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Tourism climate information based on human thermal perception in Taiwan and Eastern China

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ABSTRACT

Human thermal perceptions are closely related to success in the tourism sector. However, a single climatic parameter or thermal index based on empirical equations cannot fully assess the thermal conditions at tourist destinations. While examining Taiwan and Eastern China, this study attempts to determine tourist thermal perceptions based on physiologically equivalent temperature (PET) and thermal comfort classifications (TPCs) for temperate and (sub)tropical regions. Seasonal distribution maps of PET indicate that Taiwan and Eastern China are perceived as comfortable during spring and autumn for those residing in temperate regions, while only the southern region during spring and the northern region during summer are perceived as comfortable for those residing in (sub)tropical regions. Furthermore, the annual thermal comfort distribution (ATCD) is determined to identify comfortable months for 20 tourist destinations. The PET frequencies, which are calculated using hourly climate data, describe climate variability and change. This climate information will prove useful to tourism authorities, travel agencies, resorts and tourists.

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1. Introduction

Weather and climate are critical to tourists and the success of tourist destinations. Bigano, Hamilton, and Tol (2005) indicated that climate is a significant factor for tourists when choosing a travel destination. Notably, climate during different seasons affects tour schedules of travel agencies and tourists. For resorts and scenic destinations, good weather can increase the number of tourists, whereas adverse weather conditions can increase operating costs (e.g., energy usage by air-conditioners in hotels during hot months). Furthermore, climate changes also significantly influence nature-based tourism (Scott, Jones, & Konepek, 2007). A number of studies have determined that British, German, and Dutch tourists have decreased the number of times they visit warm countries due to rising temperatures (Berrittella, Bigano, Roson, & Tol, 2006; Bigano et al., 2005; Hamilton, 2004; Lise & Tol, 2002).

Tourism climate can be represented by thermal, physical (rain or snow), and aesthetic conditions (visibility, sunshine and cloud cover) (de Freitas, 2005). Since most physical and aesthetic factors are subjective, the thermal factor is frequently analyzed as it has an important role in tourism. When tourists are exposed to an outdoor thermal condition that causes thermal stress, i.e., extremely high or

low temperatures, tourist health can be adversely affected. Conversely, when tourists experience thermal conditions that are close to their thermal comfort zones, the number of tourists visiting resorts and scenic destinations can increase (Lin, 2009).

When discussing the thermal characteristics of tourism climate, one must choose a suitable thermal index to assess outdoor thermal environments. The simplest approach is to assess a thermal environment using a single climate factor such as air temperature, relative humidity, or number of sunshine hours. Notably, drought, heat waves, and sea surface temperatures have also been utilized to assess thermal environments (Perry, 2005).

An advanced scheme integrates factors using an empirical equation for evaluating thermal environments (e.g., the wind-chill index (Steadman, 1971), discomfort index (Thom, 1959), apparent temperature (Steadman, 1979), tourism climate index (TCI) (Mieczkowski, 1985). However, these indices only address some of the relevant meteorological parameters and do not include thermal physiology or heat balance of the human body. Thus, these indices cannot be considered state-of-the-art indices. Although these indices may prove effective in very specific situations, they have significant disadvantages (Höppe, 1999; Matzarakis, Mayer, & Iziomon, 1999). Therefore, climate-tourism-information-scheme (CTIS) addresses most of meteorological parameters and includes heat balance of the human body (Lin & Matzarakis, 2008; Zaninovic & Matzarakis, 2009). De Freitas, Scott, & McBoyle (2008) developed

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the climate index for tourism (CIT) that includes the heat balance of the human body, but also integrates thermal, aesthetic, and physical facets of weather. Moreover, the construction and interpretation of CIT is based on empirically tested criteria, as opposed to arbitrarily selected variables and thresholds. For evaluation simplicity, Robinson (2001) defined heat waves using air temperature and relative humidity. However, the thermal index for tourist destinations is based on thermal comfort, not thermal stress periods (e.g. heat waves). Therefore, microclimate parameters, such as wind speed and solar radiation, markedly impact the energy balance of the human body.

People from different regions with different thermal experiences may have different thermal perceptions when exposed to the same thermal condition; this is called thermal adaptation. Since tourists are typically from different regions and have different climatic experiences, Lin and Matzarakis (2008), in investigating how climate affects tourism to Sun Moon Lake, Taiwan, determined annual thermal perceptions of tourists from different regions using the thermal perceptions and thermal comfort zone of tourists from Taiwan and Europe as assessment criteria.

Taiwan and Eastern China are near the sea and, therefore, have considerable potential for domestic and international tourism. Furthermore, direct flights between Taiwan and China are now common, allowing those from mainland China to visit Taiwan, and vice versa. Notably, the number of tourists from both countries has increased significantly. This study, which focuses on Taiwan and Eastern

China, generates tourism climate information based on the thermal requirements of tourists. The primary steps in this study are as follows.

1. Select an appropriate thermal index and incorporate tourist thermal perception into the thermal index while considering the characteristics of thermal adaptation of tourists from different climatic regions and countries.
2. Determine the tourist temporal–spatial distribution of thermal perception using climate data, and then define the thermal comfort period and tourism potential for Taiwan and Eastern China.
3. Discuss detailed variations in thermal perceptions using a daily scale. This study then presents suitable and practical tourism climate information in an easily understood framework for tourists to promote the development of the tourism industry in Taiwan and Eastern China.

2. Methods

2.1. Study area

The study area is located at 21.9–38.2°N latitude and 113.6–122.7°E longitude, encompassing Taiwan and Eastern China (Shandong, Jiangsu, Zhejiang, Anhui, Fujian, and Jiangxi provinces, and Shanghai City). Fig. 1 shows the study region, which is home to eight capital cities and 12 tourist destinations. Fig. 2 shows study area topography. The mountainous area in Eastern China (elevations >500 m) encompasses the center of Shandong Province, areas southwest and southeast of Anhui Province, the area south of Jiangxi, and most of the Zhejiang and Fujian provinces. The highest elevation in the study area is Jade Mountain (Yushan, 3952 m) in Taiwan's Central Mountain Range (CMR). The climate of Eastern China can be classified as warm and temperate (regions north of the



Fig. 1. Study area and main tourist locations.

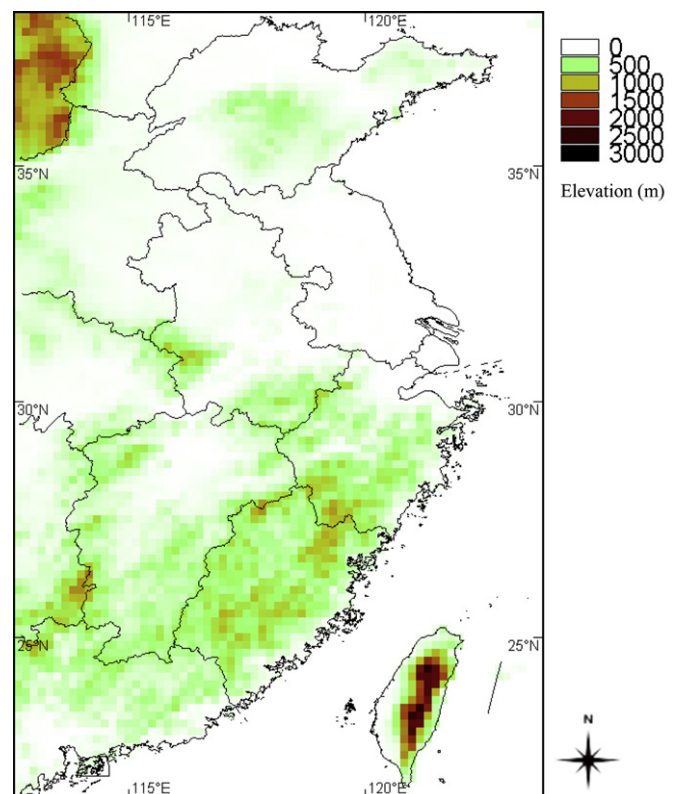


Fig. 2. Topography of the study area.

North Jiangsu Irrigation Main Channel) and subtropical (regions south of the North Jiangsu Irrigation Main Channel). In Taiwan, the climatic region is generally divided into a subtropical region (north of 23.5°N latitude) and a tropical region (south of 23.5°N latitude).

2.2. Climate data

This study uses two climate data types with different resolutions to present the mean monthly thermal conditions and frequencies of thermal index. During the first stage of analysis, mean monthly thermal conditions are calculated using climate data provided by the Climatic Research Unit, U.K. (New, Hulme, & Jones, 1999a, 1999b; New, Lister, Hulme, & Makin, 2002). The data required for the study area (air temperature, vapour pressure, cloud cover, and wind speed) are available in a monthly resolution for 1961–1990 with a spatial resolution of 0.5° latitude × 0.5° longitude (WMO, 1996), offering mean monthly conditions of human biometeorological conditions as basic information (Section 2.6). New et al. (1999a) demonstrated that surface climate variables have been constructed using a new dataset of station 1961–90 climatological normals, from 19,800 and 3615 stations. Station data were interpolated as a function of latitude, longitude, and elevation using thin-plate splines. The accuracy of interpolations was determined using cross validation and by comparison with other climatologists.

In the second stage of analysis, since hourly data were required to calculate the frequencies of each physiologically equivalent temperature (PET) classification, detailed climate data were obtained from local weather stations in Taiwan with an hourly resolution for 1999–2008. Thus, PET can be calculated precisely and analytical results can be presented in detail (Section 2.7).

2.3. Thermal indices

An appropriate thermal index must be utilized that can objectively represent the thermal perceptions of a climate by tourists. In 1938, Büttner (1938) proposed that one must assess the effects of all thermal components on the heat balance of the human body when determining the effects of a climate on humans. Several indices, which integrate thermal environmental factors based on the heat balance of the human body, have since been applied to assess outdoor thermal comfort, (e.g., predicted mean vote (PMV) (Fanger, 1972), effective temperature (ET*), and standard effective

temperature (SET*) (Gagge, Fobelets, & Berglund, 1986)). The PET (Höppe, 1999; Mayer & Höppe, 1987), which is based on the Munich Energy Balance Model for Individuals (MEMIs), is also based on the heat balance equation and the Gagge two-node model (Gagge, Stolwijk, & Nishi, 1971).

The German Association of Engineers (VDI) guideline 3787 (VDI, 1998) for human biometeorological evaluation of climates in urban locations and for regional planning includes PET. As PET was developed by considering the effects of short- and long-wave radiation fluxes in outdoor environments on the human heat balance, it can be applied for outdoor assessments of thermal comfort (Lin, 2009; Lin, Matzarakis, & Hwang, 2010). Notably, PET has been frequently utilized in tourism climate studies to obtain accurate estimations of thermal comfort. Therefore, this study adopts PET as its principal thermal index.

2.4. Calculation of PET

Free software packages, such as the RayMan mode, can be used to estimate PET (Matzarakis, Rutz, & Mayer, 2007). In addition to the factors required by the RayMan model to calculate PET, such as air temperature, humidity, wind speed, human clothing and activity, and mean radiant temperature (Tmrt), PET can be derived by importing the determined value of global radiation or by importing values for cloud cover, time of year, and surrounding obstacles. Furthermore, parameters such as the albedo, Bowen ratio of ground surface, and Linke turbidity of air can also be adjusted using the RayMan model. Thus, evaluating PET via the RayMan model is both flexible and practical.

Thorsson, Lindberg, Eliasson, and Holmer, (2007), who obtained the Tmrt using integral radiation measurements (three-dimensional short- and long-wave radiation) and the RayMan model (version 1.2) for an urban square in Gothenburg, Sweden, suggested that the modeled Tmrt was lower than measured values, especially during mornings and evenings. This may be due to, say, buildings and pavement in the square, which modified solar radiation and emitted large amounts of long-wave radiation, resulting in an actual Tmrt value that was higher than the modeled value. However, modeling is the only method available for estimating long-term Tmrt. Such models as the RayMan, Solweig (Lindberg, Holmer, & Thorsson, 2008) and ENVI-Met all estimate Tmrt values such that they are close to actual values in a complex urban environment. Estimation accuracy can be further enhanced using field experiments and correction of variables.

Tourists are generally more concerned with climatic conditions in natural areas than in urban areas. As the thermal condition in natural areas is unaffected by buildings and pavement, the Tmrt and PET values calculated using the RayMan model are likely close to actual conditions. Moreover, a previous study of hot, humid

Table 1
Thermal perceptions classification (TPC) for temperate region and (sub)tropical region.

Thermal perception	TPC for (sub)tropical region ^a (°C PET)	TPC for temperate region ^b (°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: obtained in Taiwan (Lin & Matzarakis, 2008).

^b Source: Obtained in Western/Middle European (Matzarakis & Mayer, 1996).

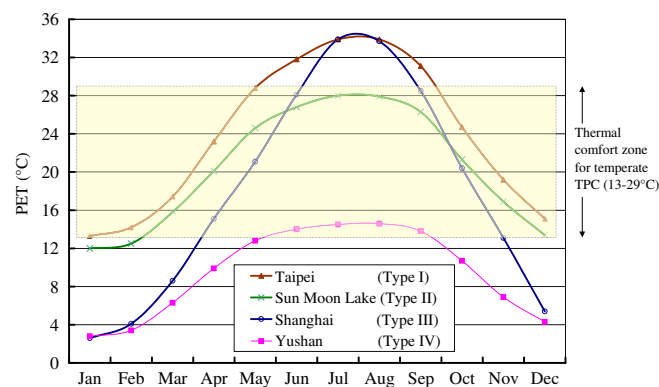


Fig. 3. Mean monthly PET for each ACTD of the representative city. Thermal comfort zone for temperate regions are used in this figure.

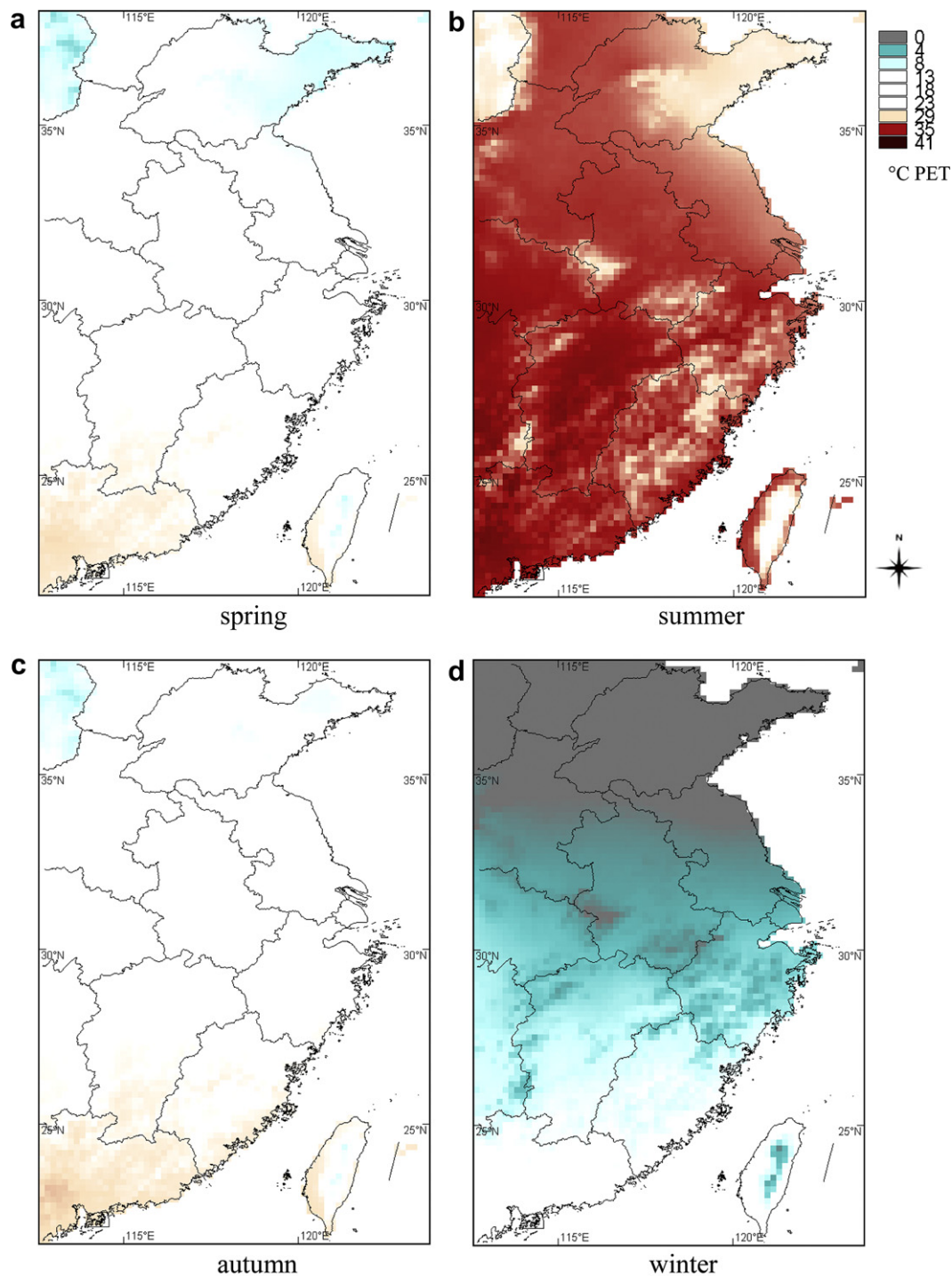


Fig. 4. PET and thermal perception distributions for tourists from temperate regions in each season.

regions revealed that the RayMan model fit the local climate well after model validation (Lin et al., 2010). Therefore, this study applied the most recent version of the RayMan model (version 2.0), which has been improved for PET calculation.

Notably, differences arise between PET calculated using mean monthly climate variables and that calculated using daily or hourly climate variables. However, this stage of analysis focuses on differences in PET spatial distributions during different seasons, rather than presenting a precise PET value for a specific time and place. Climate data provided by the Climatic Research Unit, U.K. are the only data used to calculate the PET distribution at a resolution

of 0.5° latitude \times 0.5° longitude. Therefore, this study uses mean monthly climate variables to calculate PET during the first analytical stage to construct seasonal PET distribution maps and thereby acquire background climate information for the study area.

2.5. Thermal perception classification (TPC)

After selecting PET, one must assess human perception under different PET ranges, i.e., thermal perception classifications (TPCs). Notably, the TPCs for people from different climatic regions vary with their degree of thermal adaptation. In other words, the TPC for

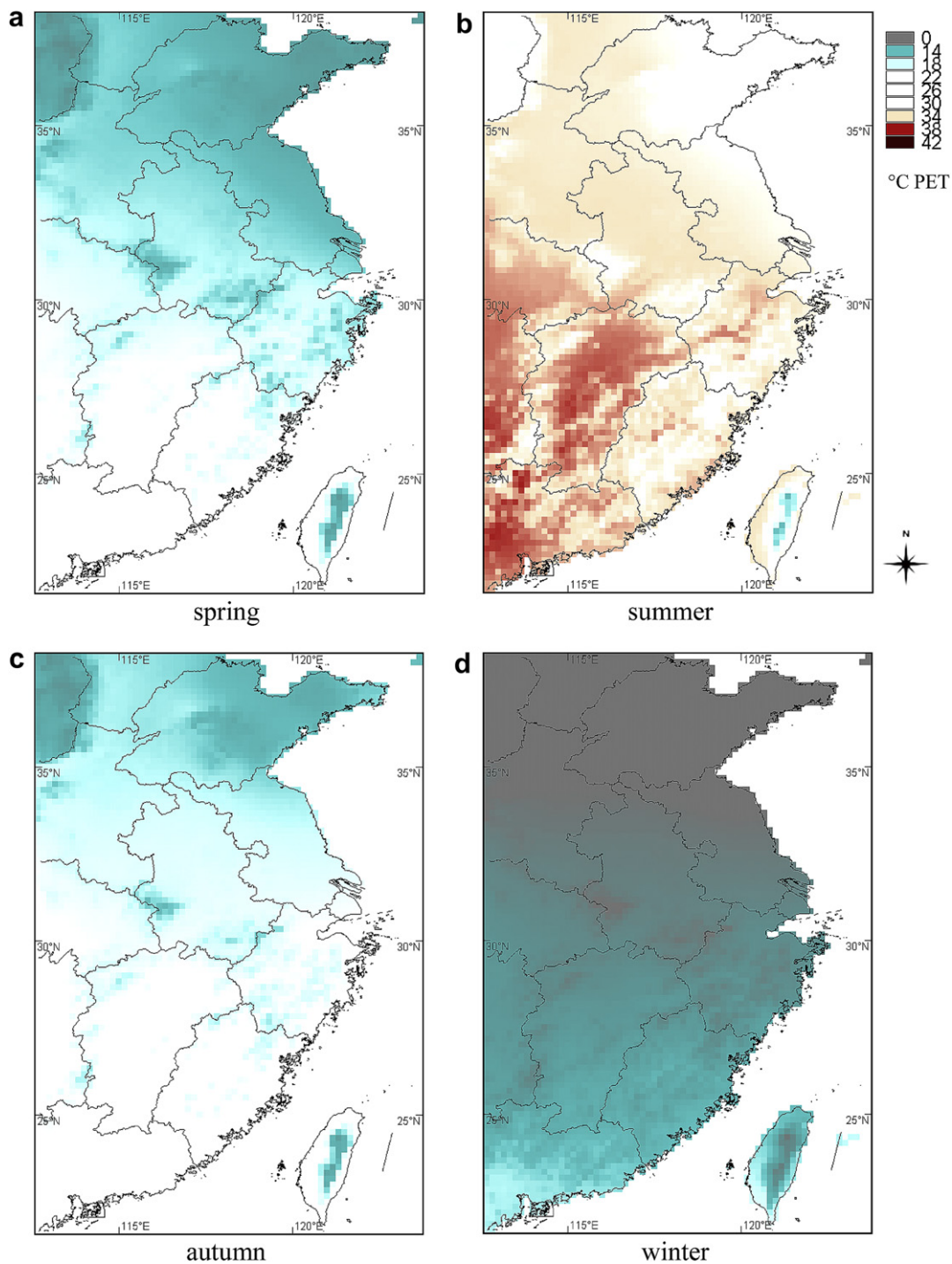


Fig. 5. PET and thermal perception distributions for tourists from (sub)tropical regions in each season.

those from a particular region may not be applicable to those from another region.

In a study by Matzarakis and Mayer (1996), the TPC for PET for western/middle Europe was obtained by transforming the PMVs of 45,000 datasets into PET values. Although that study did not use questionnaires, the TPC they suggested is frequently applied as a thermal comfort criterion for temperate regions. For Taiwan, a (sub)tropical region, 1644 interviews were conducted to determine resident thermal comfort (Hwang & Lin, 2007; Lin & Matzarakis, 2008). Interviewees were asked to subjectively rate their thermal comfort as a thermal sensation vote (TSV) on a scale

ranging from -3 for “cold” to +3 for “hot.” Additionally, thermal acceptability indicated whether respondents considered the current thermal environment “comfortable” or “uncomfortable.” Global temperature (measured using a standard globe thermometer 15 cm in diameter), air temperature, relative humidity, wind speed, and solar radiation were measured while interviews were conducted.

Finally, the TPC for Taiwan residents was obtained using probit analysis (Ballantyne, Hill, & Spencer, 1977), which is listed in Table 1 together with the TPC for people living in western/middle European countries. A comparison of these two TPCs demonstrates that

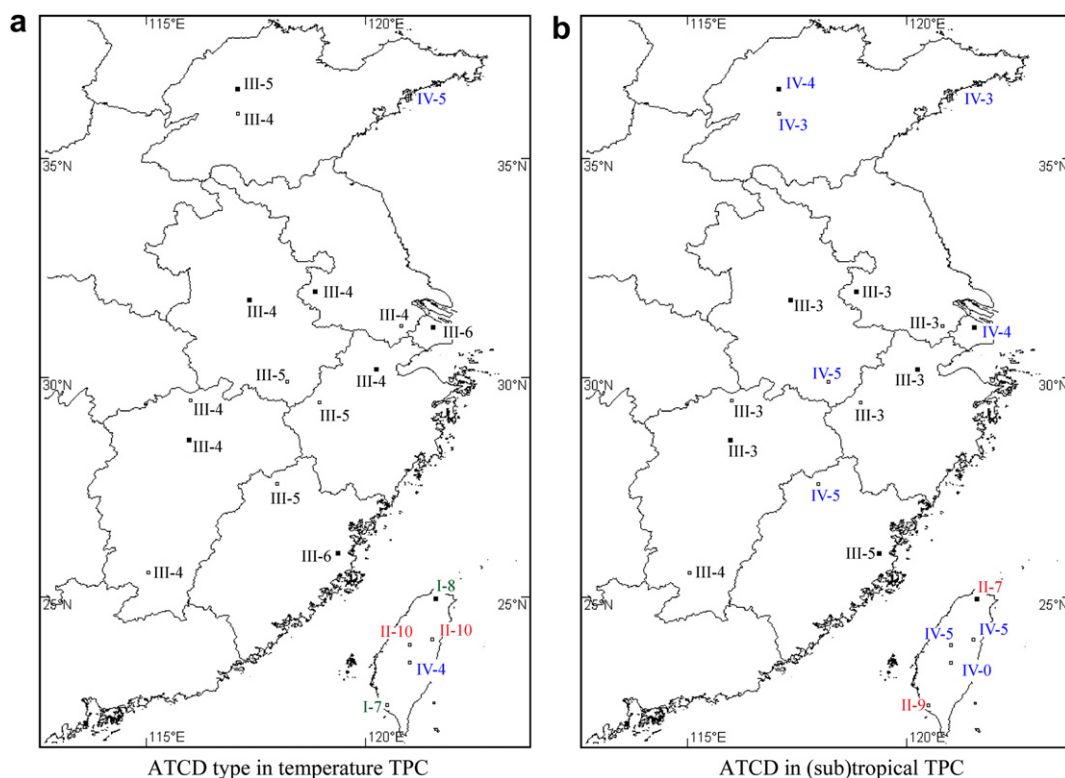


Fig. 6. Annual thermal comfort distribution (ATCD) in temperate and (sub)tropical thermal perception classification (TPC).

the “neutral perception” in Taiwan (26–30 °C PET) is higher than that for western/middle European countries (18–23 °C PET). Furthermore, the Taiwanese cannot tolerate temperatures as low as those tolerated by western/middle Europeans.

This study evaluated the thermal perceptions of tourists from (sub)tropical regions by (using OR applying) the TPC obtained for western/middle Europe for tourists from temperate regions, and the TPC obtained in Taiwan as a criterion. While they may not accurately represent the thermal perceptions of tourists from different regions worldwide, these two TPCs provide a valuable reference for efforts to discuss this issue in more detail.

2.6. Annual thermal comfort distribution (ATCD)

As tourism climate information can indicate which period within a year is thermally comfortable for tourists, this information may help tourists schedule their travel. First, climate data imported into the RayMan model for calculating PET have a monthly resolution (Section 2.2). Second, this study regards a season with a two-month average PET within the thermal acceptable range for slightly cool, neutral, and slightly warm as a comfortable season. Third, this study defines and classifies the annual thermal comfort distribution (ATCD) for 5 locations in Taiwan and 15 locations in Eastern China. The distribution varies when different TPCs are applied to a given region. Notably, if the original comfort range (18–23 °C PET for the temperate TPC and 26–30 °C PET for the (sub)tropical TPC) is applied as an ATCD criterion to evaluate whether locations are comfortable during a specific month, the resulting comfortable months will be too few for practical use. Therefore, a relatively wider “acceptable range” for slightly cool, neutral and slightly warm, i.e., 13–29 °C PET for the temperate TPC and 22–34 °C PET for the (sub)tropical TPC, is applied for ATCD evaluations.

Following calculation and analysis, four ATCDs (types I, II, III and IV) are defined for the study area. Fig. 3 shows example locations that have these four ATCDs based on the temperate TPC during 1961–1990. Type I represents thermally comfortable in spring, autumn and winter—summer is too hot and outside the comfortable range (e.g., Taipei). Type II refers to thermally comfortable during spring, summer, and autumn—winter is too cold and outside the comfortable range (e.g., Sun Moon Lake). Type III has varying temperatures during summer and winter—the comfortable period is spring and autumn (e.g., Shanghai). Type IV is defined as low temperatures all year—the comfortable period is summer (e.g., Yushan, the highest mountain in the study area).

2.7. Annual thermal perception frequencies

Although mean monthly PET roughly describes the distribution of thermally comfortable periods within an entire year or season, when the frequencies of each thermal perception can be represented by tourism climate information, tourists will be informed about when to schedule travel. Additionally, travel agencies will be able to offer suitable travel schedules. Therefore, this study calculates PET frequencies and those of each thermal perception from hourly resolution data for 1999–2008 (Section 2.2). To meet the characteristic of tourist travel time, the time periods for calculation using original climate data are corrected before analysis. First, to reflect the exact duration tourists are typically exposed to outdoor environments, only climate data for daytime (i.e., 06:00–18:00) are utilized when calculating thermal perception frequencies. Second, although daily and hourly climate data are available, this study utilized data for 10-day periods as climatic parameters because 10-day periods are both stable and easily interpreted.

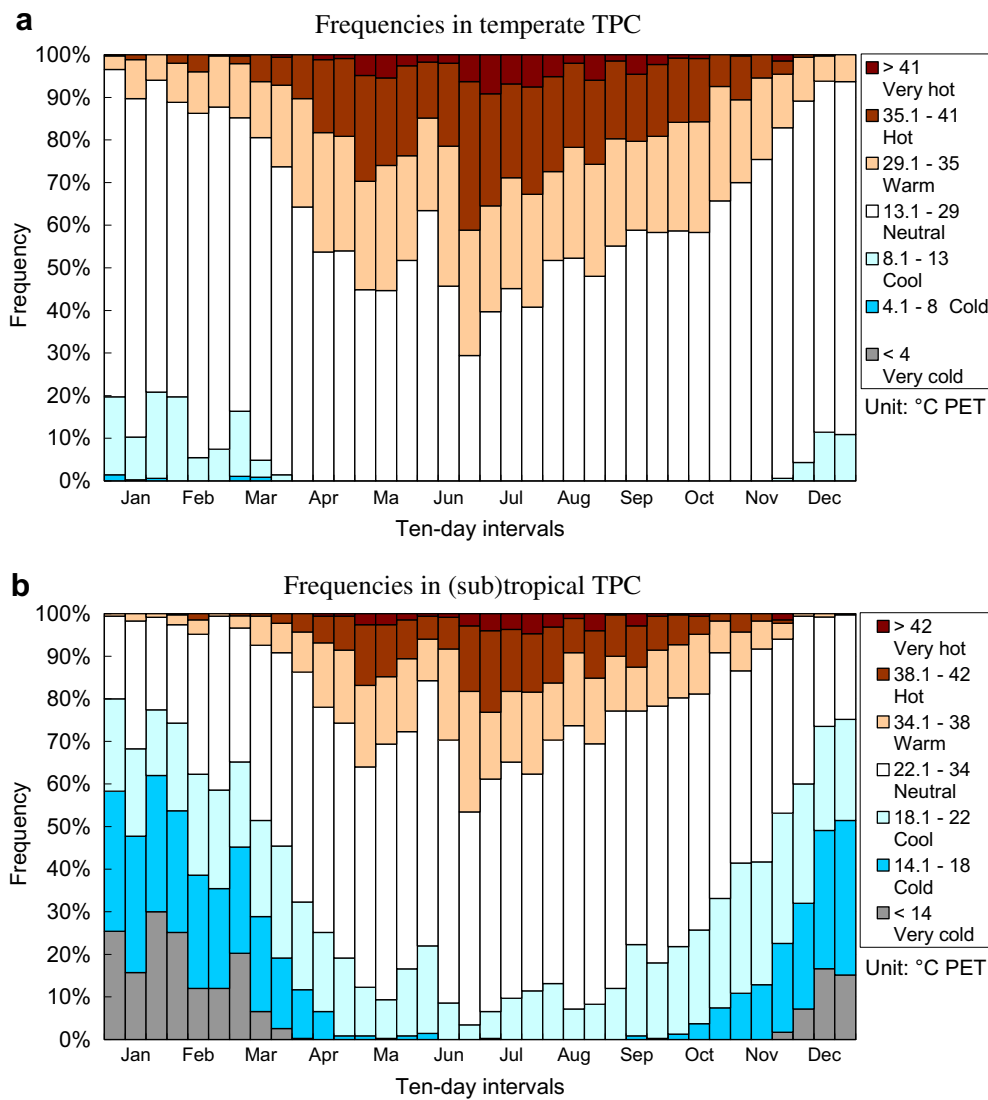


Fig. 7. Frequencies of thermal perceptions in Kaohsiung City during 06:00–18:00 (1999–2008).

3. Results and discussion

3.1. Average seasonal PET map with TPCs for temperate and (sub) tropical regions

This study attempts to determine the possible thermal perceptions of tourists from different regions during different seasons by utilizing TPCs for tourists to generate seasonal spatial PET distributions. The spring PET is the average value for March–May; the summer PET is for June–August; the autumn PET is for September–November; and the winter PET is for December–February. Figs. 4 and 5 show the TPCs for temperate regions and (sub)tropical regions (Table 1), respectively. The white areas in these figures represent regions that are thermally comfortable, i.e., slightly cool, neutral, or slightly warm (Table 1). The thermal comfort zone is 13–29 °C PET for those residing in temperate regions, and 22–34 °C PET for those residing in (sub)tropical regions. Cool and cold areas are marked in blue and gray, and warm and hot areas are in yellow and brown, respectively.

Fig. 4 shows the PET and thermal perception distributions for tourists from temperate regions during each season. During spring, most regions in the study area are considered “comfortable.” Perceived “cool” (8–13 °C PET) is distributed throughout the

Shandong Peninsula and Taiwan’s CMR. Regions perceived as “warm” (29–35 °C PET) is distributed throughout southern Jiangxi Province and Taiwan’s southwest coast. During autumn, the average PET for each of these regions is slightly higher than that during spring; the “comfortable” regions stretch northward to Shandong, China. During summer, most regions in the study area are perceived as “hot.” Only some regions are perceived as “warm”; these regions are distributed throughout the Shandong Peninsula, the CMR in Taiwan, the mountainous area southwest and southeast of Anhui Province, and the mountainous areas in Zhejiang and Fujian provinces. During winter, the northern regions in the study area (Shandong Province and northern Jiangsu Province) are perceived as “very cold” (<4 °C PET), whereas the central regions (southern Jiangsu, Zhejiang, Anhui, and northern Jiangxi provinces) and the CMR in Taiwan are generally perceived as “cold” (4–8 °C PET). The “comfortable” regions are only distributed along the coastlines of Fujian Province and Taiwan in winter.

Fig. 5 presents the distributions of thermal perceptions for tourists in (sub)tropical areas in each season. During spring, the northern regions (Shandong and Jiangsu provinces) and mountainous areas (southwest and southeast of Anhui province, and the CMR in Taiwan) are perceived as “cold” (14–18 °C PET), the central regions (Zhejiang and Anhui provinces) are perceived as “cool”

(18–22 °C PET), and the southern regions (Jiangxi and Fujian provinces) and Taiwan's coastline are perceived as “comfortable” (22–34 °C PET). During autumn, the average PETs for each region are slightly higher than those during spring. Regions perceived as “comfortable” stretch to Shandong Province. In summer, most regions in the study area are perceived as “warm,” and are distributed in the central and southern regions in China (Jiangsu, Zhejiang, Anhui, and Fujian provinces). The regions considered “hot” (38–42 °C PET) are located in Jiangxi Province. Regions considered “cool” are Taiwan's CMR. The region considered “comfortable” is the Shandong Peninsula. In winter, the northern and central regions (Shandong, Jiangsu, Anhui and Zhejiang provinces) are generally “very cold” (<14 °C PET), and the remaining regions in the study area range from “cold” to “cool.” No “comfortable” regions exist in winter.

A comparison of thermal perception distribution maps under two TPCs demonstrates that thermal perception distributions differ when the two TPCs are applied to the same PET distributions. While considering Shanghai City as an example, although temperate tourists may feel thermally comfortable during spring, (sub)tropical tourists may feel cold during spring, as summer is their thermally comfortable period.

3.2. Annual thermal comfort distribution (ATCD) type

Based on the definitions of the four ATCDs (Section 2.6), 8 capital cities and 12 tourist destinations have ATCD types based on temperate and (sub)tropical TPCs (Fig. 6(a) and (b)), respectively. The number of comfortable months (seasonal average PETs within the thermal comfort zone) is added after the ATCD type (Fig. 6(a) and (b)).

Based on TPCs for temperate regions, most locations were type III, i.e., comfortable during spring and autumn (Fig. 6(a)). Other types existed in southern Taiwan and northern Eastern China; for example, Taipei and Kaohsiung were Type I (comfortable during spring, autumn and winter), Taroko and Sun Moon Lake were type II (comfortable during spring, summer and autumn) and Qingdao and Yushan were type IV (comfortable during summer only). If one focuses on the number of comfortable months, locations in the southern area are comfortable for >6 months, suggesting that tourists from temperate regions will feel comfortable for at minimum half of a year when visiting these destinations.

Based on the TPCs for (sub)tropical regions, some locations in Jiangsu (Suzhou and Nanjing provinces), Zhejiang (Hangzhou provinces and Qiandao Lake), Jiangxi (Nanchang and Lushan provinces) are type III (Fig. 6(b)). Some locations in northern regions or at high elevations are type IV, indicating that they are comfortable during summer. Compared with ATCD types based on the temperate TPC, those based on (sub)tropical TPCs have fewer comfortable months. Notably, the number of comfortable months was high for Kaohsiung City, as it has a high PET all year, indicating that it is a potential destination for tourists from (sub)tropical regions.

3.3. Thermal perception frequencies

Since mean monthly PET can only describe average thermal comfort, this study calculates the frequencies of each thermal perception to generate tourism climate data, which will help tourists schedule itineraries and pack suitable clothing. The thermal perception frequencies for Kaohsiung City are calculated using hourly data (Section 2.7), and presented in 10-day intervals based on temperate and (sub)tropical TPCs (Fig. 7(a) and (b)).

Under the temperate TPC (Fig. 7a), the frequencies at which “warm,” “hot,” and “very hot” are perceived are high during summer and reach 70% during June. The period perceived as “cool” is short (December–March). Under the (sub)tropical TPC (Fig. 7b),

the frequencies at which winter is perceived as “cool,” “cold,” and “very cold” are high, reaching 80% in January. The frequencies (<30%) for “warm” to “very hot” are low during summer. Comparison results demonstrate that thermal perception frequencies differ over an entire year and under different TPCs.

Fig. 7 presents the frequencies of thermal comfort in hours for both TPCs. Under the temperate TPC, over 60% of the thermal comfort period is in spring, autumn and winter, whereas summer has a relatively short thermal comfort period (30%). Under the (sub)tropical TPC, the frequencies of thermal comfort are high during summer (50%) and very low during winter (20%). Above results demonstrate that thermal comfort frequencies for tourists from temperate regions are higher than those for tourists from (sub)tropical regions, indicating that tourism potential based on thermal comfort in Kaohsiung City is high for those from temperate regions.

4. Conclusions

Tourism climate information related to thermal comfort is typically utilized to describe the value of a single climate factor, i.e., maximum air temperature or average relative humidity. However, such factors cannot fully explain the heat balance of the human body (which is the basis of thermal comfort assessment). Furthermore, the values of these factors are not easily understood by tourists. This study adopts Taiwan and Eastern China as its study area, and characterizes tourist thermal perceptions based on the thermal index PET and TPCs for tourists from different regions.

This study applied three novel approaches. First, this study applied “thermal adaptation” theory for tourism climate analysis, and applied two TPCs from temperate and (sub)tropical regions to the temporal-spatial PET diagram, which generated various thermal comfort distributions. Second, this study for the first time defined four types (types I–IV) of ATCDs and applied these ATCDs to tourist locations. Third, since mean monthly PET can only approximate average thermal comfort, this study calculated the frequencies of each PET classification based on temperate and (sub)tropical TPCs of tourist locations for which hourly climate data are available.

Analytical results demonstrate that most regions in the study area are thermally comfortable during spring and autumn under a temperate TPC. Under the (sub)tropical TPC, southern regions are comfortable during spring and autumn and northern regions are comfortable during summer. This study further defined four ATCDs, indicating that many locations have different ATCDs when different TPCs are applied. Analytical results underline the importance of TPCs for each country/region. Since TPCs do not change from place to place or from season to season, local TPCs are required for future tourism climate studies.

Results of this study contribute to efforts to help tourists identify appropriate periods for travel. If tourists have already scheduled a trip, this information will help them determine which clothing to pack. Additionally, travel agencies can promote different schedules in different seasons based on tourist thermal comfort. Different TPCs can be designed for different marketing programs and products. For resorts and scenic locales, facilities that comply with the local climate and tourist thermal requirements should be provided, i.e., shade trees and outdoor shelters. Study findings also contribute to the development of tourist destinations by local governments. Governments should be aware that TPCs for different regions affect tourism seasons. Tourism climate information should then be utilized to promote/improve existing tourist destinations and develop new destinations. This study is, to our knowledge, the first to describe the tourism climate in Taiwan and Eastern China.

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References

- Büttner, K. (1938). *Physikalische Bioklimatologie*. Leipzig: Akademische Verlagsgesellschaft mbH.
- Ballantyne, E. R., Hill, R. K., & Spencer, J. W. (1977). Probit analysis of thermal sensation assessments. *International Journal of Biometeorology*, 21, 29–43.
- Berritella, M., Bigano, A., Roson, R., & Tol, R. S. J. (2006). A general equilibrium analysis of climate change impacts on tourism. *Tourism Management*, 27, 913–924.
- Bigano, A., Hamilton, J. M., & Tol, R. S. J. (2005). *The impact of climate on holiday destination choice*. Fondazione Eni Enrico Mattei. Working Papers 04.05.
- de Freitas, C. R. (2005). The climate-tourism relationship and its relevance to climate change impact assessment. In C. M. Hall, & J. Higham (Eds.), *Tourism, recreation and climate change* (pp. 29–43). Clevedon: Channel View Publications.
- de Freitas, C. R., Scott, D., & McBoyle, G. (2008). A second generation climate index for tourism (CIT): specification and verification. *International Journal of Biometeorology*, 52, 399–407.
- Fanger, P. O. (1972). *Thermal comfort*. New York: McGraw Hill.
- Gagge, A. P., Fobelets, A. P., & Berglund, L. G. (1986). A standard predictive index of human response to the thermal environment. *ASHRAE Transactions*, 92, 709–731.
- Gagge, A. P., Stolwijk, J. A. J., & Nishi, Y. (1971). An effective temperature scale based on a simple model of human physiological regulatory response. *ASHRAE Transactions*, 77, 247–257.
- Höppe, P. (1999). The physiological equivalent temperature - a universal index for the biometeorological assessment of the thermal environment. *International Journal of Biometeorology*, 43, 71–75.
- Hamilton, J. M. (2004). *Climate and the destination choice of German tourists*. Fondazione Eni Enrico Mattei. Working Papers 21.04.
- Hwang, R. L., & Lin, T. P. (2007). Thermal comfort requirements for occupants of semi-outdoor and outdoor environments in hot-humid regions. *Architectural Science Review*, 50, 60–67.
- Lin, T. P. (2009). Thermal perception, adaptation and attendance in a public square in hot and humid regions. *Building and Environment*, 44, 2017–2026.
- Lin, T. P., & Matzarakis, A. (2008). Tourism climate and thermal comfort in Sun Moon Lake, Taiwan. *International Journal of Biometeorology*, 52, 281–290.
- Lin, T. P., Matzarakis, A., & Hwang, R. L. (2010). Shading effect on long-term outdoor thermal comfort. *Building and Environment*, 45, 213–221.
- Lindberg, F., Holmer, B., & Thorsson, S. (2008). SOLWEIG 1.0 – modelling spatial variations of 3D radiant fluxes and mean radiant temperature in complex urban settings. *International Journal of Biometeorology*, 52, 697–713.
- Lise, W., & Tol, R. S. J. (2002). Impact of climate on tourist demand. *Climatic Change*, 55, 429–449.
- Matzarakis, A., & Mayer, H. (1996). *Another kind of environmental stress: Thermal stress*. WHO Collaborating Centre for Air Quality Management and Air Pollution Control.
- Matzarakis, A., Mayer, H., & Iziomon, M. G. (1999). Applications of a universal thermal index: physiological equivalent temperature. *International Journal of Biometeorology*, 43, 76–84.
- Matzarakis, A., Rutz, F., & Mayer, H. (2007). Modelling radiation fluxes in simple and complex environments – application of the RayMan model. *International Journal of Biometeorology*, 51, 323–334.
- Mayer, H., & Höppe, P. (1987). Thermal comfort of man in different urban environments. *Theoretical and Applied Climatology*, 38, 43–49.
- Mieczkowski, Z. (1985). The tourism climate index: a method for evaluating world climates for tourism. *The Canadian Geographer*, 29, 220–233.
- New, M., Hulme, M., & Jones, P. (1999a). Representing twentieth century space-time climate variability. Part I: development of a 1961–90 mean monthly terrestrial climatology. *Journal of Climate*, 12, 829–856.
- New, M., Hulme, M., & Jones, P. (1999b). Representing twentieth century space-time climate variability. Part II: development of 1901–1996 monthly grids of terrestrial surface climate. *Journal of Climate*, 13, 2217–2238.
- New, M., Lister, D., Hulme, M., & Makin, I. (2002). A high resolution data set of surface climate over global land areas. *Climate Research*, 21, 1–25.
- Perry, A. (2005). *Impacts of climate change on tourism in the Mediterranean: adaptive responses*. Working Papers 35.00. Fondazione Eni Enrico Mattei.
- Robinson, P. J. (2001). On the definition of a heat wave. *Journal of Applied Meteorology*, 40, 762–775.
- Scott, D., Jones, B., & Konopek, J. (2007). Implications of climate and environmental change for nature-based tourism in the Canadian Rocky Mountains: a case study of Waterton Lakes National Park. *Tourism Management*, 28, 570–579.
- Steadman, R. G. (1971). Indices of windchill of clothed persons. *Journal of Applied Meteorology*, 10, 674–683.
- Steadman, R. G. (1979). The assessment of sultriness. Part I. A temperature–humidity index based on human physiology and clothing science. *Journal of Applied Meteorology*, 18, 861–873.
- Thom, E. C. (1959). The discomfort index. *Weatherwise*, 12, 57–60.
- Thorsson, S., Lindberg, F., Eliasson, I., & Holmer, B. (2007). Different methods for estimating the mean radiant temperature in an outdoor urban setting. *International Journal of Climatology*, 27, 1983–1993.
- VDI. (1998). *Methods for the human biometeorological evaluation of climate and air quality for the urban and regional planning. Part I: Climate. VDI guideline 3787. Part 2*. Berlin: Beuth.
- WMO (1996). *Climatological normals (CLINO) for the period 1961–1990*. Geneva.
- Zaninovic, K., & Matzarakis, A. (2009). The bioclimatological leaflet as a means conveying climatological information to tourists and the tourism industry. *International Journal of Biometeorology*, 53, 369–374.