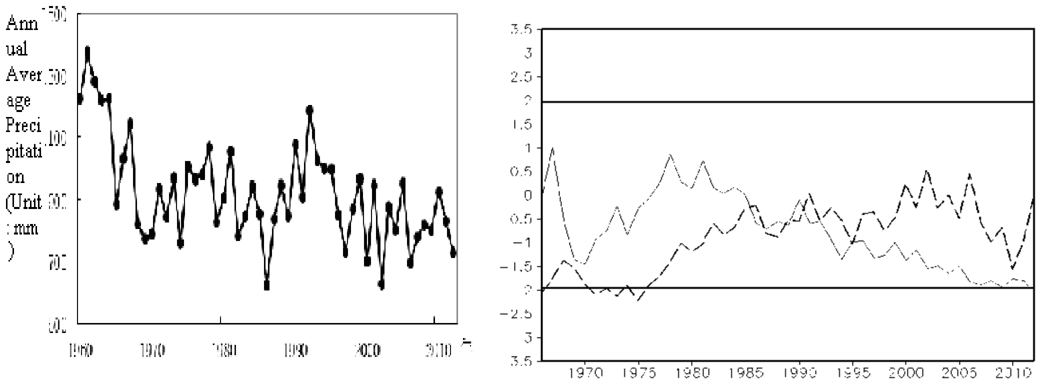
Fig. 3: Real-part Diagram of Morlet Wavelet Transformation Coefficient (Left) and Wavelet Variance Diagram (Right) of Precipitation in Different Seasons in Wenchuan Earthquake Areas (a. Spring, b. Summer, c. Autumn, d. Winter)

Since precipitation in summer accounts for about 65% of total annual precipitation, results of wavelet analysis of annual precipitation agrees generally with results of periodic analysis for summer. In addition, precipitation in spring accounts for 20% or so of total annual precipitation, therefore, precipitation in both spring and summer accounts for 85%. The predominant cycle of 6-8 years express itself visibly in annual precipitation. It is quite evident that periodic variation of precipitation in Wenchuan Earthquake Areas presents a multi-scale periodic oscillation with long, medium and short cycles. Medium cycle of 6-8 years presented itself clearly in the past 47 years. Short cycle of 3 years (existing in summer in the period 1970-2000, in autumn in the period of 1970-1990 and in winter in the period of 1980-2000) was a conspicuous periodic oscillation even in different eras.

3.3. Mutation Characteristics of Annual Precipitation in Wenchuan Earthquake Areas

Fig.4a shows the curve of change of annual precipitation in Wenchuan Earthquake Areas, in which it can be seen that drop of annual precipitation was notable before 1970, reducing from 1300mm or so to about 750mm; Annual precipitation fluctuated around 900mm after 1970 but it increased dramatically in the period of from the middle of 1980s to the middle of 1990s, variation of value of which was nearly 600mm, and precipitation dropped down again after 1996 and it fluctuated around 850mm after 1998. Fig.4b is a M-K test pattern of annual precipitation of Wenchuan Earthquake Areas and it shows that down trend of total annual precipitation of the region was quite obvious in the period of 1970-1977 and UB line has surpassed the critical line of -1.96. It was also a decreasing period of total annual precipitation in the period from 1980 or so to 1987, during which total annual precipitation dropped down to 621.4mm, the lowest value in the past 47 years. In addition, the year of 1986 was a mutational site where total annual precipitation turned from downward trend to upward trend, in which increase of mean annual precipitation in the region was dramatic and such trend had continued until 1993 in which a mutation occurred and precipitation turned from upward trend to downward trend. There was a notable downward turn in 1995 or so and there was no apparent change of trend in the period of 1998-2012. Therefore a conclusion can be drawn basically from the M-K test pattern that a mutation of precipitation in Wenchuan Earthquake Areas occurred in the middle of 1980s and 1990s respectively.

In general, precipitation in Wenchuan Earthquake Areas had experienced three notable decreasing periods in the past 47 years from 1966 to 2012, i.e. from the middle of 1960s to the early of 1970s, in the early of 1980s and in the middle and latter of 1990s, respectively. And there were two increasing periods, i.e. in the early of 1970s and from the latter of 1980s to the early of 1990s, respectively.



a) b)

Fig. 4: Inter-annual Variation in Wenchuan Earthquake Areas in the Period of 1966-2012 (a) and Results of Mann-Kendall Inspection (b) (Straight line indicates critical value of significance level when α=0.05; black-colored solid line is the UF line; black-colored dotted line is the UB line)

3.4 Characteristics of Precipitation of Different Intensities in Wenchuan Earthquake Areas

Statistics have been made for number of days and distribution of amount of precipitation in five rainfall grades, i.e. light rain [0.1,9.9] mm, moderate rain [10,24.9] mm, heavy rain [25,49.9] mm, rainstorm to downpour [50,∞] mm respectively, in accordance with standard of China Meteorological Administration for classification of grades of accumulative total of precipitation in 24 hours. As far as distribution pattern of precipitation intensity is concerned, variation state of number of rain day s and amount of precipitation are out of step with each other under many circumstances. For example, annual number of days of light rainfall has reached 80% of annual number of rain day s at all the areas of the 12 stations in the earthquake areas, but annual amount of precipitation of light rainfall varies greatly from area to area. Therefore, a better study can be made on features and differences of precipitation types in the region when distribution characteristics of both the number of rain day s having different precipitation intensity and amount of precipitation are taken into consideration.

3.4.1 Distribution Characteristics of Rain Days with Different Precipitation Intensities in Wenchuan Earthquake Areas

Table 1 shows climatological means of number of days of light rain, medium rain, heavy rain and rainstorm in area of each station in Wenchuan Earthquake Areas. Climatological means of number of days of light rainfall indicates that number of days of light rainfall decreases progressively from south to north and there is a notable large-value center in the south area, at the location of Dujiangyan station, where average number of days of light rainfall is up to 134.8 days. Qingchuan station is located at the northernmost area, where annual number of days of light rainfall is 85.7 days only, having the least distribution in all the stations. It demonstrates that probability of occurrence of light rainfall is greatly associated with water-vapor transfer of general atmospheric circulation. Distribution of climatological means of number of days of medium rainfall indicates that distribution pattern at each station agrees highly with climatological distribution of annual precipitation in the earthquake areas. Similarly, high-value centers exist in the areas of Dujiangyan, Anxian and Jiangyou, where average number of days of medium rainfall is 12 days, with Dujiangyan station having the highest record of 15.5 days. Number of days of medium rainfall in high-altitude areas of Wenchuan, Maoxian and Lixian is normally in the range of 9-11 days, which demonstrates that probability of precipitation of medium rainfall has some correlation with landform and annual precipitation. Distribution of climatological means of number of days of heavy rainfall, rainstorm and above demonstrates average number of days of heavy rainfall in the earthquake areas is 4 days or so, and average value of number of days of heavy rainfall in the past 47 years in the three areas of Maoxian, Wenchuan and Lixian is 1 day only (in Maoxian) or less than 1 day (0.7 day in Wenchuan and 0.8 day in Lixian). Number of days of rainstorm in these three areas is almost zero, while that at other stations is approximately at 4-6 days. Number of days of rainstorm distributes mainly in the two large-value zones in Beichuan, Anxian, Jiangyou and Dujiangyan, where climatological mean of number of days of rainstorm can be up to 3-4 days. It can be seen that centers of heavy rainfall are located in areas of Beichuan, Anxian, Jiangyou and Dujiangyan, which are disaster-prone areas with multiple and repeated occurrence of geological disasters.

TABLE 1 Distribution of Rain Days with Different Precipitation Intensity in Wenchuan Earthquake Areas (Unit: Day)

	Bei chuan	Dujiang yan	Li xian	Mao xian	Mian zhu	Ping wu	Qing chuan	Shi fang	Wen chuan	Jiang you	An xian	Peng zhou
Light rain	103	134.8	123.9	111.7	106.9	95.7	85.7	101	110.5	92.6	108	103.4
Medium rain	11.8	15.5	12.8	9.1	11.1	12.9	11.9	10.9	9.8	13	14.6	11.4
Heavy rain	5.9	5.7	0.8	0.9	5.1	4.5	5	4.3	0.7	5.5	5.4	4.6
Rainstorm	4.9	2.9	0	0.1	2.8	1.4	2.1	2.6	0.1	3.2	3.8	2.3

3.4.2 Distribution Characteristics of Precipitation with Different Intensities in Wenchuan Earthquake Areas

Fig.5a is the average distribution diagram of cumulative annual precipitation of light rainfall in Wenchuan Earthquake Areas. It shows that general distributions of cumulative precipitation and number of days of light rainfall are similar with each other, i.e. higher in south and lower in north. But average values of precipitation of light rain at majority of stations are at 250.0mm or so, tapering uniformly from the largest value of Dujiangyan station in the south (326.9mm) to the smallest value of Qingchuan station in the north (208.7mm). Fig.5b is the average distribution diagram of cumulative annual precipitation of medium rain in Wenchuan Earthquake Areas. It indicates that there is a low-value zone of distribution of cumulative precipitation of medium rain in Wenchuan and Maoxian, while those of other areas stay basically above the average value of 180.00mm. On the average distribution diagrams of cumulative annual precipitation of heavy rain and rainstorm (Fig.5c and 5d), distribution of precipitation presents a notable characteristic of extreme distribution, with cumulative means of amount of heavy rainfall of Wenchuan and Maoxian stations at about 20-27mm only, while those of Beichuan and Dujiangyan exceeding 200.0mm. Distribution of cumulative means of amount of rainstorm is more extreme. Since all average values of annual cumulative number of days of rainstorm of Lixian, Wenchuan and Maoxian are less than 1 day, all average amounts of precipitation of rainstorm thereof are less than 10mm, because of this, precipitation of these three stations belongs to the type which is small in amount of precipitation and less in number of days of rainfall. Average annual amount of precipitation of rainstorm at Beichuan station exceeds 440.0mm every year, and cumulative amount of precipitation of heavy rain – rainstorm at Beichuan station accounts for 60.0% of annual precipitation. According to statistic results of annual mean value of number of days of rainstorm at Beichuan station (4.9 days), it can be concluded that grades of rainstorm at Beichuan station are normally of rainstorm and downpour with precipitation exceeding 100mm. Therefore, precipitation in Beichuan area belongs to the type which is large in amount of precipitation and high in intensity. Precipitation type of Jiangyou and Anxian is similar to that of Beichuan and it is just slightly smaller in precipitation intensity. Precipitation of Dujiangyan station has relatively uniform distribution in all intensities and it accounts for 20%-33%. Precipitation type of the five stations of Mianzhu, Pingwu, Qingchuan, Pengzhou and Shifang is similar with Dujiangyan station but annual precipitation thereof is about 150-300mm less.

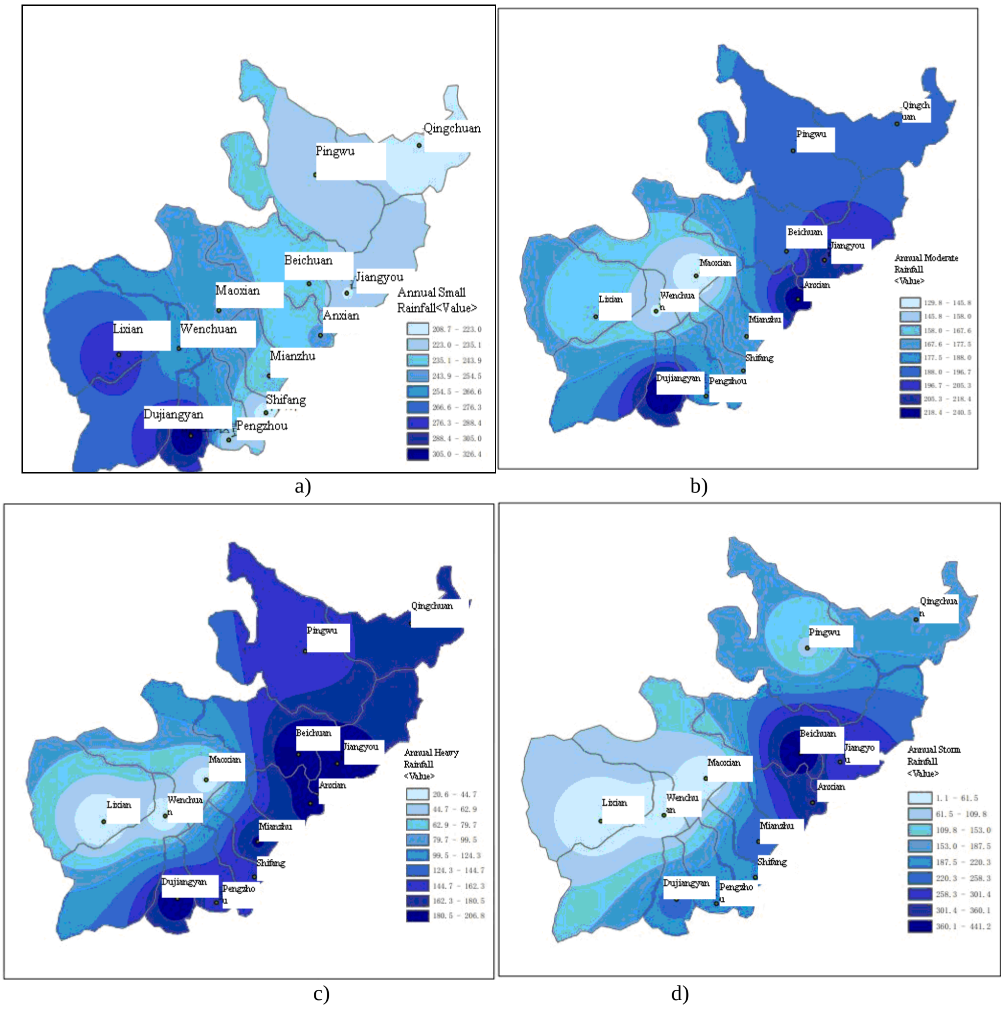


Fig. 5: Distribution Diagram of Precipitation with Different Intensities in Wenchuan Earthquake Areas (a. Slight rain, b. Medium rain, c. Heavy rain, d. Rainstorm)

4 CHARACTERISTICS OF PCD AND PCP IN WENCHUAN EARTHQUAKE AREAS

4.1. Inter-annual Variations of PCD and PCP in Wenchuan Earthquake Areas

PCD represents degree of concentration of precipitation in 72 pentads of a year and value of which varies within the range of 0-1. When annual precipitation concentrates in 1 pentad, value of PCD is 1; when annual precipitation is evenly distributed in all pentads, value of PCD is 0. PCP describes features of concentration of precipitation in a certain area in another perspective. Period in which the pentad having the greatest proportion of precipitation belongs can be determined per value of PCP. Fig.6 presents inter-annual variations of PCD and PCP in Wenchuan Earthquake Areas. It can be seen that PCD in the earthquake areas is basically at the level of 0.6 or so and there is an apparent positive correlation between PCD and annual precipitation. Coefficient of correlation is 0.674 and it has passed 99% of significance test. PCD in the region dropped down slightly in the past 47 years at a rate of -0.015/10a. Inter-annual variation of PCP is large and it concentrates at the beginning of July – September (37th – 49th pentads) in main years. In addition, period with maximum precipitation lies in September in 7 years. The earliest and the latest appearance of PCD occurred in the 36th pentad of 1980 (the 6th pentad of June) and in the 53rd pentad of 2008 (the 5th pentad of September), respectively.

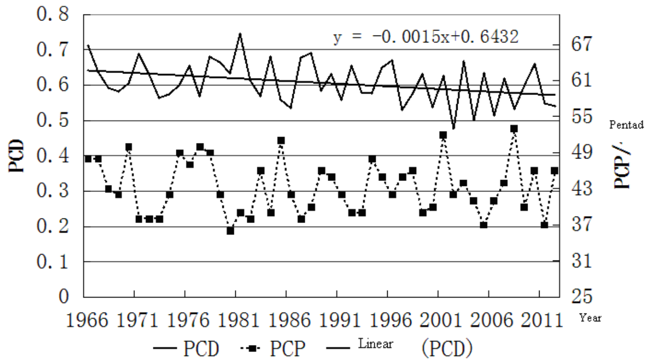
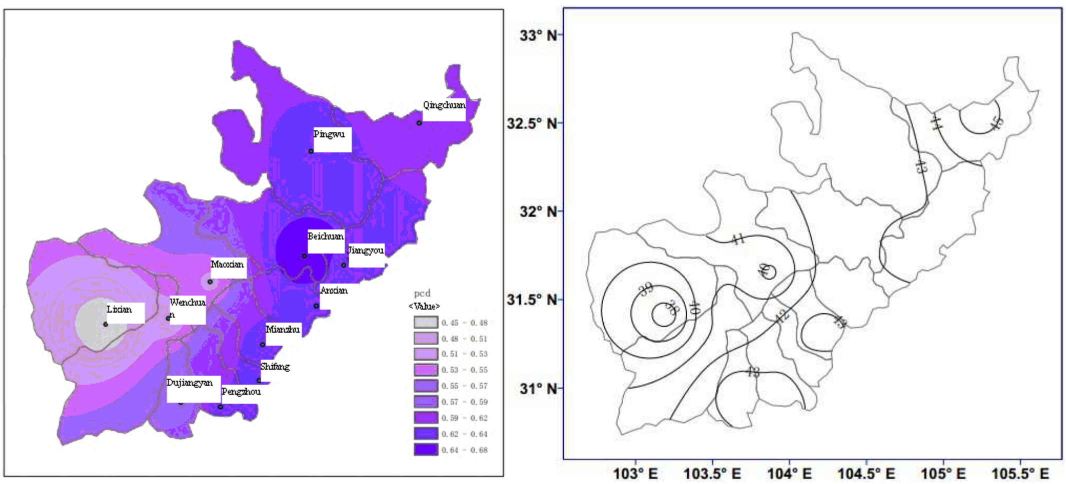


Fig. 6: Inter-annual variation Curve of PCD and PCP in Wenchuan Earthquake Areas

4.2. Geographic Distribution of PCD and PCP in Wenchuan Earthquake Areas

Fig.7 is a geographic distribution diagram of PCD and PCP in Wenchuan Earthquake Areas. Distribution of the two values is consistent with climatological distribution of annual precipitation. Coefficient of correlation between climatological mean of annual precipitation and PCD and between climatological mean of annual precipitation and PCP is 0.727 and 0.640 respectively, both of which have passed 95% of significance level test. Lixian and Maoxian have high altitude and PCD of which is small. Corresponding PCP of the two areas comes early too, which lies in the first half of July (the 37th – 39th pentads). It is especially so in Qingchuan, Jiangyou, Mianzhu, Pengzhou and Dujiangyan, i.e. areas along the eastern edge of the earthquake areas, where almost all of the PCPs lie in the 6th pentad of July and the 1st pentad of August (the 42nd – 43rd pentad). This is consistent with the phenomenon that period of rainstorms in majority regions of Sichuan Province concentrates in late July and early August. A common feature of these regions is that they are located at the transitional zone between basin and highland. Therefore, it shows some precipitation characteristic of basin as well.



a) b)

Fig. 7: Mean Geographic Distribution of PCD(a)and PCP(b) in Wenchuan Earthquake Areas in the Period of 1966-2012 (Unit of PCP: Pentad)

4.3 Composite Analysis of Wet Years and Dry Years

In order to study relationship between concentration of precipitation and annual precipitation, this article takes mean annual precipitation of the region as the criterion for classification. Five years with the highest mean annual precipitation of the region in the past 47 years are taken as wet-year group, i.e. 1966, 1967, 1978, 1981 and 1990 respectively; Five years with the lowest mean annual precipitation of the region is the past 47 years are taken as dry-year group, i.e. 1986, 1991, 2000, 2002 and 2006 respectively. In this way, contrast ratios of PCD and PCP of the wet-year group and dry-year group are obtained as shown in Table 2 hereunder.

It can be seen from contrast ratio of PCDs that all PCPs of the 12 stations present a consistent feature: PCDs of wet years is notably larger than PCDs of dry years and distribution of the two groups of data is also consistent. Distributions of PCDs are all in the pattern of continuous reduction from east to west, and all smaller values appear in areas of Lixian, Maoxian and Wenchuan which are located at the western of the earthquake areas, with the lowest value at 0.4 only. Values of PCDs of 7 stations along the eastern part are nearly at 0.7 or so. It can also be seen from distribution of PCPs that PCPs of wet years of majority of stations appear later than PCPs of dry-year group. But distribution of the two groups of data differs greatly with each other. Correlation between magnitude of difference value of the two groups of data and geographic distribution is not notable. PCP of wet-year group of Wenchuan station is 10 pentads later than that of dry-year group. PCPs of wet-year groups of Anxian and Dujiangyan stations are around 6 pentads later than that of dry-year groups. On the contrary, PCPs of wet-year groups of the 3 stations of Lixian, Qingchuan and Shifang are 2-4 pentads earlier than that of dry-year groups. Therefore, it can be seen that great regional difference exist between time of PCPs of wet years and that of dry years, cause of which is yet to be researched.

TABLE 2 Contrast Ratios of PCD and PCP of Wet-year Group and Dry-year Group (Unit of PCP: Pentad)

Station Name	Bei chuan	Dujiang yan	Li xian	Mao xian	Mian zhu	Ping wu	Qing chuan	Shi fang	Wen chuan	Jiang you	An xian	Peng zhou	Total Amount of the Area
PCD of wet year	0.77	0.67	0.45	0.56	0.71	0.69	0.70	0.70	0.56	0.70	0.71	0.72	0.68
PCD of dry year	0.60	0.50	0.41	0.46	0.51	0.52	0.55	0.53	0.48	0.58	0.55	0.58	0.52
PCP of wet year	43.2	47.6	37.0	41.2	43.2	42.4	41.4	41.4	43.6	44.0	47.0	46.2	45.8
PCP of dry year	43.2	42.4	40.4	36.6	38.4	40.0	44.2	43.2	33.6	41.4	40.8	42.2	41.4

CONCLUSION

Analysis made on multi-scale periodical and PCD of daily precipitation data sequences recorded by 12 meteorological stations in Wenchuan Earthquake Areas where a great earthquake took place on May 12, 2008 demonstrates the follows:

1. Wenchuan Earthquake Areas have a NE-SW strike along Longmeng Mountain and distribution of annual precipitation in the region presents a basic pattern of high in east and low in west. Two large-value centers of precipitation lie in the eastern areas of Beichuan, Jiangyou and Dujiangyan, where climatological mean of annual precipitation exceeds 1000.0mm and that of Beichuan exceeds 1300mm; The western areas of Wenchuan, Lixian and Maoxian is a low-value zone, where mean annual precipitation is lower than 540.0mm. Viewed from seasonal precipitation, precipitation in spring and summer accounts for 85% of annual precipitation. As far as Wenchuan Earthquake Areas are concerned, areas with multiple and repeated occurrences of geological disasters that are induced by heavy rainfall are located in those eastern areas, i.e. Beichuan, Jiangyou and Dujiangyan. Therefore, special attention shall be attached to prevention of geological disasters in these areas. These two zones are the very sites of a number of serious landslides, debris flows and other geological disasters occurred after 2008.

2. Precipitation has the features of multi-time-scale quasi-periodical variations. Superposition of wave crest and wave hollow of multi-cycle precipitation often results in the increase or decrease of precipitation in some years or seasons, which could cause clusters of geological disasters triggered by heavy rainfall or concentrated precipitation. Annual precipitation and seasonal precipitation in Wenchuan Earthquake Areas have reveal a long period of 10-13 years, a medium period of 6-8 years and a short period of 4-6 years and about 3 years. And 2 times of dramatic increase in trend of precipitation, 3 times of notable decrease in trend of precipitation and 2 times of mutation in features occurred in the past 47 years from 1966 to 2012. Through detailed analysis of related patterns, some signals for prediction of precipitation trend in inter-era, inter-annual and inter-month dimensions can be obtained, which can be served as theoretical and technical support for decision making in prevention and control of geological disasters.

3. Number of rain days with different intensities and distribution characteristics of amount of precipitation in Wenchuan Earthquake Areas demonstrate that number of days of light rain and medium rain distributes basically in a tapered pattern, reducing progressively from south to north, with two large-value centers located in Jiangyou, Anxian and Dujiangyan; Number of days of heavy rain and rainstorm in Wenchuan, Maoxian and Lixian is 1 day only and

number of days of rainstorm is nearly zero, which shows that heavy rainfall in these areas is almost zero, while sum of number of days of heavy rain and rainstorm in other areas normally exceeds 8 days. According to cumulative distribution of precipitation of different intensities in Wenchuan Earthquake Areas, the region can be divided into 3 precipitation types: Lixian, Wenchuan and Maoxian belong to a type with small amount of precipitation and small number of rain days; Beichuan, Jiangyou and Anxian belong to a type with large amount and high intensity of precipitation as well as large number of rain days; Dujiangyan, Mianzhu, Pingwu, Qingchuan, Pengzhou and Shifang belong to a type with uniform intensity of precipitation and large number of rain day. Apparently, the latter two types are likely to trigger geological disasters.

4. Long-time average annual value of PCD in Wenchuan Earthquake Areas is 0.6 and PCD concentrates in the beginning of the months from July to September (the 37th – 49th pentad) in main years, appearing at the earliest in the 36th pentad of 1980 (the 6th pentad in June) and at the latest in the 53rd pentad of 2008 (the 5th pentad in September). PCDs of the two areas of Lixian and Maoxian are relatively smaller and the corresponding PCPs are earlier, occurring in the first half of July (the 37th – 39th pentads of the year); At areas along Qingchuan, Jiangyou, Mianzhu, Pengzhou and Dujiangyan, PCPs occur almost all in the 6th pentad of July and the 1st pentad of August (the 42nd – 43rd pentad of the year), that is to say that occurrence period of rainstorm concentrates at the end of July and beginning of August. In addition, PCD of wet year is apparently larger than that of dry year. PCDs in eastern areas are larger than those of western areas of Wenchuan Earthquake Areas. There is great geographic variation in PCDs. Study of PCD enables us to focus our mind and energy in making sound policies in the process of prevention and control of geological disasters induced by heavy rainfall.

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