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ORIGINAL PAPER

Tourism climate and thermal comfort in Sun Moon Lake, Taiwan

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Abstract Bioclimate conditions at Sun Moon Lake, one of Taiwan's most popular tourist destinations, are presented. Existing tourism-related climate is typically based on mean monthly conditions of air temperature and precipitation and excludes the thermal perception of tourists. This study presents a relatively more detailed analysis of tourism climate by using a modified thermal comfort range for both Taiwan and Western/Middle European conditions, presented by frequency analysis of 10-day intervals. Furthermore, an integrated approach (climate tourism information scheme) is applied to present the frequencies of each facet under particular criteria for each 10-day interval, generating a time-series of climate data with temporal resolution for tourists and tourism authorities.

Keywords Physiologically equivalent temperature · Thermal comfort · Tourism climatology · Sun Moon Lake · Taiwan

Introduction

In addition to geographic location, topography, landscape, vegetation and fauna, all factors which influence tourist decision-making, weather and climate also determine the attractiveness of a tourism region (Matzarakis et al. 2004a). Questionnaire results indicate that climate information is the first or second factor tourists use when choosing a travel destination (Hamilton and Lau 2005; Lin et al. 2006). According to previous studies in tourism climatology (i.e., de Freitas 2003; Matzarakis et al. 2004a), regional features, including visual factors, the physical environment and thermal comfort, are important to tourism.

Several climate–tourism indices have been employed in past research (Rackliffe 1965; Davis 1968; Murray 1972; Yapp and McDonald 1978; Mieczkowski 1985). A summary and short explanations of these are given in Abegg (1996) and Matzarakis (2006). The most widely known and applied index is the Tourism Climate Index proposed by Mieczkowski (1985), which combines seven factors and parameters. Also, several methods based on the human energy balance exist for the calculation of thermal comfort (Fanger 1972; VDI 1998).

Three tourism climate issues are worthy of discussion. The first issue is how one establishes an index for tourism climate. Although previous tourism-related climate information is based on mean monthly air temperature and precipitation for a destination (Matzarakis 2006), choosing suitable climate parameters and calculating the data for appropriate time intervals is important.

The second issue is how one includes subjective thermal perception of tourists in the tourism climate index. Numerous studies analyzed indoor thermal comfort and demonstrated that occupants have different thermal comfort ranges in different regions (de Dear et al. 1993; Chan et al. 1998; Hwang et al. 2006); this situation also occured for outdoor and semi-outdoor spaces (Spagnolo and de Dear 2003; Nakano and Tanabe 2004; Lin et al. 2005). Therefore, identifying thermal comfort ranges for tourists for different regions are essential to meet tourist demands.

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The last issue is whether tourists prefer to visit destinations in good weather. This issue encompasses the relationship between tourists flow and climate, and the tourism potential for a particular travel destination. Clarifying these three issues will generate climate information important to tourists and tourism authorities.

Sun Moon Lake, with 2 million visitors of whom 95% are domestic, is a popular destination in Taiwan. The study presented here was carried out in Taiwan, a tropical region, and includes the analysis of simple meteorological elements (air temperature, wind speed, cloudiness, air humidity), as well as calculations of thermal comfort for both domestic and international visitors. The analysis is based not on mean monthly values but on frequencies of classes of climate parameters and thermal comfort indices, as well as the occurrence of extreme conditions. Thermal comfort classes developed for moderate climates (Matzarakis and Mayer 1996) were modified to suit conditions at Sun Moon Lake, Taiwan, by means of information gleamed from Taiwan's residents' interviews.

Materials and methods

Previous methods

Analysis of tourism climatology is based on climate indices, such as those used in applied climatology and human-biometeorology (Matzarakis and de Freitas 2001; Matzarakis et al. 2004a). In general, tourism climate indices can be grouped into three categories, i.e., elementary, bioclimatic and combined indices (Abegg 1996; Matzarakis 2006). Elementary indices calculate synthetic values which do not have any thermo-physiological relevance and are generally unproven (de Freitas 2001). The bioclimatic and combined tourism climate indices are based on more than one climatological parameter and consider the combined effects of these. The most commonly known combined index is the Tourism Climate Index developed by Mieczkowski (1985). This index uses a combination of seven parameters, three of which are independent and two in a bioclimatic combination.

The climatic indices described above have a number of weaknesses (Matzarakis 2006). In terms of climatology, they do not include the effects of all climate parameters, have less thermo-physiological significance, and have not been verified through empirical analysis. Several research groups are currently working worldwide on the development of new and more appropriate climate tourism indices (Matzarakis et al. 2004a).

Approach for analysis in Sun Moon Lake

In this study, thermal comfort, analyzed using PET (physiologically equivalent temperature) values (see below) modified for Taiwan, and the resultant human–biometeorological classes are combined with the precipitation analysis, the frequencies of extremes for relative humidity, wind speed, cloud cover, vapour pressure, and extreme thermal comfort conditions, to offer a complete picture of local climate for tourism demand.

Thermal comfort analysis based on thermal indices

Commonly used indices that measure the effect of the thermal environment on humans are PMV (predicted mean vote) (Fanger 1972), PET, and SET* (standard effective temperature) (Gagge et al. 1986). The advantage of any one of these three thermal indices is that they can evaluate the thermal conditions year round; they require input from the same meteorological variables (air temperature, air humidity, wind speed, short- and long-wave radiation fluxes), and they can all be calculated with free software packages, e.g., RayMan (Matzarakis et al. 2007). In this study, PET is used, as it has a widely known unit, °C, as an indicator of thermal stress and/or comfort. This easily understood unit is of particular importance for users such as planners and policy makers, who most likely are unfamiliar with human biometeorological terminology.

PET evaluates the thermal conditions in a physiologically significant manner (Höppe 1999; Matzarakis et al. 1999). It is defined as the air temperature at which the human energy budget for the assumed indoor conditions is balanced by the same skin temperature and sweat rate as under the actual complex outdoor conditions to be assessed. Hence, PET enables users to compare the integral effects of complex thermal conditions outside with their own experience indoors. Meteorological parameters influencing the human energy balance, such as air temperature, air humidity, wind speed and short- and long-wave radiation, are represented in the PET values, as it also considers the heat transfer resistance of clothing and internal heat production (Matzarakis et al. 1999). For the present analysis, the thermal indices PET, PMV, and SET* have been calculated, but only the PET index has been included in the more detailed analysis.

Database of thermal comfort in Taiwan

In order to account for tourists' thermal perception under different temperatures of PET, it is necessary to define PET ranges in which tourists feel comfortable, i.e., "thermal comfort range". In addition to the physiological factor of the human heat balance, thermal sensitivity and thermal comfort ranges vary amongst residents of different regions due to psychological factors, e.g., people who live in tropical regions might be more tolerant of high temperatures due to their experience. In other words, the thermal comfort range of a particular region may not be applicable for another region. In order to calculate the thermal comfort range of tourists in Taiwan, results from a field study based on 1,644 interviews in the outdoor environment were used. In the survey (Lin et al. 2005), basic information on the person's activity level and clothing were obtained. Secondly, objective measurements of ambient air temperature, globe temperature (measured by standard globe), air humidity, air velocity and global radiation were carried out, which were then used, together with the activity and clothing level, to calculate the PET. Also, the interviewed person was asked to subjectively evaluate thermal sensation vote (TSV), thermal preference, and thermal acceptability. TSV ranged from -3 to +3, indicating cold, cool, slightly cool, neutral, slightly warm, warm, and hot. The individual's preferences regarding the thermal environment were assessed by their reply to questions relating to their desire for "warmer or colder" conditions or "no change" in the weather. Moreover, thermal acceptability indicated whether respondents considered the current thermal environment "acceptable" or "unacceptable".

Thermal sensations differ amongst individuals even when they are in the same environment. To reduce these differences, this study applied the de Dear and Brager (1998) method to calculate subjective thermal responses for each 1°C PET bin. Therefore, the relation between mean thermal

Table 1 Climate data for Sun Moon Lake, Taiwan, based on 10-day intervals for 1996–2005

Month	No. of 10-day interval	Air temperature (°C)	Relative humidity (%)	Vapour pressure (hPa)	PET (°C)	Wind speed (m/s)	Cloud cover (octas)	Sunshine duration[a] (h)	Precipitation[a] (mm)
Jan	1	14.6	70.9	11.8	13.4	0.57	4.0	58.7	5.2
	2	14.6	76.9	12.7	13.1	0.59	4.9	51.5	18.1
	3	13.7	81.3	12.7	12.1	0.58	5.2	45.1	25.7
Feb	4	14.2	78.9	12.8	12.8	0.60	5.1	46.3	25.2
	5	15.5	76.7	13.4	14.7	0.63	4.7	59.1	30.5
	6	15.4	81.8	14.2	14.1	0.63	5.3	42.1	51.6
Mar	7	15.4	78.6	13.8	14.7	0.63	4.7	54.6	44.5
	8	17.7	82.0	16.5	17.1	0.63	5.5	43.2	32.6
	9	18.1	81.3	16.8	17.9	0.59	5.8	40.0	38.6
Apr	10	18.6	82.9	17.7	18.1	0.62	6.2	35.3	71.9
	11	19.2	82.6	18.4	19.1	0.60	6.1	36.5	43.3
	12	20.0	83.8	19.5	20.0	0.60	5.9	35.0	61.3
May	13	20.5	84.1	20.2	20.5	0.65	6.3	33.2	103.2
	14	21.2	83.7	21.0	21.1	0.65	6.1	41.5	104.9
	15	21.2	85.7	21.6	21.5	0.58	6.3	34.3	108.5
Jun	16	21.8	86.8	22.6	21.6	0.66	6.7	31.8	157.2
	17	21.8	85.4	22.3	22.1	0.65	6.4	34.5	135.4
	18	22.8	83.6	23.1	23.7	0.64	5.9	48.5	87.5
Jul	19	22.5	85.4	23.2	22.8	0.74	6.2	40.1	197.5
	20	22.7	85.0	23.4	23.4	0.68	5.8	50.1	146.6
	21	23.0	84.1	23.5	23.9	0.61	5.6	55.3	107.6
Aug	22	22.4	87.2	23.5	22.5	0.71	6.2	34.4	221.5
	23	22.7	84.9	23.4	23.5	0.62	5.6	46.2	71.4
	24	22.5	85.0	23.0	22.3	0.70	6.0	44.6	135.4
Sep	25	22.1	85.4	22.7	21.7	0.65	6.1	37.0	103.4
	26	22.0	83.9	22.1	22.1	0.57	5.4	45.1	24.6
	27	21.6	85.3	21.9	21.2	0.55	5.7	38.7	39.2
Oct	28	21.3	83.2	21.0	21.2	0.60	4.9	53.8	20.6
	29	20.5	82.9	19.9	20.4	0.56	4.9	46.6	16.9
	30	19.8	82.3	19.0	19.6	0.55	4.8	50.6	8.1
Nov	31	19.3	80.5	18.0	19.1	0.54	4.4	58.3	15.3
	32	18.7	78.9	17.1	18.3	0.53	4.4	55.8	6.1
	33	18.1	77.2	16.0	17.4	0.54	4.4	58.0	6.3
Dec	34	16.5	79.0	14.8	15.3	0.57	4.5	56.0	10.9
	35	15.7	78.4	14.0	14.2	0.57	4.9	51.6	25.4
	36	14.4	74.6	12.3	13.0	0.57	3.9	57.3	9.2

[a] Indicates that the value of the parameters are sums; the rest are mean values

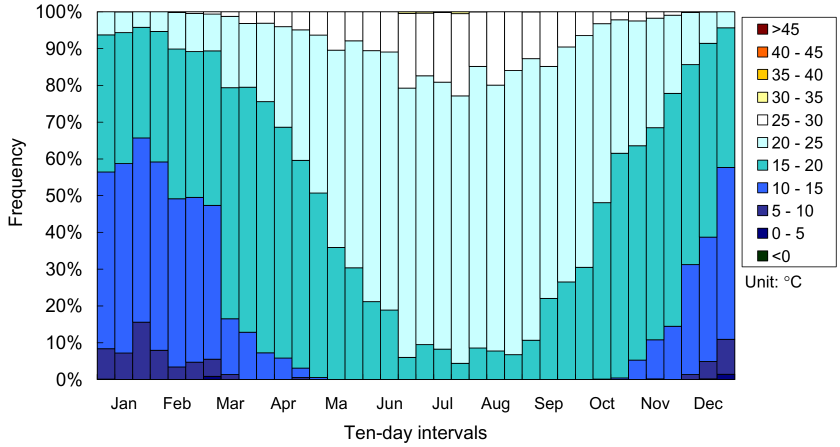

Fig. 1 Air temperature frequencies for Sun Moon Lake, Taiwan, for 1996–2005. The frequencies of air temperature are calculated using hourly data from 1996–2005 and is presented in 10-day units

sensation vote (MTSV) and PET and neutral temperature (the temperature at which MTSV=0) can be obtained. Furthermore, thermal preference data were employed to calculate the thermal comfort range of humans based on their voting of "no change" as acceptable.

Study area and climate data

Sun Moon Lake is one of the National Scenery Areas in Taiwan and is the most popular destination region for both domestic and international tourists. It is located in central Taiwan at 23°52′N, 120°55′E, and at an elevation of 748 m. According to the Tourism Bureau of Minister of Transportation and Communication (MOTC), with about 2 million tourists visiting the region per year, Sun Moon Lake is the nation's most popular National Scenery Area.

The climate data used in this research are obtained from the Sun Moon Lake weather station owned by the Central Weather Bureau, MOTC. Due to measurement errors and missing values in solar radiation and wind speed prior to 1996, this research only uses the hourly climate data from 1996 to 2005. In order to calculate PET in the RayMan model (Matzarakis et al. 2007), the following variables were included in the model: air temperature, vapour pressure, average wind speed, and global radiation. Additional analysis required data on precipitation, sunshine duration hours and cloud cover.

Results

Mean values and frequencies of climate parameters

Previous tourism-related climate information is based on mean monthly conditions of air temperature and precipitation for a destination area. In order to offer more comprehensive and useful weather information for each season, average climate parameters are calculated for each 10-day

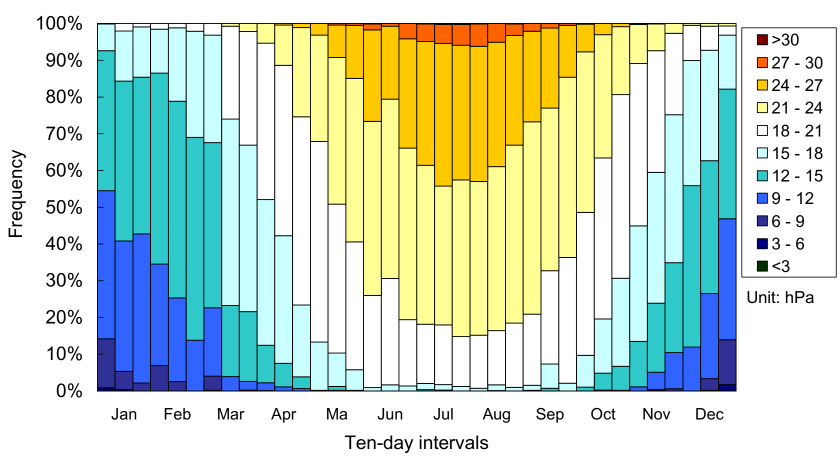

Fig. 2 Vapour pressure frequencies for Sun Moon Lake, Taiwan, for 1996–2005. The frequencies of vapour pressure are calculated using hourly data from 1996–2005 and is presented in 10-day units

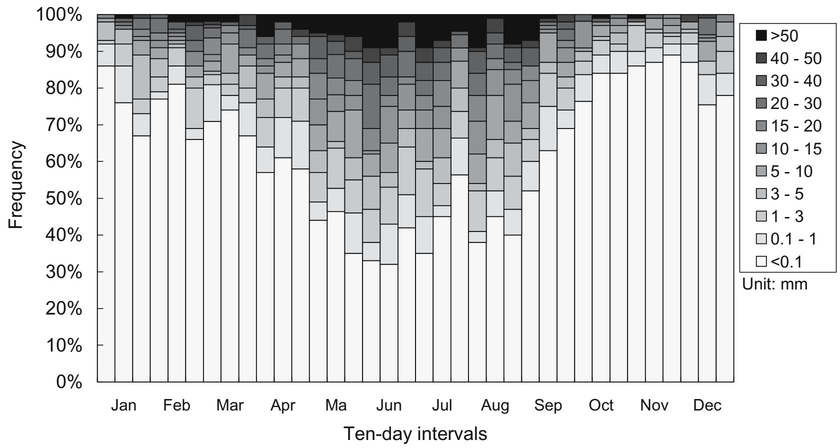

Fig. 3 Precipitation frequencies for Sun Moon Lake, Taiwan, for 1996–2005. The frequencies of precipitation are calculated using hourly data from 1996–2005 and is presented in 10-day units

interval, which are summarized in Table 1. During the 36th to 4th 10-day interval, i.e., late December to early February, air temperature, mean radiant temperature (MRT) and PET are all below 15°C. Other parameters do not vary extensively throughout the year, e.g., 74– 88% for the relative humidity, 4–7 octas for cloud cover, 0.5–0.7 m/s for wind speed. The amount of sun duration and precipitation during each 10-day interval are also displayed in Table 1. Sun duration exceeds 50 h during each dekas from the 30th to 2nd 10-day interval, and the cumulative precipitation exceeds 100 mm per month from the 13th to 25th 10-day interval.

Average values for each climate parameter cannot be used in analyses of specific time periods. Therefore, temperature, vapour pressure and precipitation were classified, and frequencies of these parameters for each 10-day interval were calculated as shown in Figs. 1, 2 and 3.

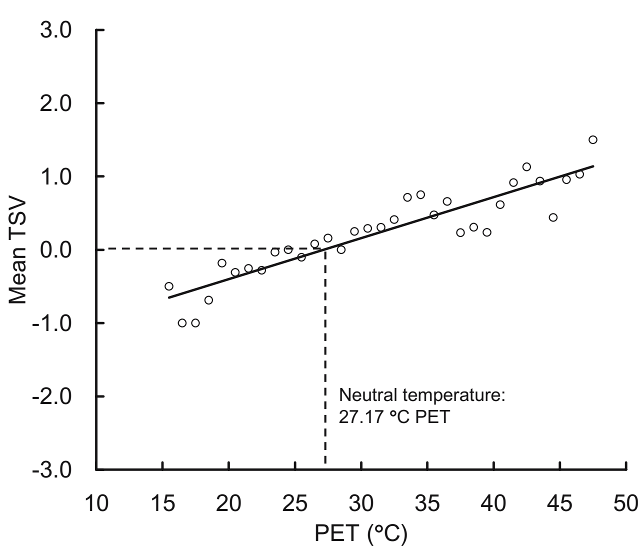

Fig. 4 Thermal sensitivity and neutral temperature. According to the fitted equation, outdoor occupants feel comfortable at PET=27.17°C

Figure 1 shows that air temperatures are below 15°C for over 20% of the time period from December to February, indicating low temperatures in these months. The temperatures are between 20°C and 25°C for over 70% of the time period from June to August. Vapour pressure exceeds 21 hPa over 80% of the time period from June to August (Fig. 2). With regards to precipitation, Fig. 3 shows that it rains at least during 10% of the year. It should be noted that the precipitation is not only concentrated between June and August but exceeds 40mm for each 10-day interval during 10% of the time.

Thermal comfort range of Taiwan

The MTSV is calculated for each 1°C PET interval. For example, while the mean thermal sensation among 78 survey participants who were exposed to 32°C–33°C PET is 0.41, it can be regarded as MTSV=0.41 while PET equals 32.5°C. Based on this method, a total of 1,644 thermal sensation votes of participants can be calculated for each 1°C PET interval as shown in Fig. 4. The fitted regression lines for person sensation versus PET is

$$MTSV = 0.0559 \cdot PET - 1.5186\left(R^2 = 0.83,\, p < 0.001\right) \tag{1}$$

Furthermore, neutral temperature indicates that the temperature at which people feel thermal neutrality. In this study, neutral temperature can be assessed using the fitted equation (1) with MTSV=0, where 27.2 is the neutral temperature. Figure 5 shows the percentages of unacceptability obtained by application of the method described in Materials and methods. The 80% acceptability limits are the intersections of the fitted curve and the 20% unacceptability line, which is 21.6–35.4°C. In order to focus precisely on

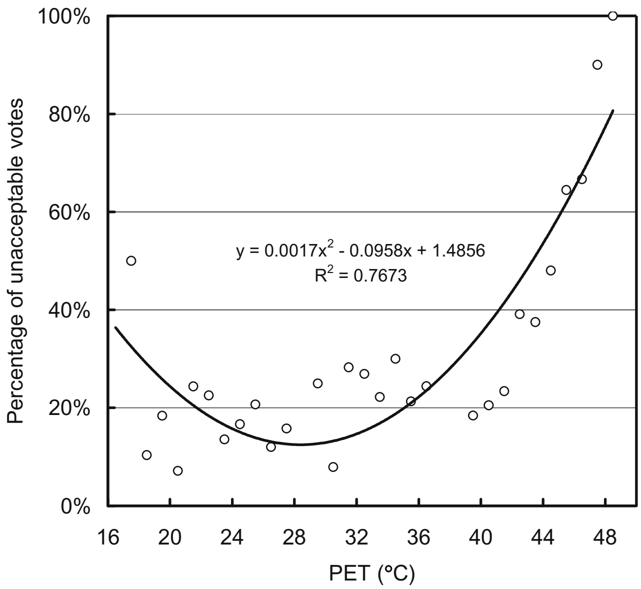

Fig. 5 Thermal comfort range for outdoor environments in Taiwan

the comfort range and to minimize the data range, the 88% acceptability limits were chosen for "neutral", that is, 26°C and 30°C. Correspondingly, the range of feeling "slightly warm", "warm" and "hot" are obtained through a 4°C increase of the range of "neutral"; and "slightly cool", "cool", "cold" are obtained through a 4°C decrease of the "neutral" range. Table 2 shows the PET classification for Taiwan relative to the Western/Middle European scale (Matzarakis and Mayer 1996) and applied to the PET frequencies (Figs. 6 and 7).

The comparison of the two PET thermal scales shows that the neutral temperature scale of Taiwan is higher than that of Western/Middle European. Furthermore, the PET range of Taiwan is larger than that of Western/Middle European for each thermal sensation scale.

PET bioclimate diagrams

The thermal comfort classification using both the Taiwan and Western/Middle European scale (Table 2) were applied to the PET frequencies (Figs. 6 and 7). The frequencies of "neutral" under the Taiwan (26–30°C) and Western/Middle European scale (19–23°C) are very similar, with almost 10% of the time of each 10-day interval being identical. However, the frequencies of "feeling cold" in the Taiwan scale (PET<18°C) exceed 70% in each 10-day interval for the whole year, whereas only 30% of "feeling cold" occurred between December and February under the Western/Middle European scale (PET<8°C). The results of this analysis reveal that the climate seems to be colder under the Taiwan scale than under the Western/Middle European scale. The difference in the PET bioclimate diagrams illustrates that the comfort range for a specific region should be carefully applied depending on whether it is going to be applied to marketing for local or international tourists. Bioclimate diagrams with an adequate thermal comfort range will offer tourists a convenient and reliable way of judging comfort periods and frequencies.

Percentiles and thermal comfort range

In order to give an overview of the PET variation compared to the thermal comfort range, plots of the mean values and percentiles of PET for each 10-day interval coupled with thermal comfort ranges are shown in Fig. 8. The quartiles of PET represent the distribution of PET in detail, while 90, 95 and 98 percentiles represent extremely high values of PET frequencies. The thermal comfort range with 80% and 85% acceptability represents a PET range in which 80% or 85% of people will feel comfortable. Theses two ranges can be obtained based on the results of Fig. 5, which gives 21.6–35.4 for 80% acceptability and 24.2–32.8 for 85% acceptability.

First, Fig. 8 shows that between June and September the mean PET values are within the comfort range for 80% acceptability, and never reach a comfort range which is acceptable for at least 85% of persons for the whole year. The 25 and 50 percentiles lines show similar conditions which are often lower than the comfort range, while 75 percentiles of PET are within comfort range for 85% acceptability from April to October. Also, the 90, 95 and 98 percentiles show an extremely high PET of over 40°C from June to September.

Table 2 Thermal sensations and PET classes for Taiwan and Western/Middle European classes

Thermal sensation	PET range for Taiwan (°C PET)	PET range for Western/Middle European[a] (°C PET)
Very cold		
	14	4
Cold		
	18	8
Cool		
	22	13
Slightly cool		
	26	18
Neutral		
	30	23
Slightly warm		
	34	29
Warm		
	38	35
Hot		
	42	41
Very hot		

[a] Source: Matzarakis and Mayer (1996)

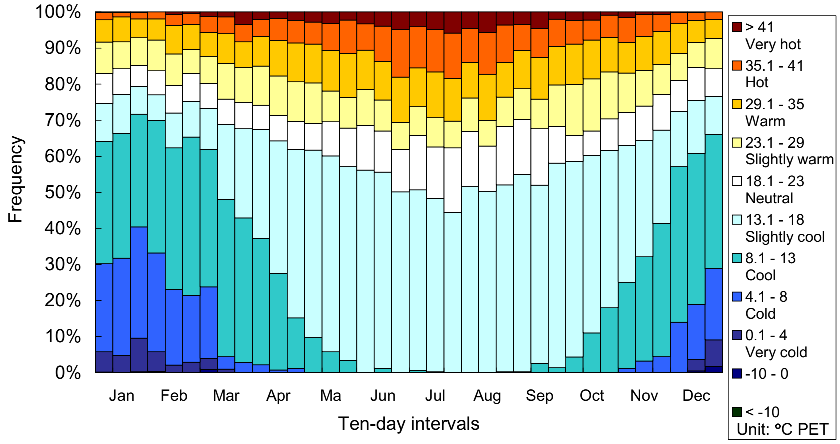

Fig. 6 PET frequencies with Western/Middle European Scale for 1996–2005. The comfort period for Europeans ranges from early April to mid-November, during which 50% of the period is "slightly cool" to "slightly warm"

Discussion

Thermal comfort evaluations

When comparing frequencies of air temperature and PET, it has to be noted that frequencies of air temperature only provide a broad indicator of the thermal environment. For example, high temperatures frequently occur from June to August, with the remaining time being cooler. However, the frequencies of PET reveal more information about thermal conditions. For example, even the cooler seasons have hot periods (PET>34°C) during at least 2% of each day, which corresponds to approximately 30 min per day (Fig. 7). This is due to the fact that PET considers not only air temperature but also humidity, wind speed and solar radiation. While the frequencies of humidity and wind speed in Sun Moon Lake are almost the same for the whole year (Table 1), it becomes evident that the solar radiation at noon contributes to the high PET.

Figure 9 illustrates the PET frequencies (on the Taiwan scale) around noon (1000–1400 hours), which again shows that high PETs occurred between 1000 and 1400 hours occurred frequently from June to August, and also during the cooler seasons. The results show that the PET can reflect the thermal condition better than air temperature.

With regards to the application of this research to tourism, the results also emphasize that even during the cool season it is suggested that tourists consider the impact of strong solar radiation on their thermal comfort. Tourists may protect themselves or stay indoors at noon. On the other hand, the authorities or the tourism industry may offer sheltered outdoor areas (e.g., trees, covered spaces or sunshades) to ensure the thermal comfort of tourists in periods with extreme high solar radiation.

The PET not only provides an integrated index for thermal environment but also allows tourists to predict their perception of weather conditions. Therefore, it is important to analyze the characteristics of thermal adaptation and comfort range of residents from different regions to adequately describe the perception of people from different regions. Previous calculations of PET thermal comfort range were based on questionnaires of Western/Middle Europeans,

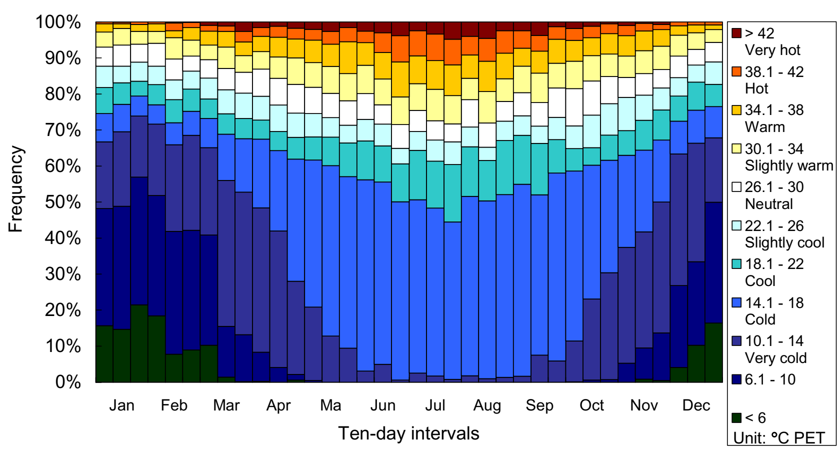

Fig. 7 PET frequencies with Taiwan Scale for 1996–2005. The comfort period ("slightly cool" to "slightly warm") for Taiwan residents is only achieved during 20% of the year

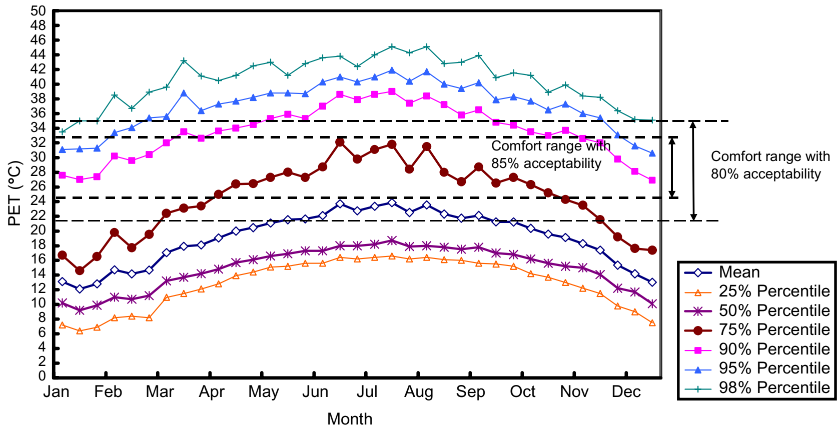

Fig. 8 PET variations and comfort range with 80% and 85% acceptability for 1996–2005

showing their high tolerance of lower temperatures, which is represented in the lower neutral temperature of PET (18–23°C). On the other hand, the thermal comfort questionnaire of Taiwan's residents shows their high tolerance of higher temperatures, which is represented in a higher neutral temperature of PET (26–30°C). Based on the two thermal comfort scales, the comfort period for Europeans ranges from early April to mid-November, where 50% of the period are "slightly cool" to "slightly warm". In contrast, the comfort period of residents in Taiwan is only achieved during 20% of the year. The results reveal that the thermal comfort of international tourists coming from areas of high latitude (or moderate climate zone) is better than that of local tourists.

Integral assessments

More detailed climate information can be provided to the tourists if not only thermal comfort but also aesthetic and physical factors are included in an integrated assessment of tourism climate. Therefore, the assessment of the climate–tourism–information–scheme is applied (Matzarakis et al. 2007) in order to present the frequencies of each factor under specific criteria for each 10-day interval, as shown in Fig. 10. The selected factors and criteria for the thermal component include: thermal suitable (PET between 22–34°C), thermal stress (PET >38°C), and cold stress (PET <18°C). To account for aesthetic aspects, the factors visibility and sunshine (cloud cover >5 octas) and a fog factor (relative humidity>93 %) are included. The physical factors include sultriness (vapour pressure >18 hPa), rain (precipitation >1 mm), long rain (precipitation >5 mm) and windy (wind speed >8 m/s) to account for extreme events like cyclones. The value of each factor represents the occurrence in percentages of 10-day intervals period. Some factors can be positive while others can be negative.

As shown in Fig. 10, the frequencies of thermal suitable and thermal stress are similar for the whole year, while cold stress is only significant from November to March and moderate from June to August. Besides this, cloud cover, fog, and wind are almost the same over the whole year, but rain occurs during 50% of the period from June to August. The results of the analysis reveal that there is no cold stress from June to August, but sultry and rainy conditions occur frequently during this period. Therefore, this integral assessment diagram offers a complete picture of the different

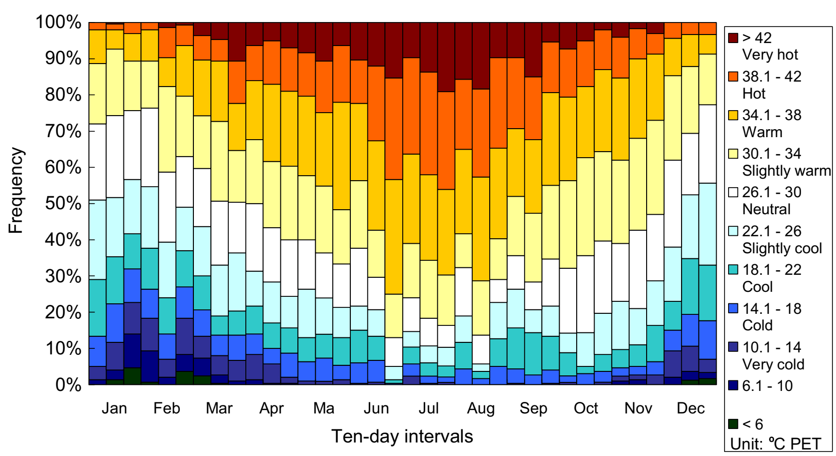

Fig. 9 PET frequencies around noon (1000–1400 hours) for 1996–2005

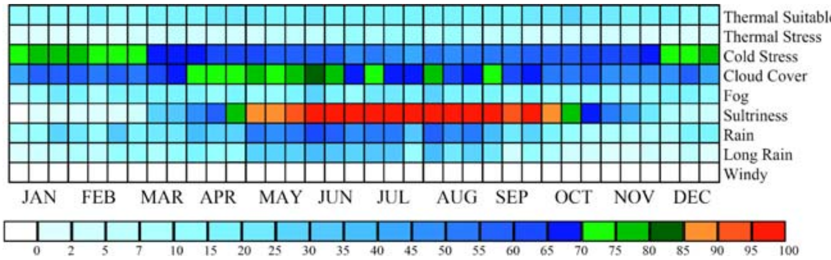

Fig. 10 The assessment of the climate–tourism–information–scheme for 1996–2005. The *colour* of each blank represents the occurrence of each parameter for specific criteria during 10-day periods

factors affecting local climate. The results can be applied to different activities depending on tourist demand.

Climate and tourism potential

So, are tourist numbers affected by climate? Do tourists visit Sun Moon Lake preferably in good weather conditions? What is the climate potential for Sun Moon Lake? In 2000–2005, the average number of tourists in Sun Moon Lake were 2 million (95% were local tourists) per year, with peaks in February (winter vacation and Chinese New Year) and July to August (summer vacation), as shown in Fig. 11. Correlation analysis also shows that the tourist numbers are not significantly affected by each climate factor, e.g. PET, air temperature, precipitation, sunshine duration hours ($P>0.05$). Furthermore, the more frequently visited periods are not the best time for visiting as tourists may suffer from cold stress or rainy periods in February and from July to August. The results show that few tourists currently visit the area during the periods with comfortable climate. Since the number of tourists from Mainland China is rising significantly, it is therefore important to offer more tourism climate information based on the thermal comfort range of the residents of Mainland China and suggest suitable visitation periods.

Comparison with other studies

Compared with previous studies of tourism climate in specific regions, e.g., Spain (Gómez Martín 2004), Austria (Matzarakis et al. 2004b), Phoenix, Arizona (Hartz et al. 2006), Lisbon, Portugal (Alcoforado et al. 2004), Slovenia (Cegnar and Matzarakis 2004), and Florence, Italy (Morabito et al. 2004), the advantage of the method employed in this research is that the PET index is more understandable for tourists who can assess the outdoor thermal condition based on their experience in an indoor environment. Furthermore, the PET frequencies for 10-day intervals combined with the results of the analysis of thermal comfort range display the likelihood of certain perceptions in detail for the whole year. The integrated assessment included aesthetic, physical, and thermal factors, which also offer tourists detailed information on climate. The results of this research reveal that most tourists did not visit the tourist area in the period of most suitable climate. It is important for government agencies to offer detailed tourism climate information to improve the region's tourism potential.

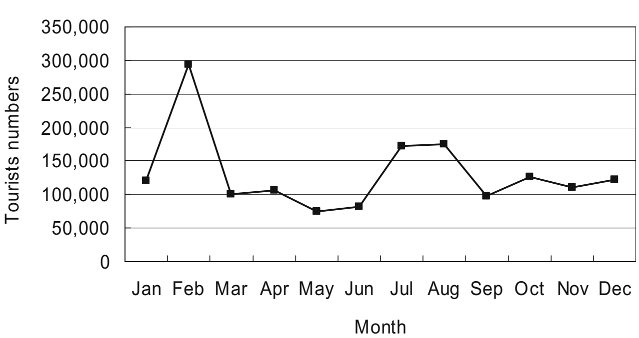

Fig. 11 Average numbers of tourists of Sun Moon Lake in each month for 2000–2005

Conclusion

The traditional implementation of climate in tourism demand estimation, and approaches based on standard monthly and simple climatological elements, do not provide sufficient information. A detailed analysis of climate and weather for tourism purposes is suggested, which should draw on detailed data and include important parameters. Besides, solely thermal comfort analysis does not cover all demands concerning climate and tourism issues. The implementation of various aspects of climate (thermal, physical and aesthetic) provides a reliable way to quantify weather and climate for tourism and recreation. The availability of data of good temporal and spatial resolution commonly restricts analyses. So, the use of long term climate data and the grouping of months in 10-day intervals provide some solution. Additionally, the use of classes for specific climatological parameters offers detailed information for tourists.

The demand of tourism authorities and tourists themselves requires an integrated approach, which includes the most important factors of the different climate facets relevant for tourism. The method presented here (climate tourism information scheme) allows a time-series assessment of climate with high temporal resolution. The criteria or thresholds used can be modified to be employed for the analysis of winter conditions, i.e., snow. They can also be reduced if a factor is not important for the region of interest. The short-term adaptation factors for tourists and recreationists can be applied by using region specific thermal comfort scales and values. The method presented here can be applied for any other climate region through a modification of thresholds and criteria used.

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