Research on the Comfort of Outdoor Thermal Environment in Old Communities in Mild Climate Areas

Yiming Xing and Yan Wang(✉)

Guizhou University, Guiyang 550000, China
53783147@qq.com

Abstract. Taking four representative old communities in Guiyang City, a representative city in mild climate areas, as the research objects, the current situation of thermal environment and thermal sensation of residents in the old communities in each season were understood through field measurement and questionnaire survey, and relevant thermal comfort indexes—PET, SET* and UTCI were calculated to analyze and determine the functional relationship between each index and subjective feeling. The neutral thermal sensitivity range, thermal comfort zone and 90% thermal acceptance range of residents in different seasons were obtained. Based on the prediction accuracy of the comfort range of different indicators, the thermal comfort ranges of indicators in different seasons were respectively: SET* (20.8 °C–26.1 °C) in spring, SET* (20.2 °C–31.9 °C) in summer, PET (≤25.5 °C) in autumn, and UTCI (9.9 °C–13.6 °C) in winter.

Keywords: Old community · Mild climate area · Thermal comfort evaluation

1 Introduction

Outdoor thermal environment is related to human settlement comfort and human flow activities, which is restricted by weather, space, greening and other factors. In China's economically underdeveloped mild climate areas, densely populated residential areas, there are a large number of old communities before 2000. Poor ventilation, insufficient shading and insufficient green amount are common problems in these old communities. Therefore, understanding and mastering the outdoor thermal environment of old communities in relevant areas is helpful to improve the current situation of the thermal environment, and enhance the comfort level of residents and the utilization rate of space.

1.1 Research on Outdoor Thermal Environment

Early research on thermal environment mainly focused on the field of climatology, focusing on the urban thermal environment in large areas [1], In the later stage, it gradually shifted to small and medium scale or micro-space, and improved the quality of human settlements by studying the thermal environment [2]. At present, the research

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on outdoor thermal environment mainly focuses on thermal environment evaluation, influencing factors and thermal comfort evaluation.

Outdoor thermal environment evaluation can be divided into two types: thermal safety evaluation and thermal comfort evaluation [3], For example, Wet Bulb Globe Temperature (WBGT) is often used as the basis for thermal safety evaluation of residential thermal environment. In terms of evaluation methods, observation and simulation are usually used [4], Due to its characteristics of both flow [5] and fixed [6], observation method has been widely used in the study of residential thermal environment [7].

The research on the factors affecting outdoor thermal environment is more extensive. In addition to meteorological factors, the main environmental factors include urban spatial form, vegetation cover, skin material and so on [8], and individual characteristics and differences will also affect the perception of outdoor thermal environment [9]. Therefore, the research on outdoor thermal environment gradually began to break the disciplinary barrier, involving more fields including physiology, medicine, mathematics, computer and so on, in order to seek the most authentic environmental evaluation and perception.

1.2 Research on Thermal Comfort

The research on thermal environment comfort evaluation has a history of nearly one hundred years, during which it mainly experienced three stages of development, namely the early single measurement data stage, the empirical model stage and the mechanism model stage. The most common thermal comfort index based on the mechanism model at present, Including Physiological Equivalent Temperature (PET), New Standard Effective Temperature (SET^*), Universal Thermal Climate Index (UTCI), etc.[10], because of its consideration of many factors, including physical environment parameters and human physiological behavior factors, so it is widely used in outdoor thermal comfort research. Some scholars found in the adaptive study of thermal comfort indexes in Shanghai that UTCI and PET indexes in summer and winter are more appropriate to predict subjective feelings [11]. In the study on the thermal environment of urban slow walking space in Guangzhou, some people concluded that the most comfortable voting interval of pedestrian SET^* in spring is 18.0–22.0 °C [12], Some people think that UTCI can accurately predict outdoor thermal comfort in cold regions in Tianjin [13].

To conclude, existing studies mainly focus on cold areas with significant climate characteristics or areas with hot summer and cold winter, rarely involving mild climate areas, and research objects rarely involve old urban communities. With economic development, residents have increasingly higher requirements for the comfort level of human settlements, so there is still a large space for exploration on the thermal environment characteristics of mild climate areas and the applicability of various thermal comfort indexes. Taking four old communities in Guiyang as an example, this paper analyzed the outdoor space thermal environment in different seasons and determined the applicability and value range of thermal comfort indexes PET, SET^* and UTCI through on-site meteorological parameter measurement and residents' actual thermal sensation survey, which provided theoretical basis for the research on outdoor thermal environment of old communities in mild climate areas.

2 Research Content

2.1 Research Object

Guiyang is located in the middle of the original hills of the central Guizhou mountains on the Yunnan-Guizhou Plateau. The climate type of Guiyang belongs to the subtropical monsoon humid climate. In the building thermal zone of China, it is a mild area with abundant rainfall and mild climate in all seasons. The research sites are mainly Nanming District and Huaxi District, Guiyang City. The target residential areas are mainly multi-storey residential areas built before 2000, including original unit residential areas, old-fashioned apartments, factory family areas, etc. Among them, Dianli Lane community and Memorial Tower community are selected in Nanming District, Xibei Community and Ziguangxuan Community are selected in Huaxi District. Due to their early construction, Long time, often lack of sufficient external activity space, easy to produce poor thermal environment experience.

2.2 Field Test

The test time is divided according to the season, and the weather suitable for outdoor activities is usually sunny or cloudy. The test time is two days in each season, from 8:00 to 20:00 on the same day. See Table 1 for the specific test time. Two public Spaces with frequent residents' activities were selected as measuring points in each community, with a total of eight measuring points. The specific distribution is shown in the figure (Fig. 1). The weather on the test day was clear and rainless, which was suitable for outdoor activities.

Fig. 1. Distribution of measuring points

The main outdoor thermal environment parameters collected during the measurement include air temperature (Ta), relative humidity (RH), bulb globe temperature (Tg),

Table 1. Parameter records and questionnaire survey time

Year	Season	Date	Parameter records	Questionnaire survey	Quantity
2022	Spring	5.3, 5.4	7:00–19:00	8:00–12:00&14:00–18:00	329
	Summer	7.12, 7.13	7:00–20:00	7:00–12:00&14:00–18:00	310
	Autumn	10.23, 10.24	7:00–19:00	8:00–12:00&14:00–18:00	302
	Winter	12.13, 12.14	7:00–19:00	8:00–12:00&14:00–18:00	280

wind speed (V)and solar radiation (G), and each thermal comfort index and average radiant temperature (Tmrt) are calculated accordingly. The calculation of average radiant temperature is shown in Formula (1) [14].

$$T_{mrt} = \left[(Tg + 273.15)^4 + \frac{1.10 \times 10^8 V^{0.6}}{\varepsilon D^{0.4}} (Tg - Ta) \right]^{1/4} - 273.15 \quad (1)$$

where: Tg is the bulb globe temperature (°C); ε is black sphere radiation coefficient, ε = 0.95 in this study; D is the diameter of the black sphere (m), D = 0.075 in this study; V is wind speed (m/s); Ta is the air temperature (°C).

The main instruments used in the testing process include temperature and humidity instrument, anemometer, black ball thermometer and solar radiation instrument. The specific parameters are shown in Table 2.

Table 2. Details of test instrument parameters

Parameter	Instrument	Range	Accuracy	Resolution
Ta	JTR08 Temperature and humidity meter	− 20–80 °C	± 0.2 °C	0.1 °C
RH		0–100%	± 1.5% RH	0.1%
Tg	AZ8778 Thermal index meter	− 10–80 °C	± 1.5 °C	0.1 °C
V	YGY-FSXY2 Anemometer	0–30 m/s	± 0.3 m/s	0.1 m/s
G	TES-1333 Solar radiometer	0–2000 W/m^2	± 5%	0.1 W/m^2

2.3 Questionnaire Survey

In addition to the measurement of thermal environment parameters, a questionnaire survey on the thermal environment was carried out among the residents living in the measurement area. A total of 1221 valid questionnaires were collected in four seasons, including 329 in spring, 310 in summer, 302 in autumn and 280 in winter. The questionnaire mainly consists of two parts. The first part is the basic information of the respondents, including age, height, weight, clothing (clothing heat resistance), activity status and activity duration. The second part is the respondents' thermal environment feeling, including cold and hot feeling, comfortable state, environmental acceptance, thermal environment expectation, etc. In order to improve the matching degree between the questionnaire content and the actual Thermal Sensation, the Thermal Sensation Vote (TSV) adopts the bipolar 9-level (extended) scale. TSV ranges from − 4 to 4, indicating the temperature from cold to hot. Thermal Comfort Vote (TCV) and Unaccept Rate Vote (URV) are single-level scales [15], TCV ranges from 0 to 4, indicating comfort to extreme discomfort, URV ranges from 0 to 3, indicating complete acceptance to difficult acceptance. At the same time of questionnaire survey, relevant thermal environment parameters of interviewees in the range were recorded.

2.4 Calculation of Thermal Comfort Index

The thermal comfort indexes such as PET, SET* and UTCI are calculated with RayMan-Pro software. The environmental parameters involved and residents' personal characteristics are collected through measurement and questionnaire. The individual metabolic rate was determined as sitting (60 W/m^2), standing (70 W/m^2), walking (115 W/m^2), light exercise (120 W/m^2), moderate exercise (200 W/m^2), vigorous exercise (350 W/m^2) and taking care of children (150 W/m^2) according to the main activity state of the respondents within 15 min.

3 Result Analysis

3.1 Subjective Questionnaire Analysis

As shown in Fig. 2, residents' outdoor thermal environment sensation voting in spring and summer is generally hot (+1), and 49% and 52% of residents' thermal sensation voting is slightly warm or above, respectively. This may indicate that in spring, residents still retain the memory of cold winter and the climate feature of large temperature difference after rain in Guiyang, which makes residents' clothing thicker in spring and overall thermal sensation hotter. Summer may be due to the overall warmer climate. The overall thermal sensation of residents in autumn is neutral, and 54% of them vote as not cool or hot. The reason may be that the outdoor thermal environment in autumn is relatively stable. The overall thermal perception of residents in winter is relatively cold, and 73% of them vote slightly cold or above for thermal perception, which may be due to the cold overall thermal environment in winter and the inherent cold impression of residents in winter.

As shown in Fig. 3, residents' outdoor thermal environment comfort vote shows that in autumn, residents' comfort (0) accounts for the highest proportion, about 64%, probably because the overall temperature in autumn is suitable and does not fluctuate much. The proportion of residents' comfort in spring and summer is similar, about 48%. Large temperature fluctuation in spring, high overall temperature in summer and heat energy generated by exercise may reduce residents' comfort in thermal environment. The proportion of residents' comfort in winter is the lowest, which is about 19%. The decrease of exercise in winter and the increase of instantaneous wind speed may reduce residents' thermal comfort.

As shown in Fig. 4, the outdoor thermal environment acceptance vote of residents shows that the overall outdoor thermal environment acceptance of residents is about 84.7% in spring, 83.5% in summer, 90.7% in autumn and 61.1% in winter, which reflects that residents have poorer adaptability to outdoor thermal environment in winter and prefer autumn with stable thermal environment.

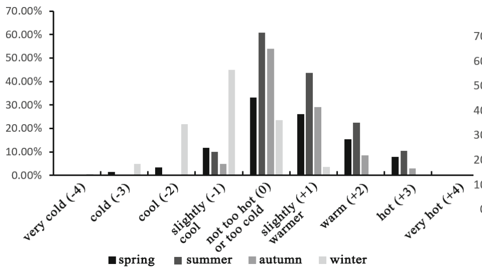

Fig. 2. Thermal Sensation Vote (TSV)

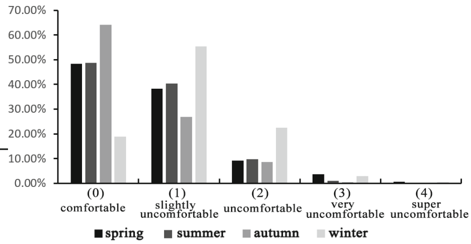

Fig. 3. Thermal Comfort Vote (TCV)

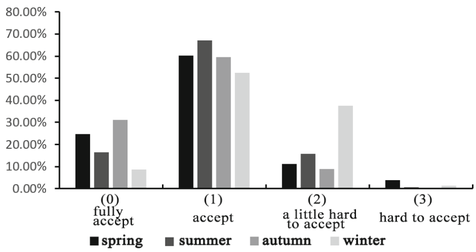

Fig. 4. Unaccept Rate Vote (URV)

3.2 Analysis of Thermal Comfort Index

The result range of each thermal comfort index is shown in Fig. 5. In spring and summer, PET index is significantly higher than other indexes, and SET* index is between other indexes on the whole. The value of SET* index in summer and autumn is lower than other indexes on the whole; The SET* index value in winter was higher than other indexes, and the UTCI index value was between the other two indexes in all four seasons.

In order to better grasp the relationship between the thermal environment comfort index and residents' subjective thermal environment perception, correlation analysis should be carried out between the index and residents' voting. Each index value should be grouped at 1 °C and the average value of TSV, TCV and URV within each group should be calculated. Linear regression analysis was conducted for each thermal comfort index through the above voting, and the analysis results were as follows:

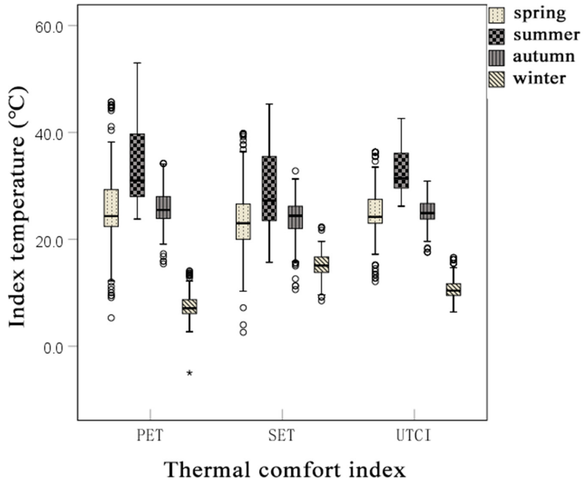

Fig. 5. Results range of each thermal comfort index

Thermal Sensation Vote (TSV). The regression equations of thermal voting and PET, SET* and UTCI of residents in different seasons are shown in Table 3:

Table 3. Regression equations between different indexes and TSV

	PET	SET*	UTCI
Spring	$TSV = 0.1PET - 2.06$ ($R^2 = 0.726$)	$TSV = -0.0022SET^{*2} + 0.2SET^* - 2.92$ ($R^2 = 0.726$)	$TSV = 0.12UTCI - 2.36$ ($R^2 = 0.864$)
Summer	$TSV = 0.06PET - 1.42$ ($R^2 = 0.653$)	$TSV = 0.0036SET^{*2} - 0.16SET^* + 2.22$ ($R^2 = 0.680$)	$TSV = 0.12UTCI - 3.2$ ($R^2 = 0.778$)
Autumn	$TSV = 0.09PET - 1.72$ ($R^2 = 0.842$)	$TSV = 0.017SET^{*2} - 0.78SET^* + 9.2$ ($R^2 = 0.722$)	$TSV = 0.03UTCI^2 - 1.46UTCI + 18.11$ ($R^2 = 0.897$)
Winter	$TSV = 0.02PET^2 - 0.31PET + 0.14$ ($R^2 = 0.653$)	$TSV = 0.06SET^* - 1.99$ ($R^2 = 0.541$)	$TSV = 0.08UTCI - 2.07$ ($R^2 = 0.690$)

When TSV = [−0.5, 0.5], it is known as the neutral thermal sensation range, which is generally acceptable. Through calculation, the neutral thermal sensation range of different indexes in each season can be obtained, as shown in Table 4. In spring, summer and autumn, the neutral thermal sensation range of PET index is the largest, while in winter, There is no neutral thermal sensitivity range in SET* and UTCI, which may be related to the high proportion of cold overall thermal sensitivity in winter.

Table 4. Range of neutral heat sensation in different seasons

Season	PET	SET*	UTCI
Spring	[15.6 °C, 25.6 °C]	[14.4 °C, 22.8 °C]	[15.5 °C, 23.8 °C]
Summer	[15.3 °C, 32.0 °C]	[18.2 °C, 26.2 °C]	[22.5 °C, 30.8 °C]
Autumn	[13.6 °C, 24.7 °C]	[19.2 °C, 26.4 °C]	[22.1 °C, 26.6 °C]
Winter	[−1.0 °C, 2.5 °C] ∪ [13.1 °C, 16.5 °C]	–	–

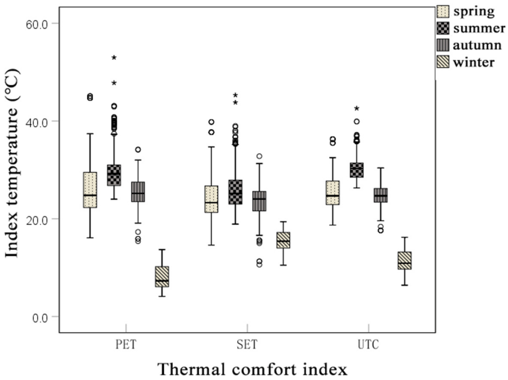

Fig. 6. Range of each index when TCV = 0

Thermal Comfort Vote (TCV). Thermal comfort zone is the range that residents deem comfortable subjectively. In this study, the value of each index when TCV = 0 is used to draw a box diagram, so as to judge the thermal comfort zone of different indexes and their data dispersion degree in different seasons. As shown in Fig. 6, UTCI index has the lowest degree of dispersion, and the 50% voting data (box type part) of each index is relatively concentrated. Therefore, it is relatively objective to take this part of data as the criterion for judging the thermal comfort zone. Through analysis, it can be obtained that the thermal comfort zone of different indexes in different seasons is shown in Table 5.

As can be seen from Table 5, the 50% voting range of the three indexes is close in spring and autumn; The index temperature range of UTCI index was narrower and

Table 5. 50% voting range when TCV = 0 for different index

Season	PET	SET*	UTCI
Spring	[21.9 °C, 27.6 °C]	[20.8 °C, 26.1 °C]	[22.5 °C, 26.7 °C]
Summer	[26.7 °C, 31.6 °C]	[23.2 °C, 28.5 °C]	[28.6 °C, 31.8 °C]
Autumn	[23.4 °C, 27.5 °C]	[21.8 °C, 25.6 °C]	[23.7 °C, 25.4 °C]
Winter	[5.8 °C, 10.0 °C]	[14.4 °C, 17.5 °C]	[9.9 °C, 13.6 °C]

higher in summer. The SET* index temperature range is significantly higher than the other two indexes in winter, which indicates that each index has different adaptability to different seasons. When the temperature is too high or too low, the difference between the indexes begins to appear.

From the analysis (1) and (2), it is not difficult to find that when the thermal sensation is voted as lukewarm state, that is, when TSV = 0, it is not the most comfortable state for residents. The most comfortable temperature in the above indexes is higher than the neutral thermal sensation (TSV = 0) temperature, so the thermal sensation and thermal comfort of residents are not equivalent. Relatively speaking, thermal sensation is only a perception of cold and hot physical environment, while thermal comfort is more complex, which is affected by multiple physiological, psychological and physical environments, and a dynamic balance between the two. In order to accurately grasp the dynamic relationship between thermal comfort and thermal sensation of residents, a mathematical model between TCV and TSV should be built, and TCV should be grouped according to the scale of TSV. A total of 9 groups were obtained. The average value of thermal comfort data was calculated for each group, and regression analysis was conducted with thermal sensation data. The regression equations for each season were shown in Table 6. TCV in summer and winter increased or decreased monotonically with the change of TSV.

Table 6. Linear relationship between TSV and TCV in each season

Spring	$TCV = 0.2TSV^2 - 0.02TSV + 0.29$ ($R^2 = 0.857$)
Summer	$TCV = 0.445TSV + 0.42$ ($R^2 = 0.914$)
Autumn	$TCV = 0.16TSV^2 + 0.32TSV + 0.14$($R^2 = 0.888$)
Winter	$TCV = -0.45TSV + 0.59$($R^2 = 0.755$)

Unaccept Rate Vote (URV). According to the internationally recognized ASHRAE. [16] standard, a comfortable thermal environment should have a thermal acceptance rate of at least 90%. Therefore, in this study, when the non-acceptance rate is less than 10%, it is considered to be the acceptable thermal comfort range for residents.

Each thermal comfort index was grouped according to 1 °C, and the proportion of acceptance voting values of 2 (slightly difficult to accept) and 3 (difficult to accept) in each group was calculated, namely, the rejection rate of each group. The regression analysis of URV and each index in each season can be obtained, as shown in Table 7. The 90% acceptance (URV $\leq$ 10%) of each index was calculated by using the correlation formula in Table 7. The results are shown in Table 8. In the presented results, PET index is always a first-order linear relation, while SET* and UTCI index are simultaneously a first-order linear relation or a quadratic polynomial relation. Therefore, the calculated 90% acceptance voting range of SET* is closer to UTCI in expression form.

Table 7. Linear relationship between seasonal indexes and URV

	PET	SET*	UTCI
Spring	URV = 0.02PET − 0.39 (R^2 = 0.803)	URV = 0.018 SET* − 0.32 (R^2 = 0.698)	URV = 0.024UTCI − 0.48 (R^2 = 0.762)
Summer	URV = 0.026PET − 0.73 (R^2 = 0.670)	URV = 0.0019 SET^{*2} − 0.1 SET* + 1.27 (R^2 = 0.644)	URV = 0.00571$UTCI^2$ − 0.35UTCI + 5.4 (R^2 = 0.818)
Autumn	URV = 0.03PET − 0.62 (R^2 = 0.736)	URV = 0.0038SET^{*2} − 0.16SET* + 1.77 (R^2 = 0.626)	URV = 0.013$UTCI^2$ − 0.655UTCI + 8.278(R^2 = 0.750)
Winter	URV = − 0.04PET + 0.7 (R^2 = 0.681)	URV = − 0.03SET* + 0.77 (R^2 = 0.773)	URV = 0.01$UTCI^2$ − 0.36UTCI + 2.78 (R^2 = 0.634)

Table 8. Voting ranges of 90% acceptance of different indexes

Season	PET	SET*	UTCI
Spring	≤ 24.5 °C	≤ 23.3 °C	≤ 24.2 °C
Summer	≤ 32.0 °C	[20.2 °C, 31.9 °C]	[27.5 °C, 33.9 °C]
Autumn	≤ 25.5 °C	[17.1 °C, 26.2 °C]	[22.9 °C, 27.4 °C]
Winter	≥ 15.0 °C	–	–

3.3 Analysis of Correct Rate of Index Prediction

Prediction Accuracy of Thermal Sensation. In order to further understand which thermal comfort index is more suitable in each season, it is necessary to carry out applicability analysis of each index. For this reason, related concepts are introduced for Predicting Accuracy (η) as a reference for seasonal applicability of indicators. In the concept of prediction accuracy, the larger the η value is, the higher the prediction accuracy and applicability is. Considering the high correlation degree between residents' thermal sensation voting (TSV) and thermal comfort, and the more detailed scale division of thermal sensation voting, the thermal sensation voting will be used as the analysis basis in the prediction accuracy analysis. The prediction accuracy formula of each index is shown in Formula 2:

$$\eta = \frac{Q_{\mathrm{TSVP-TSV}}}{Q_{all}} \times 100\% \tag{2}$$

where: $Q_{TSVP\text{-}TSV}$ is the same number of votes as the predicted thermal sensation vote and the actual thermal sensation vote; Q_{all} is the total number of votes cast.

The calculated prediction accuracy of thermal sensation in each season is shown in Table 9. As can be seen from the results in Table 9, SET* index has the highest prediction accuracy for residents' thermal environmental sensation in spring. Therefore, SET* is the first choice for outdoor thermal environment comfort evaluation index to predict thermal sensation in mild areas in spring. In summer, autumn and winter, the thermal sensation prediction accuracy of UTCI index was higher.

Table 9. Prediction accuracy of thermal sensation in each season

	Spring	Summer	Autumn	Winter
PET	69.3%	78.4%	88.1%	72.1%
SET*	71.7%	78.1%	86.7%	65.0%
UTCI	69.3%	78.7%	89.1%	74.7%

Prediction Accuracy of Thermal Comfort Range. However, thermal sensation is not completely equivalent to thermal comfort, and the prediction accuracy rate of residents' thermal comfort range still needs to be calculated. The proportion of comfort state (TCV = 0) within different comfort definition ranges is the prediction accuracy rate of index thermal comfort range. The prediction results of different comfort definitions of different indicators in different seasons are sorted out and analyzed, and the contents are shown in Table 10. As can be seen from the analysis results in Table 10, the prediction accuracy of the average index in the thermal comfort range in autumn is the highest, while the prediction accuracy in winter is the lowest, with an average of about 15%. The main reason is that the thermal comfort condition in winter is poor and the overall comfort level of residents is not high, resulting in fewer samples in the comfort state. At the same time, the temperature difference on the test day in winter is small, resulting in a small comfort range. In view of the above situation, according to the analysis results of (1), UTCI indexes with higher accuracy of thermal sensation prediction are selected to predict the comfort range, and thus the comfort range of outdoor thermal environment in Guiyang old communities in different seasons is finally determined, as shown in Table 11.

Table 10. Prediction accuracy of different comfort ranges in different seasons

	TSV = [−0.5, 0.5]			50% voting data (TCV = 0)			90% acceptable range		
	PET	SET*	UTCI	PET	SET*	UTCI	PET	SET*	UTCI
Spring	52.51%	51.11%	55.96%	57.93%	60.30%	56.29%	51.53%	50.90%	52.56%
Summer	66.46%	67.15%	66.93%	63.25%	68.04%	61.54%	66.46%	68.10%	64.00%
Autumn	77.08%	69.05%	67.45%	67.33%	70.90%	66.36%	77.12%	69.48%	64.76%
Winter	10.00%	–	–	14.06%	18.46%	–	–	20.63%	–

Table 11. Outdoor thermal comfort range in different seasons

Season	Thermal comfort range
Spring	$SET^* \in [20.8\ °C, 26.1\ °C]$
Summer	$SET^* \in [20.2\ °C, 31.9\ °C]$
Autumn	$PET \leq 25.5\ °C$
Winter	$UTCI \in [9.9\ °C, 13.6\ °C]$

4 Conclusion

Through the questionnaire survey on the outdoor thermal environment of Guiyang residents in different seasons, it is found that the overall acceptability of autumn is the highest, about 90%, and that of spring and summer is roughly the same, respectively 84% in spring and 83% in summer. The acceptability of winter is the lowest, about 61%, which to some extent reflects that residents' adaptability to outdoor thermal environment in winter is worse. Prefer the more stable thermal environment in autumn.

The applicability of each index can be judged from the results of the accuracy of thermal sensation prediction in each season. When analyzing the overall thermal environment sensation of Guiyang residents, SET* index should be used in spring, PET index should be used in summer, and UTCI index should be used in autumn and winter.

SET* index should be adopted in Guiyang in spring and summer, PET index should be adopted in autumn, and UTCI index should be adopted in winter when calculating the prediction accuracy and judging the applicability of each index from the comfort range of different indexes in different seasons. Meanwhile, based on the prediction accuracy of different index comfort ranges, the thermal comfort ranges of each season were SET* (20.8 °C–26.1 °C) in spring, SET* (20.2 °C–31.9 °C) in summer, PET (≤25.5 °C) in autumn, and UTCI (9.9 °C–13.6 °C) in winter.

The study on outdoor thermal environment of old communities in mild climate areas can understand the overall thermal environment level and comfort level of residents in this area, and to a certain extent can provide theoretical and data reference for the improvement of outdoor space of old communities in this area. However, this paper only focuses on Guiyang, a representative of a mild climate area, and studies on the thermal environment and related thermal comfort indexes in other mild climate areas are far from enough. The research objects can be expanded in the future to provide reference and suggestions for improving the outdoor thermal environment in more old communities in mild climate areas.

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