Transfer of climate data for tourism applications - The Climate-Tourism/Transfer-Information-Scheme

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ABSTRACT

The demand and requirement of basic and easily understandable climate information leads in the development of transfer possibilities in order to apply them for different planning levels including tourism and recreation. A new approach based on climate thresholds, the Climate-Tourism/Transfer-Information-Scheme (CTIS), which is appropriate for destination analysis of present climate conditions and for climate changes issues is shown here, which can be applied to sustainable tourism. The presented approach integrates meteorological and tourism related components and factors. All factors are included in a scheme and can describe these factors in a high temporal resolution. CTIS integrates and simplifies climate information for tourism and recreation purposes. It contains detailed climate information which can be used by tourists to anticipate thermal conditions (including thermal comfort, cold stress, heat stress and sultriness) as well as aesthetical (sunshine) and physical conditions (wind, rain) when planning their vacations. CTIS provides frequency classes and frequencies of climate related information and extreme weather events on a 10-d or monthly time scale. The included factors and parameters are visualized based on thresholds. The information based on CTIS can be used for different kinds of purposes, e.g., tourism, health and urban planning. The example of Thessaloniki in Greece is shown and discussed.

INTRODUCTION

Visitors at vacation places and in general tourists are exposed climatic and extreme meteorological conditions and they can be affected positively or negatively [1,2]. Relevant information about climatic condition is of importance and interest; information needs to cover the variability of climate and extremes in high temporal and spatial resolution [2]. Climatic conditions and atmospheric phenomena for tourism purposes are well studied but mostly in a qualitative manner, and the quantity manner is not well investigated until now. Recent research is mostly focused on the quantification of strategies against climate change in tourism [3]. Knowledge of current and expected climate conditions requires interdisciplinary approaches and solutions [2].

The interactions of weather and climate in tourism are well known and described before [1-5]. The recent growing attention has been paid on sustainable tourism [5]. It is known that tourism, especially summer tourism, can be described by the triple S (sun, sea and sand). Many of the tourism factors creating the triple S are dependent on weather and climate. An additional factor that can be added to the triple S, or used as single winter S, is snow, the main decision factor for winter tourism [1,2]. Including all these factors in yearly quantification of climate for tourism is possible.

The most known example of the quantification of climate information for tourism is the Tourism Climate Index (TCI). Developed by Mieczkowski [6], the TCI uses a combination of seven parameters, three of which are independent and two in a bioclimatic combination. It includes a daytime comfort index, consisting of the mean maximum air temperature and the mean minimum relative humidity (RH), a daily comfort index, consisting of the mean air temperature and the mean RH, amount of precipitation, daily sunshine duration and mean wind speed. In contrast to other climate indices, every contributing parameter is assessed. Because of a weighting factor (a maximum

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value for TCI of 100), every factor can reach 5 points. TCI values ≥ 80 are excellent, while values between 60 and 79 are regarded as good to very good. Lower values (40-59) are acceptable, but values < 40 indicate bad or difficult conditions for tourism [6,7]. The tourism indices of the past show several weakness concerning parameters and factors. Specifically, TCI does not consider thermal comfort/stress approaches, which rely on human-biometeorology [1,2]. It also is not proven and is not valid for winter tourism [2]. New approaches as the Climate Index for Tourism [7] and the Climate-Tourism/Transfer-Information-Scheme (CTIS) [8] are quantified and assessed because they consider recent scientific research from human-biometeorology and tourism climatology [2].

In order to assess the climatic tourism potential, e.g., for human health or sustainable purposes, use of air temperature and precipitation is not sufficient. For example, winter sport enthusiasts and tourists desire snow as well as sunshine, beneficial thermal conditions, and recreation in their holidays. Nowadays, the assessment can be performed by facets of climate in tourism (thermal, aesthetical and physical facet) [4]. The thermal facet of climate is based on a complex thermal index, e.g., Physiologically Equivalent Temperature (PET), which is based on the human energy balance. It describes the effect of the climate not only for cold but also for warm conditions. In general, PET describes the effect of the thermal surroundings of the human body and includes the energy exchange between humans and environment and assesses the effect of the thermal environment. The other two facets, the aesthetical and physical, can be covered by simple and easily extracted parameters and factors, e.g., snow height and daily sunshine duration, from data records or networks [1,2]. There is a recent development of assessment indices which include new findings and rating possibilities of relevant factors [7,8].

The present study deals with this specific issue how to combine and include different factors based on measured data. The example of Thessaloniki in Greece with selected factors from the facets of climate in tourism is presented.

MATERIALS AND METHODS

For the analysis and inclusion of the data in some cases, additional tools or methods are required. For the inclusion of the thermal facets (here for PET), the RayMan model, which is based on the energy-balance equation of the human body and is based on German VDI-Guidelines 3789 Part II [9] and VDI-Guidelines 3787 Part I [10], can be applied. The model is developed for urban climate studies and has a broader use in applied climatology and tourism studies as well. Finally several thermal indices such as Predicted Mean Vote [11], PET [12-14] and Standard Effective Temperature [15] may be calculated for the assessment of human bioclimate in a physiologically relevant manner as shown in several applications [14,16-18]. Therefore, meteorological parameters are combined with physiological aspects of the human body, e.g., activity, clothing and age. To combine the wind conditions with a human body, the values for wind speed were reduced to the reference height of 1.1 m. This height represents the center of the human body. All indices have the known grades of thermal perception for human beings and physiological stress [13].

In order to quantify and visualize the facets of climate in tourism, a new approach based on climate thresholds Climate-Tourism/Transfer-Information-Scheme (CTIS) has been developed and is presented here. The method combines meteorological and tourism related components. It integrates and simplifies climate information for tourism. Thus, besides the two variables most frequently used in impact assessment studies, air temperature and precipitation, the following factors are also considered: PET, cold stress (PET < 0 °C), heat stress (PET > 35 °C), thermal comfort (18 °C < PET < 29 °C), sunshine/cloud cover conditions in terms of the number of days with a cloud cover < 5 octas, vapour pressure > 18 hPa, wind velocity > 8 m s^{-1}, RH > 93%, precipitation < 1 mm as well as precipitation > 5 mm, and snow cover > 10 cm. In general, the definitions of the several threshold values do not necessarily correspond to the universal meteorological threshold values and are adjusted to applied tourism climatology and human health applications. For example, under meteorological aspects, a stormy day is given by wind strength of at least 8 Bft, which corresponds to a wind velocity greater than 17.2 m s^{-1}, while in tourism climatology a wind velocity of 8 m s^{-1} (5 Bft) is perceived as unpleasant and uncomfortable. All the above-mentioned factors have been included in an information scheme in order to describe these factors in a high temporal resolution [8,19,20].

The following factors are considered: a) Daily basic available parameters (air temperature, air humidity, wind speed, precipitation); b) High temporal resoluted information in decades (separation of months in three intervals); c) Analysis of climatological and human-biometeorological conditions based on frequency classes and threshold values; d) Consideration of thermal comfort, heat stress, cold stress and "sultriness" based on human-biometeorological thresholds and human energy balance, i.e., PET; e) Consideration of precipitation and its amount and the type of precipitation, i.e., snow cover, dry days or wet days; f) Consideration of fog and sunshine/cloudiness conditions; and g) Consideration of high wind conditions.

CTIS contains detailed climate information which can be used by tourists to anticipate thermal comfort as well as aesthetical and physical conditions for planning their vacations [1,4]. CTIS provides all-seasonal frequency classes and frequency of extreme weather events on a 10-d or monthly time scale [8]. This method is preferred for analyzing climate stations or grid points. The conditions can be presented in terms of months or decades depending on the availability and temporal accuracy of the data used. The whole approach is usually based on daily data. For the integral quantification of climate and tourism purposes in terms of a destination analysis the CTIS builds a valuable method, because it includes in highly temporal resolution the most relevant parameters and factors [8,19,20]. The factors to be included can differ from one climate region to another. The selection of thresholds are based on bibliographic references and represent in the subsequent figures more conditions for people from western and middle Europe [8]. In addition the thresholds used can be different for climate regions and cultures and can be adjusted with the relevant ones [8,21].

For Thessaloniki the following threshold criteria have been chosen: Thermal acceptance (PET between 18 and 29 °C); Heat stress (PET > 35 °C); Cold stress (PET < 4 °C); Cloudy (> 5 octas); Fog (based on RH > 93%); "Sultriness" (based on vapour pressure > 18 hPa); Dry (precipitation < 1 mm); Wet (precipitation > 5 mm); and Windy (wind speed > 8 m s^{-1}). Ranges of PET related to thermal perception by human are shown in Table 1.

Some factors may be rated as positive or negative resulting in an in-version of the assessment scale for those rows. To add to the CTIS diagrams and to make the information easier to understand the scheme, a probability scale is included in CTIS [19] expressed in seven climate classes from "very poor" to "ideal", which gives about 14% of probability to each incorporated class (Table 2). This rating is intended to use with classification coloring, not with colors interpolated according to frequencies.

A software module which is able to provide the graphs has been developed in a user friendly way [22]. Convenient data files (i.e., .txt or .csv) can be imported into CTIS containing frequencies of all climatic factors the user wants to visualize his/her results (see subsequent figures). These factors have to be scaled on a uniform scale like 0 to 1 or 0 to 100. The CTIS program consists of two parts: the main window including data import and basic preparation and second, the report window for fine tuning the resulting image in size and font with real-time preview. CTIS-software can be also used for other kind of analysis and visualizations in applied climatology and related disciplines [22].

RESULTS AND DISCUSSION

For the developed methods, CTIS is intended to combine thermal component, based on PET ranges and thresholds, aesthetic components like cloudiness and fog, and physical components like wind speed, precipitation, and vapor pressure. The frequencies of these factors are presented in 10-d intervals visually grouped by months [19,20,23].

First of all it can be included and presented the most relevant and representative factors for a specific destination. For a better understanding a specific example for Thessaloniki in Greece is given. Detailed results are presented as:

- Bioclimate diagrams [8,19,20] have been constructed to analyze the climatic conditions in Thessaloniki. The bioclimate diagrams contain not only mean PET values but also frequency classes of thermo-physiological stress levels for PET [18]. The bioclimatic diagrams based on a 10-d period including mean, maximum and

Table 1. Ranges of physiologically equivalent temperature (PET in °C) for different grades of thermal perception by humans according to Matzarakis and Mayer [21]

PET (°C)	Thermal perception	Grade of physiological stress
	very cold	extreme cold stress
4		
	cold	strong cold stress
8		
	cool	moderate cold stress
13		
	slightly cool	slight cold stress
18		
	comfortable	no thermal stress
23		
	slightly warm	slight heat stress
29		
	warm	moderate heat stress
35		
	hot	strong heat stress
41		
	very hot	extreme heat stress

Table 2. Description of the range of rating for CTIS (color range of percent values description) [20]

Color	range of percent values, %	description
	< 14	unfavourable
	14-28	↕
	28-42	↕
	42-56	moderate
	56-70	↕
	70-84	↕
	> 84	ideal

minimum PET, as well as thresholds of days for temperate, cold and hot conditions [24].

- Precipitation diagram based on frequencies of classes is shown in Fig. 1. In addition information about the annual amount, maxima daily precipitation, fog days, windy days, sunny days and sultriness can be given.
- CTIS analysis was made for the period of 1960-2001 to analyze bioclimatic and tourism climatic factors based on the most relevant factors.

The Thermal bioclimate (PET) is shown as frequency diagram in Fig. 1 based on the assessment classes according to Matzarakis and Mayer [21]. Every class indicates a specific thermal condition, e.g., the class of 18.1-29.0 °C represents acceptable thermal conditions including thermal comfort. The data cover the period from 1955 to 2001.

Thermal comfort in Thessaloniki occurs from February to November with the best occurs in June and July (> 10%) and only 1% in February. Cold stress (< 0 °C) could be observed from the end of October to the middle of April. The highest stress occurs from December to February (approximately 50%), especially in January (> 70%). During the rest of the winter days PET values < -0 °C occur from the end of November to beginning of March. Days with heat stress (> 35 °C) occur from April to October with the higher temperatures from May to August. In the middle of September there are ideal conditions for thermal comfort. During June, July and August thermal comfort is given with more than 20%, but during these months heat stress also occurs (from 10-25%).

The frequency distribution of precipitation for Thessaloniki was analyzed to characterize rainy periods (Fig. 2). The values cover the period from 1971-2000. On the top of the diagram (Fig. 2) the average value of precipitation for the time span is shown. Precipitation mostly occurs in the winter period and less during summer period. June, July, August and September have the lowest average values. November and December show the highest average values. Below the diagram special information about the precipitation in Thessaloniki is given. The mean of annual precipitation is 436 mm and the highest precipitation ever recorded in any month is 84.7 mm. In addition information of windy, sultry, cloudy and foggy days is given too. Windy days (> 8 m s^{-1}) take place 14.3 d and sunny days (< 5 octas) are 157.4 days with 8.7 foggy days (> 93% RH).

Climatic factors important for tourism are summarized and visualized in CTIS. For a better understanding of the climatic conditions in Thessaloniki, a CTIS [8,19,20] was generated (Fig. 3). In CTIS each column describes the corresponding frequency of any parameter or factor. A frequency of 100% indicates that the specific period is characterized by the respective condition listed on the right hand side. A frequency of 50% corresponds to an occurrence of the indicated condition during the half of the days. The diagram combines thermal components like PET ranges and thresholds, aesthetic components like cloudiness and fog, and physical components like wind speed, precipitation, and vapor pressure. The frequencies of these factors are presented in 10-d intervals visually grouped by months [2]. In addition CTIS rating (according Table 2) is shown in Fig. 4.

Thermal acceptable conditions (18 °C > PET < 29 °C) take place in Thessaloniki from the middle of

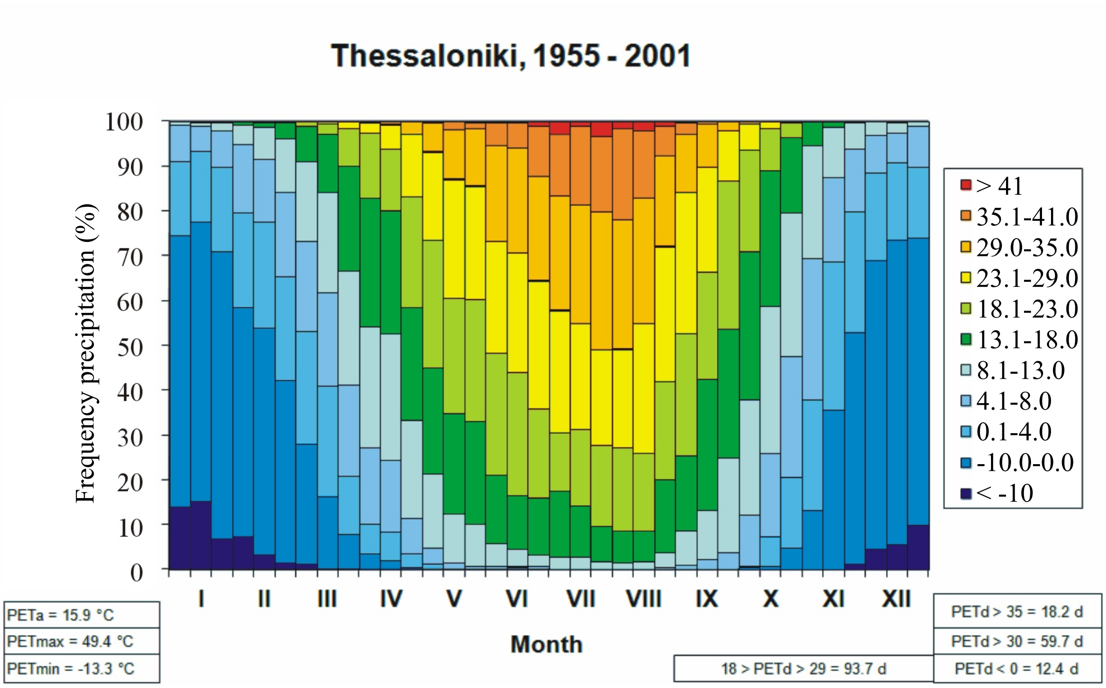

Fig. 1. Frequency diagram (in%) of PET (in °C) for Thessaloniki, period 1955-2001.

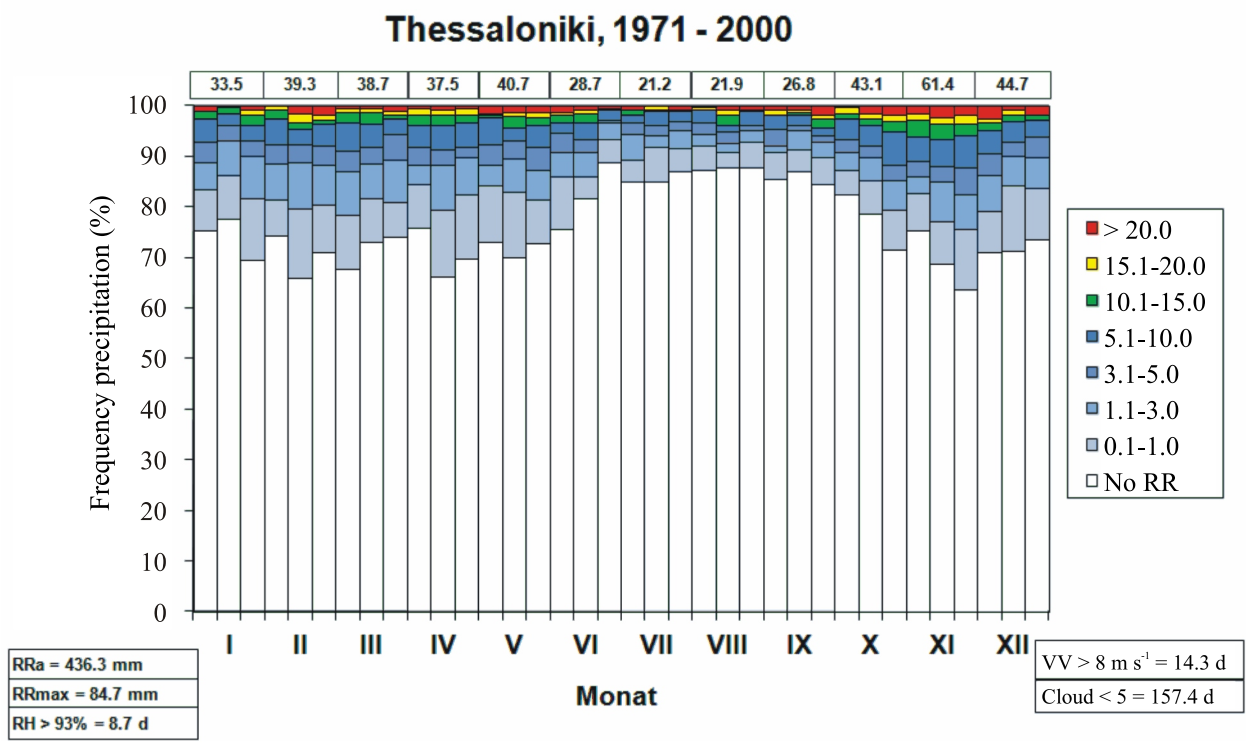

Fig. 2. Frequency diagram (%) of precipitation (in mm) for Thessaloniki, period 1971-2000.

April to the middle of October in more than 30% of the days (Fig. 3). According the rating nearly ideal conditions occur from the end of April to the end of June and partly in September and October. Heat stress occurs mostly during the high summer months (June to August) and according the rating, this period is not appropriate for ideal conditions. Cold stress (PET < 0) takes place from December to February and followed up with a non ideal rating for the period. The higher degree of sultriness could be detected (from 20-60%) between May and October, reducing the ideal conditions to less humid conditions during this period. Fog occurs mostly during winter months but according to the rating, it cannot be detected in the area of ideal conditions. Sunshine is given through the whole year with about 30-50% and high levels during summer months of more than 70%. Dry days take place during winter period with the lowest during the summer period indicating the higher sunshine amounts during summer. Long precipitation days (> 5 mm) are less than 20%, with lower levels during summer. 10% wind occurs during the whole year with the highest detected during winter.

Climate conditions, which can build an asset of an area, can be expressed and described nowadays by human biometeorology and tourism climatological methods and approaches [1]. Traditional methods describing climate and other related information are used to be visualized mostly as monthly means or sums. The results in the present study establish a possibility how to transfer information about climate for tourism purposes. The PET, precipitation and CTIS analysis applied for diverse regions are helpful for decision making and planners [24-27]. The factors of bioclimate and tourism (including urban and other kinds of tourism) are in close context to other fields, i.e., urban climatology [23]. CTIS can be used to assess and quantify different destinations considering the most relevant factors of the specific destination. This can be performed by the use of the existing data and by climate modeling in order to develop strategies for the future. In addition, periods with occurrence of specific extremes, e.g., heat waves or periods of strong wind, can be detected.

Results based on CTIS can be easily and directly used for the preparation of tourists about a destination and for the tourism industry for more appropriate planning and the selection of appropriate kind of tourism for future inclusion in tourism offers. Also health resorts and authorities can be prepared or protected in order to avoid negative developments in the economic sectors of tourism, recreation and health. Focus can be set also in climate change issues by the use of information from climate models.

In addition, the developed methods based on the frequency diagrams of bioclimate (PET), climatological (precipitation) factors and on thresholds of facets of climate in tourism (CTIS) can provide detailed information. This builds a useful possibility for users, who are not familiar with complex terminologies of human biometeorology or climatology. Several examples based on data and regional climate models indicate and show these possibilities [23-30]. The results show that the 10-d period is closer to the time and periods people spending their vacations. The results can be used as basic climatological and

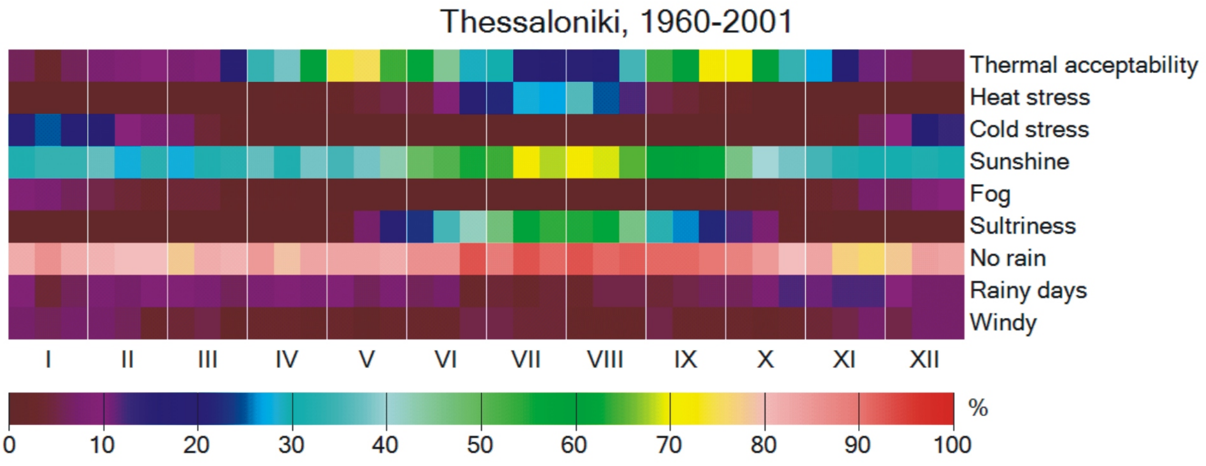

Fig. 3. CTIS for Thessaloniki period 1960-2001 as percentage.

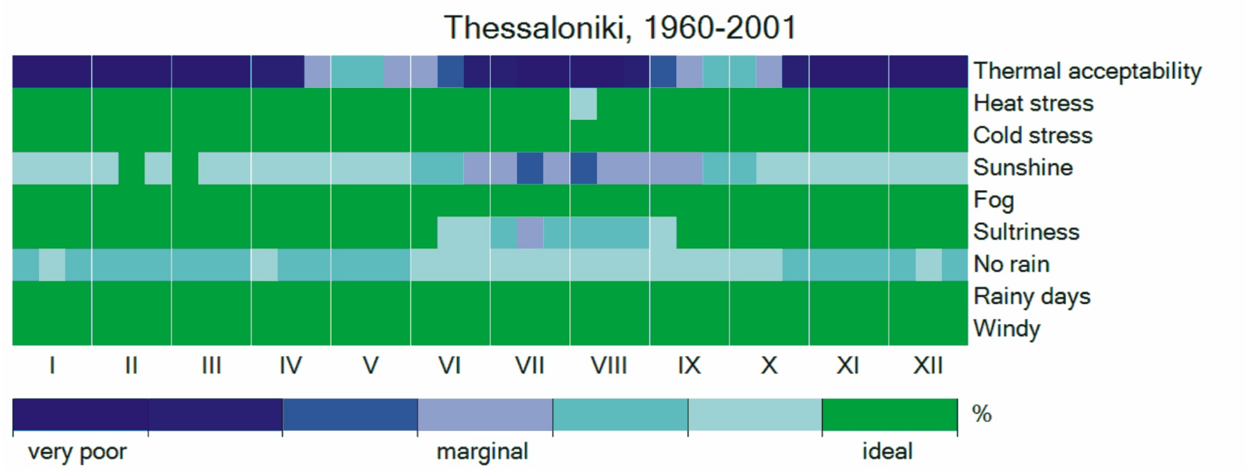

Fig. 4. CTIS for Thessaloniki, period 1960-2001 as rated (according Table 2).

bioclimate analysis of a specific destination [2], e.g., in Thessaloniki. Nevertheless, a basic analysis about climate and tourism or in general bioclimate is an issue of environmental information and is in close relationship with many environmental issues like urban planning, health and recreation or in general of quality in life [2,24-30]. In addition the major influences are connected with extreme events, which can be detected and quantified (for the past) with the shown methods, e.g., heat wave conditions.

The quantification and assessment of the extreme conditions have to be performed in an appropriate way and not only in terms of air temperature, which is one of the parameters which influence human thermal comfort and health, but also air humidity, wind speed and radiation fluxes (expressed with the mean radiant temperature) [9,10]. The results based on the frequency diagrams and CTIS approach give an additional information to the public and official responsible from urban planning and tourism the possibility to be informed about the basic conditions and expected conditions in order to develop and apply mitigation and adaptation possibilities [23,24,31]. These results and information can be visualized via user friendly manner and easily understandable for layman [23,24,27-30]. In addition the results can be helpful for other environmental issues, i.e. water or for the quantification of effects of greenhouse gas emissions [32,33].

CONCLUSIONS

New information technologies and more availability of weather and climate data as well as tools (e.g., RayMan, CTIS, etc.) can be helpful in order to transfer climate and climate relevant information for diverse applications, especially for sustainable tourism. Sustainable tourism is one of the specific types of tourism which is growing, demanded and part of the tourism industry [5]. In addition networks built in the specific issue of climate and tourism, i.e., the Commission Climate, Tourism and Recreation of the International Society of Biometeorology (www.urbanclimate.net/cctr) promote scientific exchange, stimulate research in that topic and especially in the development of assessment methods and can provide additional tools.

The presented approach for the integration of climate information in tourism has several advantages.

The separation of the months in three intervals (weeks are also possible) builds a suitable possibility for a higher resolution than monthly. The use of frequencies of climate and human-biometeorological values and variables based on the several facets of climate in tourism is an easily understandable and all-embracing approach. Depending on specific regions or specific tourism uses the extension to other parameters like days with frost etc. or reduction of parameters like for summer regions (i.e., Mediterranean) no need for snow is possible. Another advantage is that the CTIS can be used for yearly tourism, because of the implementation of several facets of climate and tourism uses.

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