

The Spatial-Temporal Characteristics of Meteorological Disasters in the Southwest Region of Zhejiang Province during 1953-2022

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How to cite this paper: Zhang, Q., Wang, Y. F., Zhu, Z. D., Shi, H. X., Yang, W. H., & Yuan, S. J. (2024). The Spatial-Temporal Characteristics of Meteorological Disasters in the Southwest Region of Zhejiang Province during 1953-2022. *Journal of Geoscience and Environment Protection*, 12, 16-27.
<https://doi.org/10.4236/gep.2024.123002>

Received: November 30, 2023

Accepted: March 18, 2024

Published: March 21, 2024

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Abstract

Meteorological disasters are some of the most serious and costly natural disasters, which have larger effects on economic and social activity. Liuchun Lake is an ecotourism area in the southwest region of Zhejiang province, where also has experienced meteorological disasters including rainstorm and cold wave. Understanding the temporal-spatial characteristics of meteorological disasters is important for the local tourism and economic development. Based on the daily temperature and precipitation from 18 meteorological stations in the southwest of Zhejiang province during 1953-2022 and some statistical approaches, the temporal and spatial characteristics of meteorological disasters (Freezing, Rainstorm, Cold wave) are analyzed. The results indicate that 1) Rainstorm occurred frequently around the Liuchun lake, the frequency was about 8 times/a, it can also reach about 3 times/a in the other region. Freezing and cold wave (including strong cold wave and extremely cold wave) had the same spatial distribution as rainstorm, however, except for Liuchun lake, they occurred less than one time in the other regions; 2) The trend of rainstorm had larger spatial difference, it increased in all the study area, but it increased more significantly around the study area than around Liuchun lake. Freezing was on the downtrend in the whole region, with 93.3% of the stations passed the 95% significant level. Cold wave also showed a declined trend, but it was insignificantly at most of the stations, only 33% of the stations passed the 90% significant level. Compared with cold wave, strong cold wave and extremely strong cold wave had weaker decline in all the regions. In general, from 1953 to 2022 rainstorm showed an increasing trend, it was the main meteorological disaster in the study area, cold wave displayed a decreasing trend, but it still occurred about 2 - 3 times/a in most regions.

Keywords

Southwest of Zhejiang Province, Rainstorm, Cold Wave, Spatial Distribution, Trend Analysis

1. Introduction

As the global mean temperature increases, the extreme climate and weather events occur more frequently (Nangombe et al., 2018), which leads to the increase of the intensity and effects of meteorological disasters. Meteorological disaster are one of the most serious and costly natural disasters in the world (Liu & Yan, 2011; Guo & Li, 2005; Jin & Ming, 1996), the effect of the meteorological disasters on economic fluctuation, social harmony and crisis gradually becomes evident and serious (Li et al., 2021; Lee et al., 2017; Pederson et al., 2014). According to the United Nations, about 90% disasters around the world are related to the weather (UNDRR, 2017). In the future the temperature will continue to increase, the meteorological disaster losses may be likely to increase, and this will bring more threats and challenges to society (IPCC, 2012). Therefore, the meteorological disasters become one of the research focuses all over the world.

Zhejiang Province is the outlet of the largest inland river, Yangtze River, where the monsoon climate is evident and the climatic resources are abundant, meanwhile, the meteorological disasters also occur frequently. Rainstorm disaster is second only to the typhoon in Zhejiang Province, persistent rainstorm can lead to more secondary disasters, such as mountain torrents, landslides and mudslides (Wang et al., 2018). According to statistics, the rainstorm disaster losses can account for 30.1% of the all meteorological disaster losses (Zhang et al., 2009). Cold wave is one of the main severe weathers in the winter-half year in China, when the cold wave hits Zhejiang Province, the temperature will decline drastically, and it also brings the rain and snow, which have serious impact on the transportation, electricity, agriculture and forestry. In January of 2016, a rare strong cold wave occurred, accompanied by rain and snow in Zhejiang Province, low temperature broke or approached the historical extremes, which have cut citrus production by as much as 30%, and it would also had negatively affected the citrus industry and caused serious economic losses in the next few years (Xu & Xu, 2016).

In recent years, many scholars focused on the meteorological disaster including wave cold (Ji et al., 2008), heavy rainfall (Yang et al., 2023b), extreme high temperature (Yang et al., 2023a) in Zhejiang Province, the relative study on freezing, rainstorm and cold wave mainly focused on case analysis, and the studies on meteorological disasters during a long period were fewer. Therefore, this paper aims to analyze the spatial-temporal characteristics of meteorological disasters (including rainstorm, freezing and cold wave) in the southwest region during the period of 1953-2022, this is helpful for the disaster prevention and

mitigation and the local economic development in the southwest region of Zhejiang Province.

2. Data and Methods

After the strictly quality control and the error values correction, daily temperature and precipitation from 18 meteorological stations in the southwest region of Zhejiang province were used. Except for the three stations (LCHSY, LCHSD and BJDC), all the other stations cover the period of 1953-2022. The information of stations can be seen in **Table 1**; the distribution of stations can be seen in **Figure 1**.

3. Results

The Spatial-Temporal Characteristic of Meteorological Disasters

Figure 2(a) showed the distribution of the annual average frequency of meteorological disasters in the study area. It can be seen that the frequency of freezing had lower value in most regions of the study area, the frequency was not more than 1, however, it had higher value around the Liuchun Lake, where the average frequency can reach about 3 time/a, maybe it was related to the topographic feature. **Figure 2(b)** showed that rainstorm had higher frequency in the southwest and lower value in the northeast, it gradually decreased from southwest to northeast. The maximum value occurred around the Liuchun Lake, it can reach about 8 times/a, in other regions rainstorm also occurred more than 3 times/a, this implies that rainstorm often happened in the study area. The frequency of cold wave can be seen in **Figure 2(c)**, cold wave also had higher value around Liuchun Lake, the frequency was about 6 times/a, while in the other regions, it was less than 2 times/a. Strong cold wave and extremely cold wave had the same distribution with cold value, the higher value still appeared around Liuchun Lake,

Table 1. The information of stations used in this paper.

Stations	Longitude	Latitude	Altitude (m)	Stations	Longitude	Latitude	Altitude (m)
CS	118°30'25"	28°54'26"	136.2	CA	119°1'57"	29°36'22"	222.1
JD	119°16'28"	29°28'29"	89.1	JS	118°36'6"	28°42'36"	126.1
JH	119°39'21"	29°6'46"	62.6	LX	119°28'32"	29°13'5"	50.2
LQ	119°7'57"	28°4'50"	105.1	LY	119°11'7"	29°2'1"	161.4
PJ	119°52'20"	29°28'30"	115.6	QZ	118°53'27"	28°59'38"	82.4
SC	119°16'9"	28°35'42"	236.6	TL	119°40'8"	29°48'21"	44.4
WY	119°48'33"	28°53'24"	105.1	YW	120°5'14"	29°20'27"	90
YH	119°35'51"	28°6'25"	169.1	LCHSY	119°5'1"	28°46'56"	903
LCHSD	119°4'18"	28°45'2"	1327	BJDC	119°7'32"	28°47'9"	273

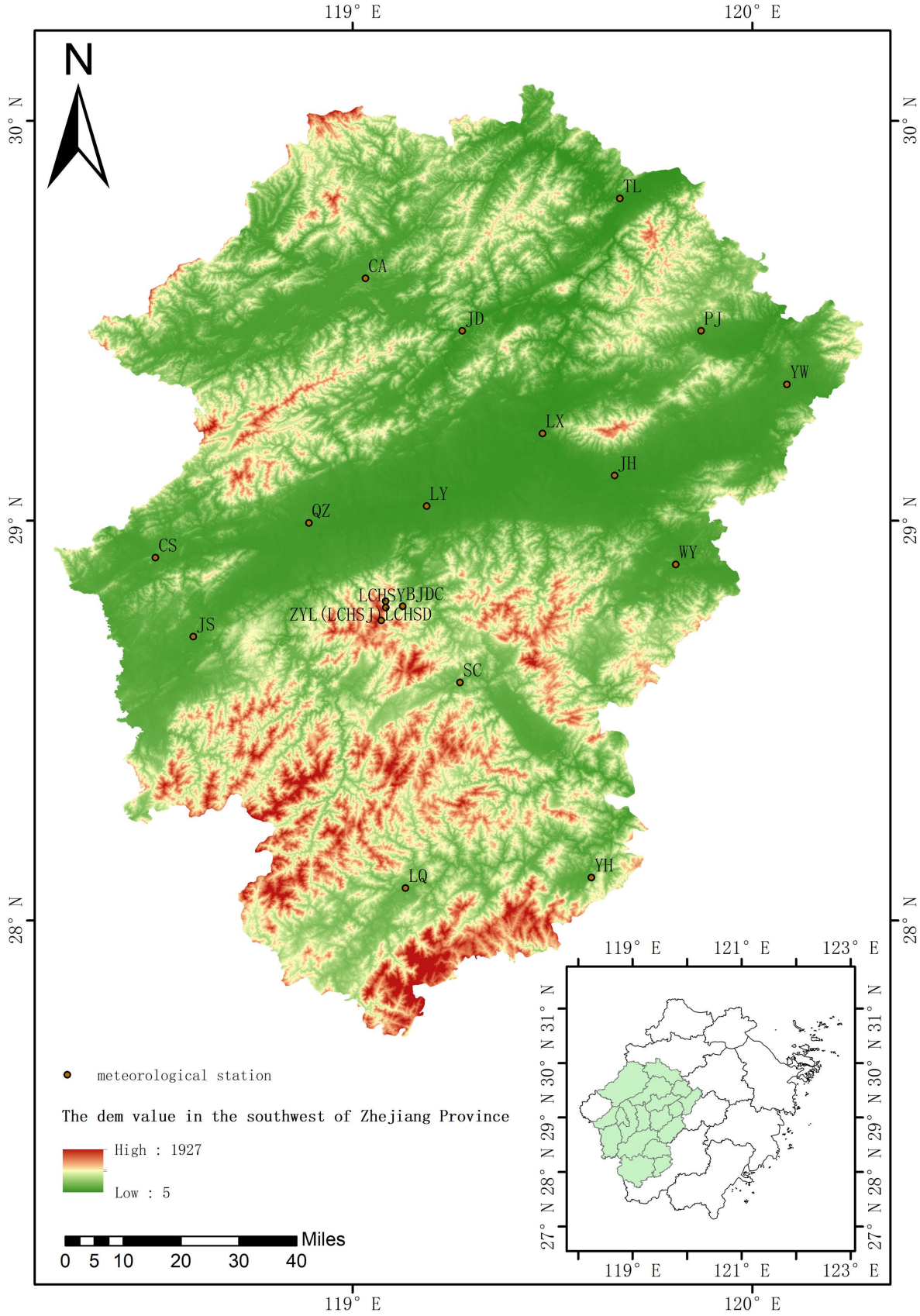


Figure 1. The study area and the location of the meteorological stations used in this study.

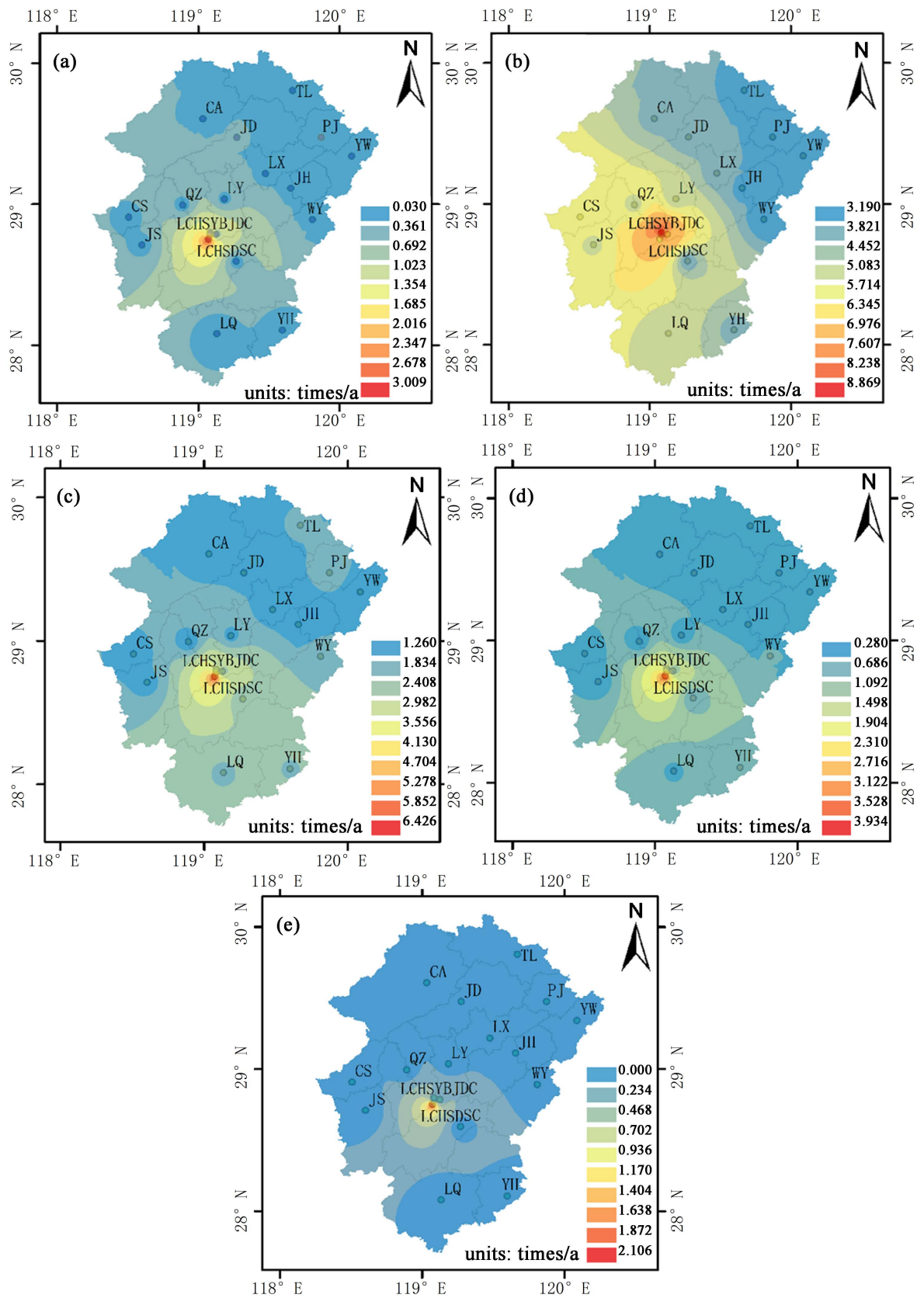


Figure 2. The distribution of annual mean frequency of freezing (a), rainstorm (b), cold wave (c), strong cold wave (d) and extremely strong cold wave (e) in the southwest part of Zhejiang province during the period of 1953-2022.

but the frequency was lower than the former. The maximum frequency of strong cold wave and extremely strong cold wave were 3 time/a and 2 times/a, respectively, in other regions, strong cold wave and extremely strong cold occurred less than one times. In general, around the Liuchun Lake all the disasters occurred more often than in other regions, rainstorm was the main disaster in all the study area.

Figure 3 displayed the change trend of freezing, rainstorm, cold wave, strong cold wave and extremely strong cold wave. It can be seen that the number of freezing decreased at all the stations, and about 93.3% of the stations passed the 95% significant level. The trend of freezing ranged from -0.06 to -0.17 times/10a, and the most significant declines occurred at PJ station in the northeast of study area. The maximum number of freezing in study area was between 1 and 4, at JD station the maximum value can reach about 4, and at most stations the maximum value was about 2 - 3 times (**Table 2**).

Figure 3(c) illustrated that cold wave was on the downtrend at most stations, with the trend of $-0.32 - 0$ times/10a, the most significant decline occurred at WY stations, about 33.3% stations passed the 90% stations, and at LY stations in the central of study area there was no change in trend of cold wave. **Table 2** showed that the maximum number of cold wave at all the stations ranged from 4

Table 2. The maximum number of meteorological disasters (freezing, rainstorm, cold wave, strong cold wave) at all the stations during the period of 1953-2022.

Stations	Classification				
	Freezing	Rainstorm	Cold wave	Strong cold wave	Extremely Strong cold wave
CS	2	12	4	2	1
CA	2	10	6	3	1
JD	4	9	6	3	2
JS	2	12	6	2	1
JH	3	8	6	4	1
LX	2	9	6	3	2
LQ	1	11	5	2	1
LY	2	10	5	2	1
PJ	3	9	5	2	1
QZ	2	13	5	3	1
SC	2	8	6	3	1
TL	3	10	6	2	2
WY	2	10	7	4	1
YW	2	8	6	4	1
YH	1	9	7	4	1

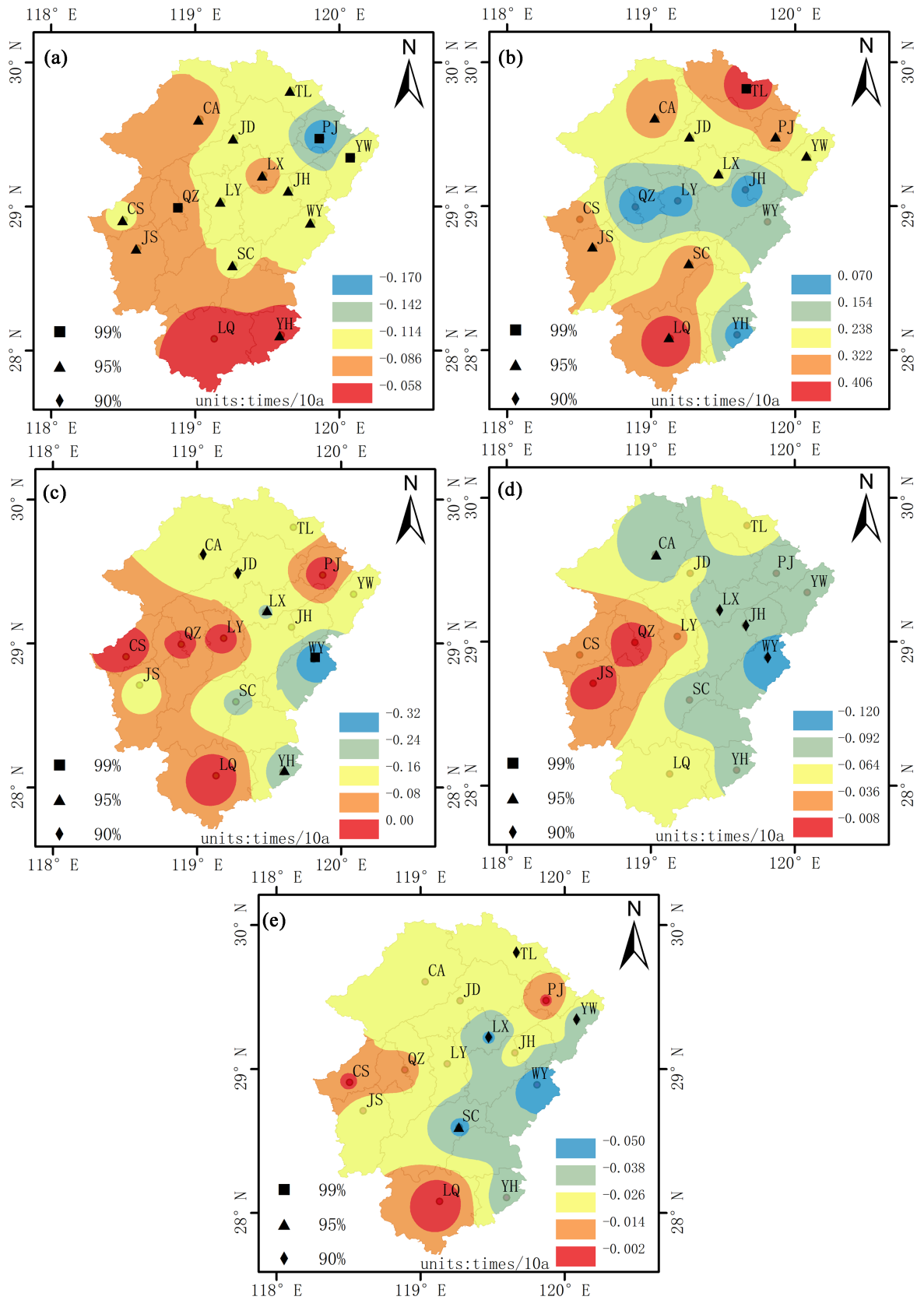


Figure 3. The spatial distribution of the change trend of freeze (a), rainstorm (b), cold wave (c), strong cold wave (d) and extremely strong cold wave (e) in the southwest part of Zhejiang province during the period of 1953–2022.

to 7 times, and at most stations the maximum value can reach about 6, this means the occurring of cold wave are consistent at all the stations.

Figure 3(d) showed that the strong cold wave also displayed a declined trend, but there are only 26.7% of the stations passing the 90% significant level. The maximum number of strong cold wave was about 2 - 4 times. **Figure 3(e)** demonstrated that extremely strong cold wave also had decreasing trend, but at most stations they were insignificant, only 26.6% of stations passed the 90% significant level, and the most significant decreasing occurred at SC stations. **Table 2** showed the maximum number of extremely strong cold wave was about 1 - 2 times.

In general, under the background warming, rainstorm displayed an increasing trend in the southwest region of Zhejiang province, while the freezing, cold wave, strong cold wave, and extremely strong cold wave were decreasing.

Figure 4 showed the annual variation of meteorological disasters in southwest part of Zhejiang province from 1953-2022. **Figure 4(a)** indicated that the number of freezing had a decreasing trend, and the trend was about -0.081 times/10a.

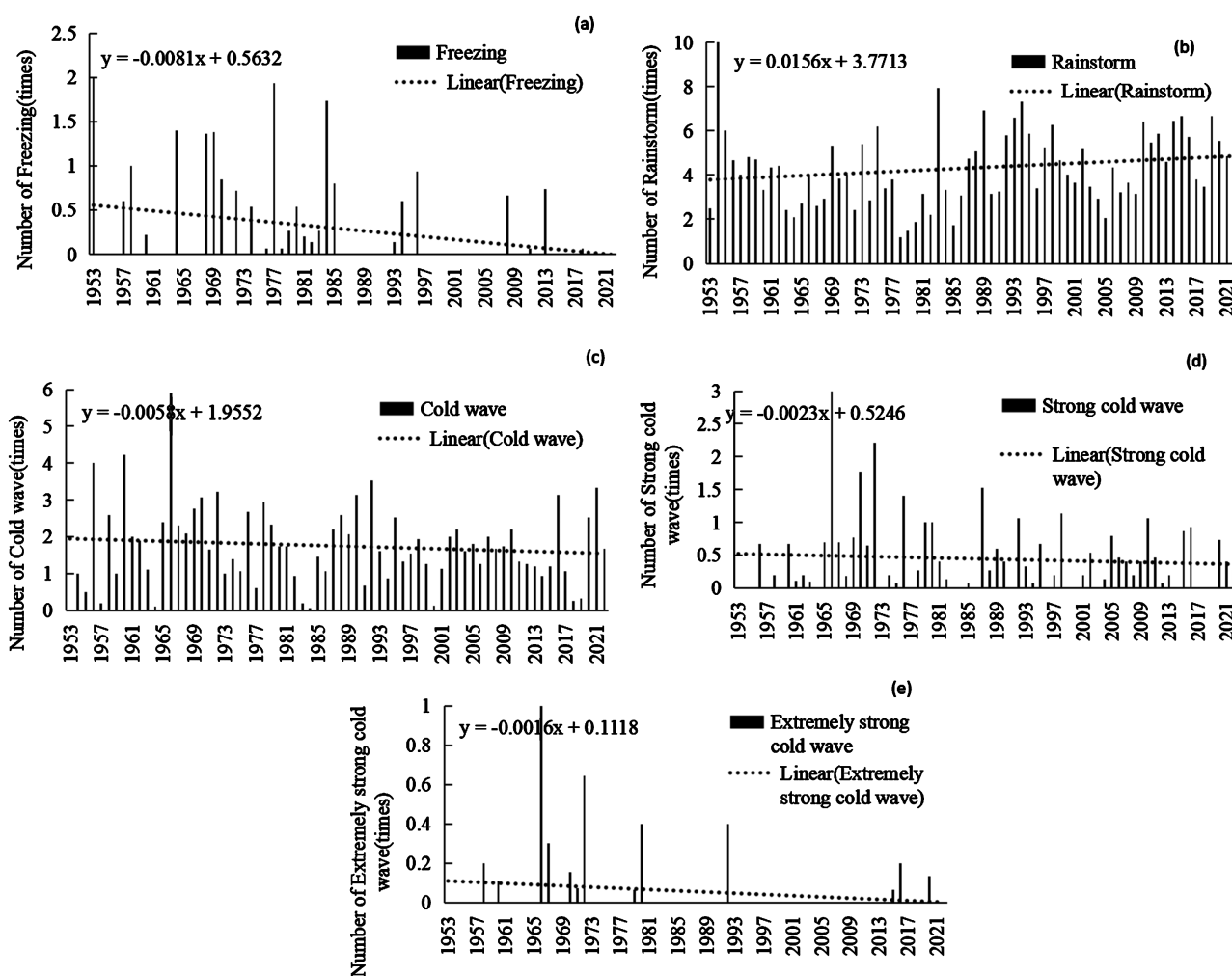


Figure 4. The annual variation of number of the meteorological disasters (freezing (a), rainstorm (b), cold wave (c), strong cold wave (d), extremely cold wave (e)) in the southwest region of Zhejiang Province during the period of 1953-2022.

Freezing did not happen in most years, and taken place twice in 1953 and 1977. It can be seen from **Figure 4(b)** that rainstorm had an increasing trend, with the trend of 0.16 times/10a, rainstorm appeared more than twice, the maximum value occurred in 1954, in which rainstorm happened 10 times. **Figure 4(c)** also displayed that cold wave had a declined trend, it was about -0.06 times/10a, cold wave basically occurred at all the stations in every year, and in most years cold wave occurred more than twice. Strong cold wave also decreased from 1953 to 2022, the trend was about -0.02 times/10a, the number of strong cold wave occurring decreased compared with cold wave. Although extremely strong cold wave also was on the downtrend, it basically did not take place in most years, only in 1966 it occurred more than one times.

Figure 5 showed the annual variation of maximum number of disasters occurring at all the stations. **Figure 5(a)** displayed that the maximum value of

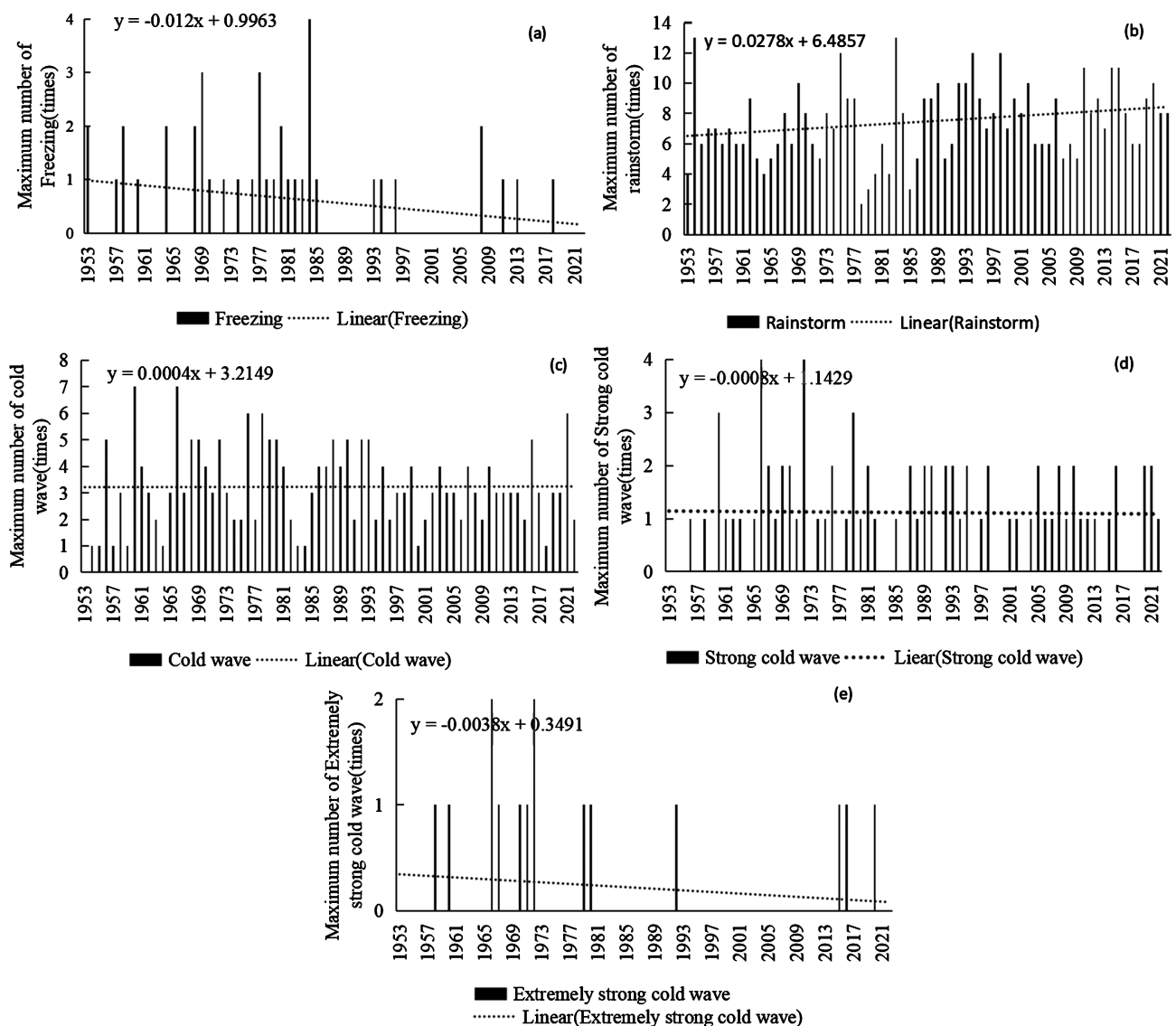


Figure 5. The annual variation of maximum number of the meteorological disasters (freezing (a), rainstorm (b), cold wave (c), strong cold wave (d), extremely cold wave (e)) in the southwest region of Zhejiang Province during the period of 1953-2022.

freezing had a declined trend, especially after 1985, freezing taken place not very often, it only happened in 9 years during 1985-2022, maybe this is related to the climate warming. **Figure 5(b)** demonstrated that the maximum number of rainstorm occurring had an increasing trend, the trend was about 0.28 time/10a, it was larger than that of the mean value of rainstorm. It can be seen that **Figure 5(c)** that the maximum number of cold wave had a weak increasing trend, most of them can reach about 3. However, the maximum of strong cold wave displayed a weak decreasing trend. The extremely strong cold wave only occurs in 14 years during the period of 1953-2022, and the maximum value was 2. This implies freezing, cold wave, strong cold wave and extremely cold wave had decreasing trend, but the frequency of cold wave was higher. Rainstorm had an increasing trend, therefore, rainstorm and cold wave were the main meteorological disasters in the study area.

4. Conclusion and Discussion

Liuchun Lake is one of the most potential leisure resorts in Zhejiang Province. The meteorological disasters had serious influence on the tourism and local economic development. Understanding the temporal and spatial characteristics of meteorological disasters is useful for disaster prevention and mitigation. Based on the daily temperature and precipitation data, the characteristics of meteorological disaster (including freezing, rainstorm, cold wave, strong cold wave and extremely strong cold wave) in the southwest region of Zhejiang are analyzed. The main results are as follows:

Liuchun Lake is the highest mountain in Longyou country, where the altitude is about 1442 m. Due to the special geographical features, around Liuchun Lake all the disasters occurred most frequently. Especially rainstorm happened about 8 times around the Liuchun Lake, and 3 times in the other regions. Compared with the other disasters, rainstorm had the wider range and greater intensity. It is the main disaster in the southwest region of Zhejiang Province.

Rainstorm had an increasing trend in the study region, the most significant decrease appeared around the study area, with the trend of 0.4 times/10a, while around the Liuchun Lake, the trend was only about 0.07 times/10a. However, the other disasters had a declined trend, this may be related to the climate warming.

This paper mainly aims to study the spatial-temporal characteristics of meteorological disasters around Liuchun Lake, but there are only three stations around Liuchun Lake, they are on the top, the foot of the mountain and on the mountainside, respectively, and the time period of the them are also relatively short, which may have certain influence on our results, furthermore, maybe we will use some grid data with high resolution to supplement and perfect the result in this paper.

Funding

This study is supported by the research and demonstration on key technologies of meteorological service for alpine tourism in Liuchun Lake (JHXM2022170),

the National Science Foundation of Sichuan Province (2022NSFSC1006).

Conflicts of Interest

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

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