

International Conference on Engineering and Technology Development



3rd ICETD 2014

28, 29 October 2014, Bandar Lampung, Indonesia

Hosted By :
Faculty of Engineering and Faculty of Computer Science
Bandar Lampung University, Indonesia



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3rd ICETD 2014

THE THIRD INTERNATIONAL CONFERENCE
ON ENGINEERING AND TECHNOLOGY DEVELOPMENT

28 -29 October 2014
Bandar Lampung University (UBL)
Lampung, Indonesia

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Bandar Lampung University (UBL)
Jl. Zainal Abidin Pagar Alam No.26 Labuhan Ratu, Bandar Lampung, Indonesia
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PREFACE

The Activities of the International Conference is in line and very appropriate with the vision and mission of Bandar Lampung University (UBL) to promote training and education as well as research in these areas.

On behalf of the Second International Conference on Engineering and Technology Development (3rd ICETD 2014) organizing committee, we are very pleased with the very good response especially from the keynote speaker and from the participants. It is noteworthy to point out that about 80 technical papers were received for this conference.

The participants of the conference come from many well known universities, among others : University Kebangsaan Malaysia – Malaysia, IEEE – Indonesia, Institut Teknologi sepuluh November – Indonesia, Surya Institute – Indonesia, International Islamic University – Malaysia, STMIK Mitra Lampung – Lampung, Bandung Institut of Technology – Bandung, Lecture of The Malahayati University, B2TP – BPPT Researcher – Lampung, University of Kitakyushu – Japan, Gadjah Mada University – Indonesia, Universitas Malahayati – Lampung, Lampung University – Lampung,

I would like to express my deepest gratitude to the International Advisory Board members, sponsor and also to all keynote speakers and all participants. I am also grateful to all organizing committee and all of the reviewers who contribute to the high standard of the conference. Also I would like to express my deepest gratitude to the Rector of Bandar Lampung University (UBL) who give us endless support to these activities, so that the conference can be administrated on time

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Thermal Bioclimate for Tourism: Case Study of Kuta, Bali Province, Indonesia

Nyoman Sugiarta ^{#1}, Andreas Matzarakis ^{*2}

¹*Department of Mechanical Engineering, Bali State Polytechnic
Bukit Jimbaran, Tuban, Badung, Bali, Indonesia
nyoman.sugiarta@yahoo.co.uk*

²*Chair of Meteorology and Climatology, Albert-Ludwigs-University Freiburg
Werthmannstr. 10, 79085 Freiburg, Germany
andreas.matzarakis@meteo.uni-freiburg.de*

Abstract—Weather and climate are influencing factors for tourism. Tourism destinations often require information about the weather and climate to assess their climate potential. In this regard, study on thermal bioclimate, i.e. human thermal comfort is essential. This study has assessed tourist thermal comfort perceptions and adaptation in Kuta, Bali Province of Indonesia, by applying physiologically equivalent temperature (PET) and thermal perception classifications (TPCs) for temperate and sub(tropical) regions. Analytical calculation of PET utilized RayMan model and synoptic meteorological data covering the period 2002-2012. The results show that frequencies of thermal comfort during whole day (02:00-23:00) for tourists from temperate region are higher than those for tourists from (sub)tropical region, indicating that tourism potential based on thermal comfort is high for those from the temperate region. However, around noon (11:00-17:00), thermal comfort of the tourists from (sub)tropical region is better (in which indicating more adaptable to the daytime climate conditions) than that of the tourists from the temperate region. In addition, it is shown that the months from June to September, particularly in July and August are the most suitable time to travel for the tourists from temperate region, whereas all year round is appropriate for those tourists from (sub)tropical region.

Keywords—climate-tourism, thermal comfort, physiologically equivalent temperature, Kuta, Bali

I. INTRODUCTION

Tourism is strongly influenced by many factors; weather and climate are two of them [1]-[3]. At some travel destinations, climate represents a natural resource on which the tourism industry is predicated [4]. Climate may act as a support, resource, locational factor and attraction for tourism [5]. Tourists consider that climate is a key factor, consciously or implicitly during travel planning, and represents both a push and pull factor for them. Weather and climate are an intrinsic component of the vacation experience and have been found to be a central motivator for travel [6]. The climate influences the way the image of a destination is formed in the mind of a tourist, particularly when seeking outdoor leisure activities [7].

Climate is a key resource for many types of tourism and as such can be measured and evaluated. An index approach is required for this task because of the multifaceted nature of weather and the complex ways that weather variables come

together to give meaning to climate for tourism [8]. The most used index in the past, among others is the Tourism Climate Index (TCI) proposed by [9]. TCI uses a combination of seven parameters, three of which are independent and two in a bioclimatic combination. It includes daytime comfort index, consisting of the mean maximum air temperature and the mean minimum relative humidity, a daily comfort index, consisting of the mean air temperature and the mean relative humidity, amount of precipitation, daily sunshine duration and mean wind speed. However, state of the art is the calculation of thermal comfort based on the human energy balance [10], e.g. PMV (predicted mean vote) [11], ET^* (effective temperature) and SET^* (standard effective temperature) [12], PET (physiologically equivalent temperature) [13],[14] and UTCI (universal thermal climate index) [15].

Tourism climate can be represented by thermal, physical (rain or snow), and aesthetic conditions (visibility, sunshine and cloud cover) [16]. Since most physical and aesthetic factors are subjective, the thermal factor of climate is frequently analysed as it has an important role in tourism. When tourists experience thermal conditions that are close to their thermal comfort zones, the number of tourists visiting resorts and scenic destinations can increase. Different tourists have different recognitions of the climate parameters priority. Even the same person will have different climate preference depending on location. Tourists from different regions with different thermal experiences may have different thermal adaptation when exposed to the same thermal condition [17]-[19].

To date, little research has been done to establish climate information to support Bali tourism potential, particularly related to human thermal comfort. The main objective of this study is to assess human thermal bioclimatic conditions by applying physiologically equivalent temperature (PET) thermal index for study area of Kuta and the surrounding areas located in Bali Province of Indonesia. The specific objectives include (1) to compare thermal perception and adaptation of the tourists reside in different regions, i.e. temperate and (sub)tropical regions using PET ranges and (2) to determine the most suitable time to travel with regards to the thermal comfort perception.

II. STUDY AREA

Tourism constitutes one of the main economic sectors in Indonesia. The contribution of tourism to Indonesian foreign exchange income rose from US\$4.3 billion in 2002 to US\$9.1 billion in 2012. Accordingly, Bali tourism revenue shared approximately 45% to the Indonesia tourism. Number of international tourist arrivals to Bali increased from 1.29 million in 2002 to a record of 2.89 million in 2012. Market contribution by nationality region during the course of period comprised Asia Pacific, Europe, South East Asia, America, Africa and Middle East, which accounted for 58.5%, 25.2%, 10.5%, 5.1%, 0.5%, 0.2%, respectively [20]. Fig. 1 shows monthly distribution of the number of international and domestic tourists to Bali island during the period 2002-2012. The total number of tourists was 50.3 million. The contribution of international tourists is approximately 36 % to the total number of tourists visiting Bali throughout the years.

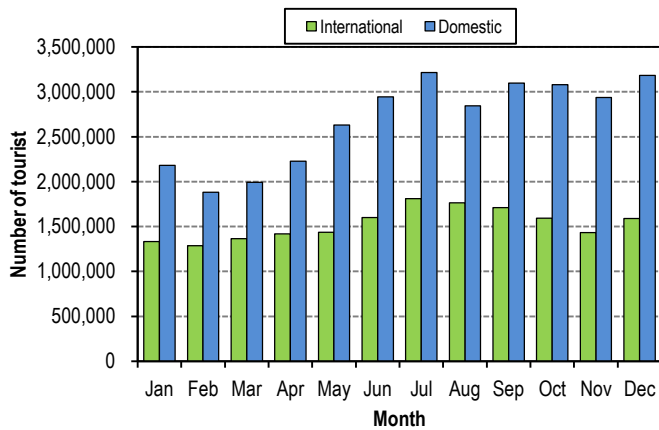


Fig. 1 Monthly distribution of the number of tourists to Bali for 2002-2012

This present study deals with human thermal bioclimate assessment for tourism. The focus of the study is Kuta and the surrounding areas as depicted in Fig. 2. Kuta is located at 8°44'S 115°10'E in the southern region of Bali island. It is known as one of Indonesia's main beach destination places for domestic tourists as well as international tourists. It attracts white sandy beaches along the southern coast of the island. With a long broad Indian Ocean beach-front, Kuta was originally discovered by tourists as a surfing paradise [21].



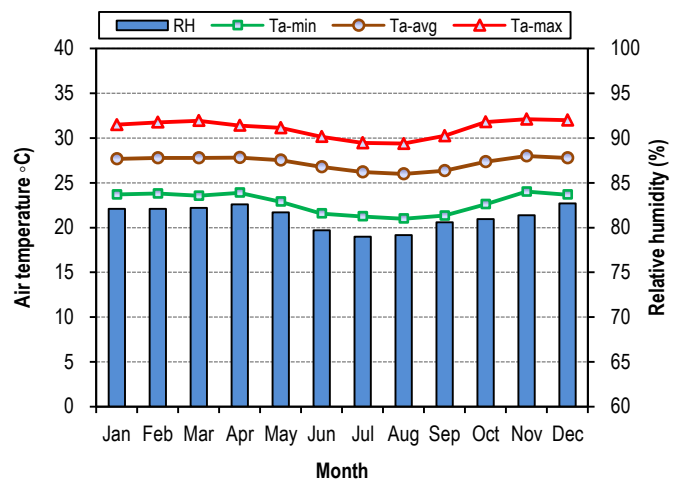
Fig. 2 Location map of Kuta area (within dot circle highlight) [23]

Kuta is now the centre of an extensive tourist-oriented urban area that merges into the neighboring beach-front towns, i.e. Legian, Seminyak and Petitenget. Legian, to the north is the commercial hub of Kuta and the site of many restaurants and entertainment spots. Seminyak and Petitenget are northern extensions of Kuta. They are somewhat quieter suburbs with cottage-style accommodations, where many of the expat crowd live [22]. Ngurah Rai international airport is situated about 3.5 km to the south of Kuta, where makes close access for the tourists to travel.

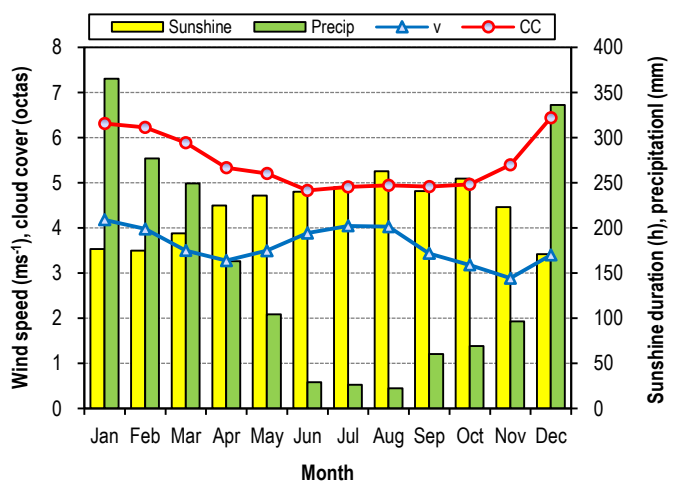
III. METHODS

III.1 Data

This study utilises 11-year synoptic meteorological datasets during the period 2002-2012 from Ngurah Rai airport meteorological station (WMO ID: 97230) authorised by the Indonesian Agency for Meteorology, Climatology and Geophysics. The data were obtained freely from Odimet website [24] for 3-hourly time steps based on the Universal Time Coordinate (UTC). For analysis, the data were firstly converted to the Bali Local Solar Time (LST) at 8 h ahead to the UTC time, i.e. 02:00, 05:00, 08:00, 11:00, 14:00, 17:00, 20:00 and 23:00 LST. Before use, the datasets were decoded from its synoptic code and the errors associated with wrong codes were corrected [25].



(a)



(b)

Fig. 3 Climate data for Ngurah Rai airport meteorological station

Figs. 3a and 3b show summary of climatic conditions for Ngurah Rai airport station on mean monthly basis in terms of sunshine duration, precipitation, wind speed (v), cloud cover (CC), air temperature and air humidity. From Figure 3a, June to October are experienced sunniest months, particularly during June, July and August having cloud cover less than 5 octas (the maximum scale is 8 indicating 100% cloudiness) and sunshine duration between 240 and 263 h. Wettest months are shown in December to March with precipitation accumulation is 250-365 mm, where the peaks are reached in January and December. The mean wind speed is low to moderate between 2.9 and 4.2 m/s. The highest wind speeds are in January, July and August, whereas the lowest one is in November. Figure 3a shows that the air temperature ranges from 21 to 32 °C, whereas the average air humidity varies between 79 and 83%. Just like precipitation and air temperature, air humidity is at lowest in June, July and August in which indicating the driest months of the year.

III.2 Applied Thermal Bioclimatic Index

In this study, one of the most widely used bioclimatic indexes, the PET, is used as it has a widely known unit (°C) as an indicator of thermal stress and thermal comfort. This makes the results easily understandable and comprehensible for potential users. This is especially the case for planners, decision-makers, and even the public who might not be familiar with modern human-biometeorological terminology [26]. PET evaluates the thermal conditions in a physiologically significant manner [27],[28]. It is based on the Munich Energy-Balance Model of Individuals (MEMI), which models the thermal conditions of the human body in a physiologically relevant manner.

The MEMI model is based on the following equation [27]:

$$M + W + R + C + E_D + E_{Re} + E_{Sw} + S = 0 \quad (1)$$

where, M is the metabolic rate (internal energy production by oxidation of food), W the physical work output, R the net radiation of the body, C the convective heat flow, E_D the latent heat flow to evaporate water into water vapour diffusing through the skin (imperceptible perspiration), E_{Re} the sum of heat flows for heating and humidifying the inspired air, E_{Sw} the heat flow due to evaporation of sweat, and S the storage heat flow for heating or cooling the body mass. The individual terms in this equation have positive signs if they result in an energy gain for the body and negative signs in the case of an energy loss (M is always positive; W , E_D and E_{Sw} are always negative). The unit for all heat flows is the watt. The individual heat flows of Eq. 1 are affected directly by the following meteorological parameters: (a) air temperature: C , E_{Re} , (b) air humidity: E_D , E_{Re} , E_{Sw} , (c) wind velocity: C , E_{Sw} , and (d) mean radiant temperature: R .

PET 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. PET enables various users to compare the integral effects of complex thermal conditions outside with their own experience indoors. In addition PET can be used for the entire year and in different climates [13],[27]. Meteorological parameters influencing the human energy balance, such as air temperature, air humidity, wind speed and short- and long-wave radiation fluxes, are represented in the PET values, as it also considers the heat transfer resistance of clothing and the internal heat production. The following assumptions and procedures are made for calculating PET [27]:

1. Mean radiant temperature equals air temperature ($T_{mrt}=T_a$)
2. Wind velocity is set to 0.1 m/s
3. Water vapour pressure is set to 12 hPa (approximately equivalent to a relative humidity of 50% at $T_a=20^\circ\text{C}$)
4. Calculation of the thermal conditions of the body with MEMI for a given combination of meteorological parameters
5. Insertion of the calculated values for mean skin temperature and core temperature into the model MEMI and solving the energy balance for air temperature T_a (with $v=0.1$ m/s, water vapour pressure (VP)=12 hPa and $T_{mrt}=T_a$)
6. The resulting air temperature is equivalent to PET.

III.3 Thermal Perception Classification

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 or thermal perception classification (TPC) [19]. In a study by [29], the TPC for PET for western/middle Europe was obtained by transforming the PMVs of 45,000 datasets for thermal perception and grade of physiological stress on human beings [11],[30] into PET ranges. 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 [19],[31]. 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". Table 1 shows comparison of the thermal perception and PET ranges for people living in western/Middle European countries (temperate regions) and the TPC for Taiwan residents, in which representing sub(tropical) regions [18].

Table 1 Thermal perception and PET ranges for temperate and (sub)tropical regions [18],[29]

III.4 RayMan Model

One of the recently used radiation and bioclimate models, RayMan, is well suited to calculate radiation fluxes [29],[32] and was chosen for all calculations for the mean radiant temperature and the most used and known thermal indices (here PET). The RayMan model, developed according to the Guideline 3787 of the German Engineering Society [14] calculates the radiation flux in easy and complex environments on the basis of various parameters, such as air temperature, air humidity, degree of cloud cover, time of day and year, albedo of the surrounding surfaces and their solid-angle proportions [26],[33]. The parameters introduced into RayMan model for the PET calculation, i.e. thermo-physiological data (heat resistance of clothing, 0.9 clo; light activity, 80 watt) and personal data (175 cm height, 75 kg weight, 35 years old and male gender) [34].

III.5 Methods of Analysis

Climate data are used for input parameters into RayMan model to calculate PET, i.e. air temperature, air relative humidity, cloud cover and wind speed. For bioclimatic analysis, the wind speeds are adjusted to the reference at 1.1 m height above ground level, instead of 10 m standard height of airport station readings, using equation provided in [35]:

$$WS_{1.1} = WS_h \left(\frac{1.1}{h} \right)^a, \quad a = 0.12z_0 + 0.18, \quad (2)$$

where, WS_h is the wind speed (ms^{-1}) at height of h (10 m), a is an empirical coefficient depending on the surface roughness, and z_0 is the roughness length (in our case $z_0 = 0.01$, applied for airport area).

The output of PET values on 3-hourly intervals are categorized into grade of physiological stress on human beings based on PET range thresholds for the tourists reside in temperate and sub(tropical regions) as depicted in Table 1. This gives detail analysis about frequencies of occurrence of each grade thermal comfort, which are summarized in the form of PET bioclimate diagrams on monthly time resolution for the year within the study period. Thermal adaptations of the tourists from the two different regions are compared for the whole day time period and also around noon (11:00-17:00) in which can represent daytime outdoor activities. Subsequently, quantitative analysis of monthly distribution of the thermal comfort grades frequency delivers recommendation for the most suitable time for the tourists to travel.

IV. RESULTS AND DISCUSSION

This study employs PET ranges at different climates, i.e. temperate and sub(tropical) regions (Table 1) to determine distribution of thermal comfort perception throughout the years. The thermal comfort zone (“neutral perception”) is 18-23 °C PET for those residing in temperate regions, and 26-30 °C PET for those residing in (sub)tropical regions.

Fig. 4 shows the PET frequencies on temperate scale during whole day (02:00-23:00). The frequencies of “neutral” are between 10 and 47% of the time of each month. From

Thermal Perception	PET range for temperate region (°C)	PET range for (sub)tropical region (°C)
Very hot	>41	>42
Hot	35 - 41	38 - 42
Warm	29 - 35	34 - 38
Slightly warm	23 - 29	30 - 34
Neutral	18 - 23	26 - 30
Slightly cool	13 - 18	22 - 26
Cool	8 - 13	18 - 22
Cold	4 - 8	18 - 14
Very cold	< 4	< 14

June to September, the neutral perception achieves the highest frequency around 38-47%, whereas similar frequencies of around 10% occur during the rest of the months. The frequencies of “feeling slightly warm to very hot” (PET>23 °C) exceed 40% of the time in each month for the whole year, where the highest frequency of 90% is occurred in November and the lowest one is from June to September of about 60%. Similar trend is found during December-May with the frequency of “feeling hot” (PET>35°C) of almost 25% of the time, whereas during June-September, the frequency is less than 7%. None of the months indicates frequencies of “feeling slightly cool to cool” over the year. From the figure it can be seen that the most thermal comfort period for the tourists residing in temperate region is between June and September, particularly in July and August. The result shows the same pattern to the trend of number of international tourists coming to Bali (Fig. 2), where from June to September are the high season. It nearly coincides with the summer vacation period in the northern hemisphere regions. Though, during December-January also shows high season, it seems that the tourist arrivals are to celebrate New Year, but the climate conditions are thermally comfortable to them.

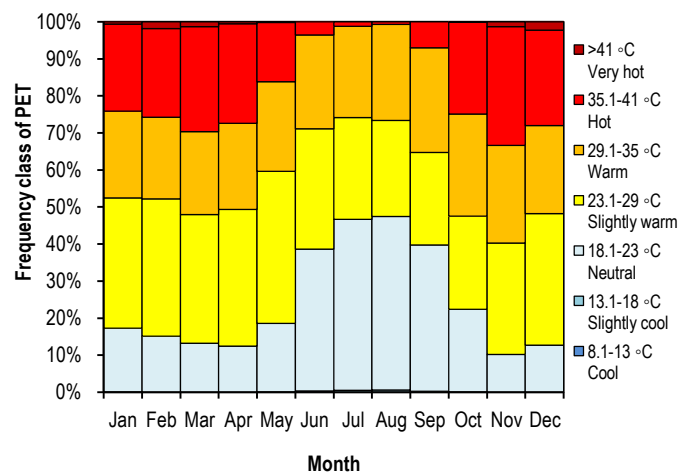


Fig. 4 Distribution of PET frequencies for temperate region during 02:00-23:00 LST (2002-2012)

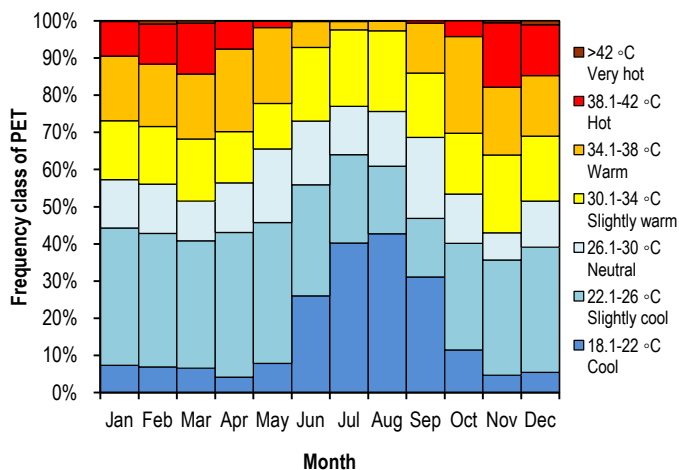


Fig. 5 Distribution of PET frequencies for sub(tropical) region during 02:00-23:00 LST (2002-2012)

Fig. 5 shows the PET frequencies during whole day (02:00-23:00) under sub(tropical) scale. The frequencies of “neutral” are almost uniform for each month for the whole year, however September and November show the highest and the lowest frequency of 22% and 7%, respectively. The frequencies for the rest of the months are of around 14% of the time. The frequencies of “feeling slightly cool to cool” (PET<22°C) achieve of about 40% for the whole year, except June, July and August indicate frequencies of 55-65%. When considering the frequency of “feeling cool” (PET<22°C), from June to September reach the frequencies in the range as high as 25-40% of the time. Similarly, the frequencies of “feeling slightly warm to very hot” (PET>30°C) indicate that from June to September achieve of as high as about 30% of the time, whereas the rest of the months shows higher around 50-65%. When the tourists can adapt to the “feeling slightly cool to cool”, they can perceive thermally comfortable during all of the months, however during May-September is more preferred time. In general, from the figure, it can be seen that, distribution of “neutral” scale is very similar for each month during the study period, which means that all the months are thermally comfortable for the tourists living in sub(tropical region), even from May to September shows more thermally comfortable than the rest of the months throughout the years.

The results analysis in Figs. 4 and 5 demonstrate that the climate seems to be colder with sub(tropical) region scale than with temperate region scale. The above results also demonstrate that thermal comfort (“neutral” perception) frequencies for tourists from temperate region are higher than those for tourists from (sub)tropical region, indicating that tourism potential based on thermal comfort is high for those from temperate regions. In addition, tourists coming from temperate region more adaptable to the climate with “feeling cool” perception than that of perceived by those from the (sub)tropical region. This is similar to the results by Lin and Matzarakis [18] for their study in Kaohsiung City of Taiwan in which represents tropical region.

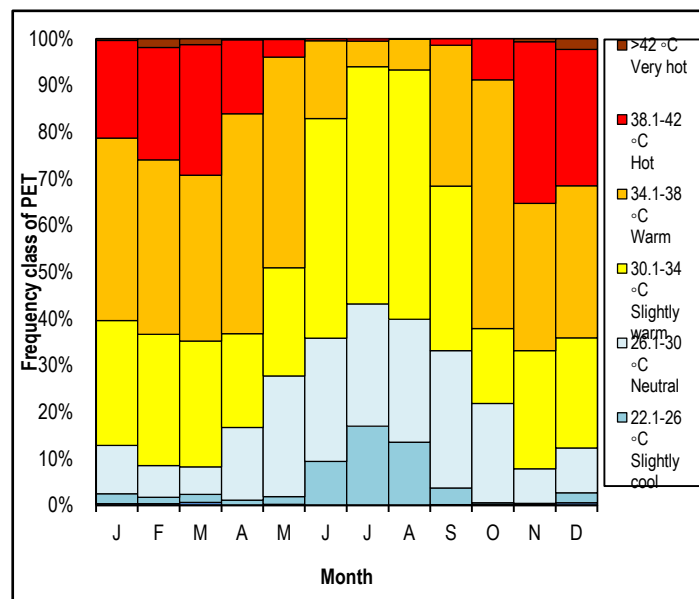


Fig. 6 Distribution of PET frequencies for temperate region around noon, 11:00-17:00 LST (2002-2012)

Fig. 6 shows the PET frequencies on sub(tropical) scale around noon (11:00-17:00 LST), which representing daytime outdoor activities. The frequencies of “neutral” are less than 1% of the time (not clearly shown on the figure), which are much lower than that of the bioclimatic conditions for the whole day observation. The frequencies of “feeling warm to very hot” (PET>29 °C) are more than 65% of the time of each month, where from June to September indicates the lowest one. The frequencies of “feeling very hot” (PET > 42 °C) are from November to March as high as 4.9% of the time, where the highest frequency is occurred in December and February. The frequencies of “feeling slightly warm to cool” (PET<29 °C) as high as 32-36% occurred during June-September, which indicates similar pattern to the “neutral perception” during observation for the whole day as shown in Figure 4. From the figure, it can be summarized that the thermal comfort of the tourists living in temperate region is very low around noon.

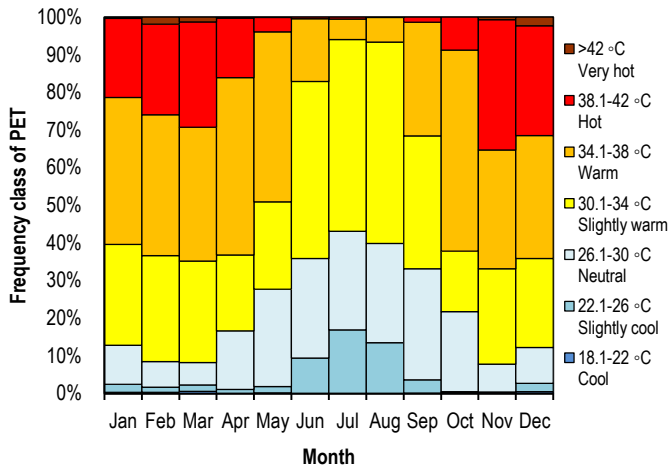
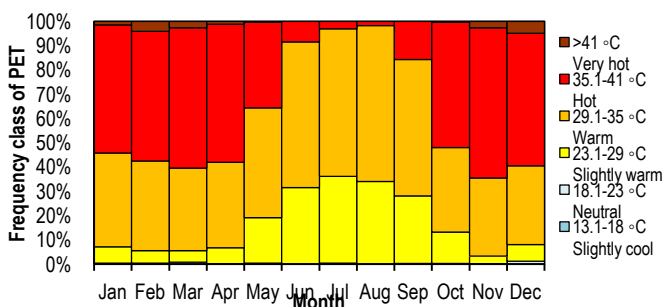


Fig. 7 Distribution of PET frequencies for sub(tropical) region around noon, 11:00-17:00 LST (2002-2012)

Fig. 7 illustrates the PET frequencies on sub(tropical) scale around noon (11:00-17:00 LST). The frequencies of “neutral” are between 6 and 29% of the time of each month. From May to September, the “neutral” perception is high as of about 27%. The frequencies of “feeling slightly cool” (PET < 22 °C) shows similar pattern to the frequencies of “neutral” perception. June, July and August show the frequency of as high as 17%, where July indicates the highest one. The frequencies of “feeling hot to very hot” (PET > 38 °C) are not profound during June-August, whereas the rest of the months indicate the frequency as high as of about 30%, where the highest frequency is in November. From the figure, it can

be seen that all of the months are comfortable for those tourists residing in sub(tropical) region. The frequencies of thermal



comfort (“neutral” perception) around noon are higher than that of those for the whole day observation.

From Figs. 6 and 7, it can be summarized that low PETs occurrence between 11:00 and 17:00 occurred frequently from June to September for both temperate and sub(tropical) scales. However, under sub(tropical) scale, the frequencies of thermal comfort are higher that of under temperate scale. The results reveal that the thermal comfort of the tourists coming from (sub)tropical region is better than that of temperate region

during around noon. In other words, the tourists from sub(tropical) region are more tolerant with warmer environment than that of tourists from temperate region around noon.

V. CONCLUSIONS

The results of present study reveal that:

- a. During whole day (02:00-23:00 LST), the tourists from temperate region perceive more comfortable than that of the tourists from (sub)tropical region. Frequencies of thermal comfort (“neutral” perception) for tourists from temperate region are higher than those for tourists from (sub)tropical region, indicating that tourism potential based on thermal comfort is high for those from temperate region.
- b. During around noon (11:00-17:00 LST), the tourists from temperate region are less tolerant with warmer environment than that of the tourists from (sub)tropical region. In other words, thermal comfort of the tourists coming from (sub) tropical region is better than that of those tourists from temperate region during course of the time.
- c. With regards to the thermal comfort perception, the most suitable time for travelling is from June to September, particularly in July and August for tourists from temperate region, whereas all year round is appropriate for the tourists from (sub)tropical region.

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