Analysis and Evaluation of Tourism Climate Comfort in Wengyuan County

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Abstract Based on the data of the national station in Wengyuan County from 1975 to 2024, the tourism climate comfort of Wengyuan County was analyzed and evaluated by using temperature-humidity index, wind chill index, holiday climate index, and linear trend analysis. The results show that in Wengyuan County, people felt most comfortable in April, May, October, and November, and the holiday climate index in each month was over 63, reaching or exceeding the "suitable" level, and there were no "acceptable" or lower levels. Spring and autumn were the best time for people to visit Wengyuan. The temperature-humidity index in Wengyuan County rose significantly at a tendency rate of 0.19/10 a, while wind chill index dropped significantly at a tendency rate of 2.9/10 a. The annual average number of comfortable days in Wengyuan was up to 164 d, accounting for over 44.9% of the total number in the whole year. It tended to decline at a tendency rate of −3.9/10 a. The annual average number of uncomfortable cold days and uncomfortable hot days showed an upward trend at a tendency rate of 1.5/10 a and 1.7/10 a, respectively. HCL and the number of days with unfavorable climate tended to decline slowly at a tendency rate of −0.236/10 a and −0.248/10 a, respectively. The number of days with suitable climate showed an upward trend at a tendency rate of 1.2/10 a, while the number of days with general and acceptable climate showed a slow downward trend at a tendency rate of −1.96/10 a.

Key words Tourism comfort; Temperature-humidity index; Wind chill index; Holiday climate index; Wengyuan

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Since the Industrial Revolution, emissions of greenhouse gases have been continuously increasing, and extreme weather and climate events have occurred more frequently, which has affected human activities[1-5]. Climate comfort, as a meteorological indicator for evaluating the exchange of energy and substances between human activities and the near-ground atmosphere[6], aims to assess people's comfort levels under different climate conditions from the aspects of meteorological factors such as temperature, humidity, and wind[7]. With people's aspiration for a better life, tourism demands have been continuously released, and the experience of tourists brought by climate comfort in different regions is significantly different. Therefore, climate comfort has also become an important reference for people when choosing a tourist destination. Many conditions can affect climate comfort. Many domestic scholars have conducted research on tourism climate comfort and climate pleasantness, *etc.*, laying the foundation for the development of climate tourism resources in different regions[8-17].

Wengyuan City, which is located in the north of Guangdong Province, has a mid-subtropical monsoon climate. It is warm and humid, with abundant rainfall. It is a mountainous and hilly area, where there is a large temperature difference between day and night, fresh air, and excellent water quality. It is very suitable for the growth of orchids, so it is called "the Land of Chinese Orchids". The diversity of climate and terrain and world-class natural heritage provide unique advantages for building the "ecological, cultural, tourism, and health care destination" of the Guangdong-Hong Kong-Macao Greater Bay Area. In this paper, based on the data of the national station in Wengyuan County, the tourism climate comfort of Wengyuan County was analyzed and evaluated by using methods such as temperature-humidity index, wind chill index, holiday climate index, and linear trend analysis, so as to provide references for the local tourism and health and leisure planning and scientific basis for people to choose the season and period for travel.

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1 Data and methods

1.1 Data The data used in this study are derived from the daily observation data of relative humidity, wind speed, temperature, cloud cover, and sunshine duration at the national meteorological station of Wengyuan County from 1975 to 2024. The seasons are defined as follows: spring is from March to May, and summer is from June to August; autumn is from September to November, and winter is from December to next February.

1.2 Methods According to the *Climatic Suitability Evaluating on Human Settlement* (GB/T 27963-2011)[18], temperature-humidity index (THI) and wind chill index (WCI) can be calculated based on formulas (1) and (2). The climate comfort of human settlement can be divided into five grades (Table 1). When the two indexes are inconsistent, THI is used in the summer half-year, and WCI is used in the winter half-year.

$$THI = t - 0.55 \times (1 - rh) \times (t - 14.4) \quad (1)$$

$$WCI = -(10\sqrt{v}) + 10.45 - v)(33 - t) + 8.55s \quad (2)$$

In formulas (1) and (2), t, rh, v and s represent temperature (℃), relative humidity (%), wind speed (m/s) and sunshine duration (h), respectively.

Table 1 Classification of the climate comfort of human settlement

Grade	Sensation	THI	WCI	Human sensation
1	Cold	<14.0	< -400	Very cold
2	Chilly	14.0 -16.9	-400 - -300	Rather cold
3	Comfortable	17.0 -25.4	-299 - -100	Comfortable
4	Hot	25.5 -27.5	-99 - -10	Rather hot
5	Sultry	>27.5	> -10	Sultry

Holiday climate index (HCI) takes into account various climatic factors related to people's travel and preferences. It is composed of three factors: thermal comfort, aesthetics, and physics. The daily maximum temperature and relative humidity constitute the thermal comfort factor, with a weight of 40%. The aesthetic factor accounts for 20%, and it is only related to cloud cover. The physical factor can be calculated based on daily precipitation and daily average wind speed (with a weight of 30% and 10%, respectively). Then, scoring and rating are conducted according to Table 2, and HCI can be calculated based on formulas (3) and (4). Finally, it is classified according to Table 3. The formulas are as below:

$$TC = t_{max} - 0.55 \times (1 - rh) \times (t_{max} - 14.4) \quad (3)$$

$$HCI = 4TC + 2A + (3R + W) \quad (4)$$

In formulas (3) and (4), TC represents the thermal comfort factor, while A, R, W, and t_{max} stand for cloud coverage (%), daily precipitation (mm), daily average wind speed (km/h), and daily maximum temperature (℃), respectively.

Table 2 Scoring of holiday climate variables

Grade	Effective temperature//℃	Daily precipitation//mm	Cloud coverage//%	Wind speed//km/h
10	23 -25	0	11 -20	1 -9
9	20 -22 26	<3	1 -10 21 -30	10 -19
8	27 -28	3 -5	0 31 -40	0 20 -29
7	18 -19 29 -30		41 -50	
6	15 -17 31 -32		51 -60	30 -39
5	11 -14 33 -34	6 -8	61 -70	
4	7 -10 35 -36		71 -80	
3	0 -6		81 -90	40 -49
2	-5 - -1 37 -39	9 -12	>90	
1	< -5			
0	>39	>12		50 -70
-1		>25		
-10				>70

Table 3 Grading standard of HCI

HCI	Grade
10 -19	Extremely unsuitable
20 -29	Very unsuitable
30 -39	Unsuitable
40 -49	General
50 -59	Acceptable
60 -69	Suitable
70 -79	Quite suitable
80 -89	Extremely suitable
90 -100	Ideal state

2 Results and analysis

2.1 Monthly and seasonal changes in tourism climate comfort

2.1.1 Monthly and seasonal changes in THI. As shown in Table 4, the monthly average THI in Wengyuan County was all below 13.5 from December to next February. This period was the coldest in Wengyuan, and the county frequently experienced significant cooling and strong winds brought by cold air, making people feel "cold". From April to May and from September to November, THI was between 17 and 25. These periods were in spring and autumn, and were characterized by moderate humidity, temperature, light, and wind speed, so people felt "comfortable". From June to August, THI was above 25.5. This period was in late spring and summer, with strengthened solar radiation, increased rainfall, and smaller wind speed, and people felt "hot".

Table 4 Monthly changes and classification of THI in Wengyuan County

Month	THI	Sensation
January	11.9	Cold
February	13.3	Cold
March	16.2	Chilly
April	20.4	Comfortable
May	23.6	Comfortable
June	25.7	Hot
July	26.7	Hot
August	26.5	Hot
September	24.7	Comfortable
October	21.3	Comfortable
November	17.2	Comfortable
December	13.1	Cold

2.1.2 Monthly and seasonal changes in WCI. From Table 5, it can be seen that the WCI in Wengyuan County was below -400 in January, and the human body felt "cold". In February, March, and December, WCI was -395, -320, and -386, respectively, and the human body also felt "cold". In April, May, October and November, the human body felt "comfortable". From June to September, the human body felt "hot".

From the above analysis, it can be concluded that in Wengyuan County, the human body felt warmer or colder mainly from June to September and from December to next March. The human body felt comfortable in April, May, October and Novem-

ber, and these periods were mainly in spring and autumn, with moderate temperature, humidity, wind speed, and light, so these periods were the best time for people to visit this area.

Table 5 Monthly changes and classification of WCI in Wengyuan County

Month	WCI	Sensation
January	-428	Cold
February	-395	Chilly
March	-320	Chilly
April	-215	Comfortable
May	-134	Comfortable
June	-80	Hot
July	-34	Hot
August	-47	Hot
September	-90	Hot
October	-172	Comfortable
November	-280	Comfortable
December	-386	Chilly

2.1.3 Monthly and seasonal changes in HCI. As shown in Table 6, the monthly average HCI in Wengyuan County was above 63 in all months, reaching or exceeding the "suitable" level, and there were no "acceptable" or lower levels. According to the national standard *Climate Resources Evaluation - Climate Livable Cities* (QX/T 570 - 2020)[18], the climate suitability of counties where the number of months with suitable HCI exceeded 10 was all excellent. In Wengyuan County, HCI was all above 70 from January to April and from September to December, and the climate was "very suitable", while it was suitable in other months. These months had less rainfall and moderate temperature, wind speed, humidity, and cloud cover, and were the best time for tourism and vacation.

Table 6 Monthly changes and classification of HCI in Wengyuan County

Month	HCI	Grade
January	72	Quite suitable
February	70	Quite suitable
March	70	Quite suitable
April	71	Quite suitable
May	68	Suitable
June	63	Suitable
July	66	Suitable
August	66	Suitable
September	72	Quite suitable
October	81	Extremely suitable
November	81	Extremely suitable
December	77	Quite suitable

2.2 Annual changes in tourism climate comfort

2.2.1 Annual changes in THI and WCI. Fig. 1 shows that the annual average THI in Wengyuan County was 20.1, and the maximum 21.0 occurred in 2021, while the minimum 19.1 appeared in 2011. THI showed an upward trend at a tendency rate of 0.189/10 a, which passed the significance test at 0.05 level. The annual average WCI in Wengyuan was -214, and WCI showed a downward trend at a tendency rate of -2.9/10 a, but it did not passed the significance test at 0.01 level.

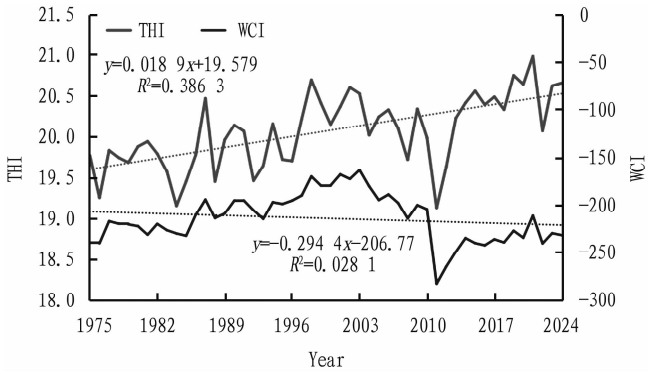

Fig. 1 Annual changes in THI and WCI in Wengyuan County during 1975 - 2024

2.2.2 Annual changes in the number of comfort days. Based on daily THI and WCI, the number of comfortable days and uncomfortable days each year can be statistically calculated. Among them, the total number of cold and chilly days is the number of uncomfortable cold days, and the total number of hot and sultry days is the number of uncomfortable hot days.

As shown in Fig. 2, the annual average number of comfortable days in Wengyuan was 164 d, accounting for more than 44.9% of the total number in the whole year. It showed a downward trend at a tendency rate of -3.9/10 a. The correlation coefficient was 0.21, not passing the significance test at 0.01 level. The annual average number of uncomfortable cold days was 98 d, and showed an upward trend at a tendency rate of 1.5/10 a, but it did not pass the significance test at 0.05 level. The annual average number of uncomfortable hot days was 101 d, and also showed an upward trend at a tendency rate of 1.7/10 a. The correlation coefficient was above 0.210 4, passing the significance test at 0.05 level.

2.2.3 Annual changes in HCI. By using daily data of HCI, the monthly and annual average number of days with suitable, acceptable, and unsuitable holiday climate can be statistically calculated. Among these, the number of days with suitable holiday climate is the total number of days with suitable, very suitable, extremely suitable, and ideal conditions, and the number of acceptable days is the total number of general and acceptable days. The number of days with unsuitable holiday climate is the total number of days with unsuitable, very unsuitable, and extremely unsuitable holiday climate.

Statistical analysis indicates that the annual average HCI in Wengyuan was 71. The maximum 78.1 occurred in 2023, and the minimum 64.5 appeared in 2016. Both of them were above the "suitable" level. Fig. 3 shows that HCL and the number of days with unfavorable climate in Wengyuan both showed a slow downward trend at a tendency rate of -0.236/10 a and -0.248/10 a, respectively, and they did not pass the significance test. The number of days with suitable climate in Wengyuan showed a slow upward trend at a tendency rate of 1.2/10 a, and did not pass the

significance test. The number of days with general and acceptable climate tended to decrease slowly at a tendency rate of −1.96/10 a, and the correlation coefficient did not pass the significance test.

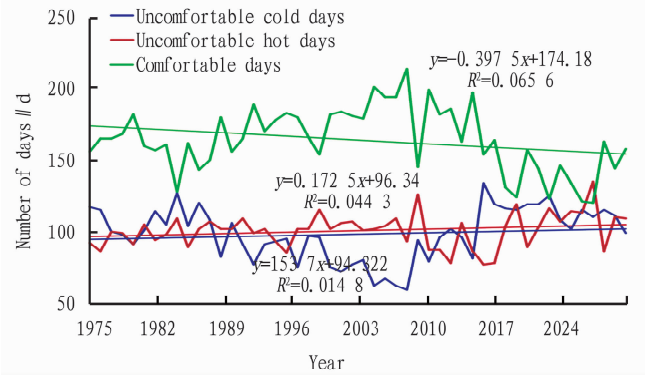

Fig. 2 Annual changes in the number of comfortable days and uncomfortable days in Wengyuan from 1975 to 2024

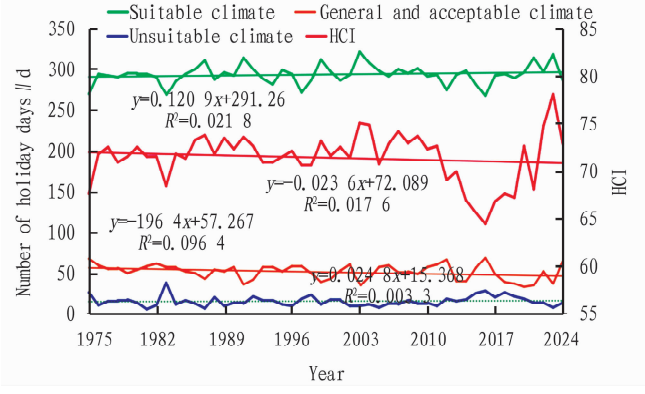

Fig. 3 Annual changes in the holiday climatic suitability of different levels in Wengyuan from 1975 to 2024

3 Conclusions

In April, May, October, and November, people felt most comfortable in Wengyuan, and the holiday climate index in each month consistently exceeded 63, reaching or exceeding the "suitable" level, and there were no "acceptable" or lower levels. Spring and autumn had moderate temperature, humidity, wind speed, and light, so they were the best time for people to visit this area.

The temperature-humidity index in Wengyuan County significantly increased at a tendency rate of 0.19/10 a, while wind chill index significantly declined at a tendency rate of 2.9/10 a. The annual average number of comfortable days in Wengyuan was 164 d, accounting for more than 44.9% of the total number in the whole year. It tended to decrease with a tendency rate of −3.9/10 a. The annual average number of uncomfortable cold days and uncomfortable hot days tended to increase with a tendency rate of 1.5/10 a and 1.7/10 a, respectively.

The annual average HCI in Wengyuan was up to 71, reaching the "very suitable" level. HCL and the number of days with unfavorable climate tended to decrease slowly at a tendency rate of −0.236/10 a and −0.248/10 a, respectively. The number of days with suitable climate tended to rise slowly at a tendency rate of 1.2/10 a. The number of days with general and acceptable climate tended to drop slowly at a tendency rate of −1.96/10 a.

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