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QUANTIFICATION OF CLIMATE-TOURISM POTENTIAL FOR ATHENS, GREECE – RECENT AND FUTURE CLIMATE SIMULATIONS

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ABSTRACT

The aim of this paper is to present in a useful and understandable way how climatic change could be interpreted for tourism and recreation. Future climate change conditions are analyzed using the Climate Version of the Local Model (CLM) based on the COSMO model, which is currently used – among other weather services – by the DWD (Deutscher Wetterdienst) for operational weather forecast. The climate simulations concern the future periods 2021-2050 and 2071-2100 against the reference period 1961-1990, under A1B scenario. Based on regional climate simulations, the analysis for tourism can be performed using the Climate-Tourism-Information-Scheme (CTIS). The CTIS contains detailed climate information, which can be used by tourists to anticipate thermal comfort, aesthetical and physical conditions for planning their vacations. Furthermore, the Physiologically Equivalent Temperature (PET), which is one of the most popular physiological thermal indices derived from the human energy balance, is used in the analysis in order to describe the effect of climate. The future simulations concerning PET and CTIS for the area for Athens have been exemplary used, in order to consider them for tourism industry and local authorities for tourism planning.

KEYWORDS: CLM, Climate and Tourism, Physiologically Equivalent temperature, Climate-Tourism-Information-Scheme, Athens

1. INTRODUCTION

Tourism is influenced by many factors; weather and climate are two of them (Abegg, 1996; Matzarakis, 2006; Scott, 2011). The knowledge of climate parameters and thresholds and their appropriateness for tourism and recreation are basic information about several possibilities for touristic activities and recreation. In addition, climate and weather extremes, e.g. heat waves or storms, are most relevant because of the possible damages on infrastructure and implications on human life. It is of importance to prepare and protect tourists, domestic population and at risk groups (retired and sick people and children) against the changing climate (Matzarakis *et al*., 2004; 2007; Amelung *et al.*, 2007; IPCC, 2007).

It is known that tourism, especially summer tourism, can be described by the Triple S (Sun, Sea and Sand) (Matzarakis, 2006). Many of the creating tourism factors for the triple S are depending on weather and climate. An additional factor that could be added to the triple S, or used as single winter S, is snow, the main decision factor for winter tourism. Usually the quantification of climate for tourism can be performed by indices. The most used index in the past, among others, is the Tourism Climate Index (TCI) developed by Mieczkowski (1985). 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. In contrast to other simple climate indices, every contributing parameter is assessed. Because of a weighting factor (maximum value for TCI equals 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.

The TCI shows several weaknesses concerning included parameters and factors. Specifically, TCI does not consider thermal comfort/stress approaches, which rely on human-biometeorology (Matzarakis, 2006; 2010). Besides, it is not proved and is not valid for winter tourism (Matzarakis, 2010). New approaches as the Climate Index for Tourism (de Freitas *et al.*, 2008) and the Climate-Tourism/Transfer-Information-Scheme (Lin and Matzarakis, 2008; Zaninovic and Matzarakis, 2009) are quantified and assessed because they consider recent scientific research from human-biometeorology (Matzarakis, 2010). In order to assess the climatic tourism potential e.g., for human health or sustainable purposes, air temperature and precipitation are not sufficient. For example, winter sports 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) (de Freitas, 2003). 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 (Mayer and Höppe, 1987; Höppe, 1999; Matzarakis *et al.*, 1999). 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 easy extracted parameters and factors, e.g., snow height and daily sunshine duration from data records or networks (Matzarakis, 2006; 2010).

A new development of a climate tourism assessment is the Climate-Tourism-Information-Scheme, which includes the most relevant and reliable parameters and tourism-climatological factors (Matzarakis 2007; Lin and Matzarakis 2008). This specific quantification of climate can be carried out by using existing climate data set or regional modeling projections based on climate simulations for the present or future time periods (Matzarakis, 2006; 2010). The prepared and extracted information have to be presented in an easy acceptable and understandable way for tourism industry and local authorities in tourism and health planning and protection of infrastructure.

The objective of this paper is to describe in a useful and understandable way how climate-tourism conditions, based on regional climate simulations, can affect the decision making for vacation time and area and how to access existing climate information not only for present but also for expected future climate conditions.

2. METHODS AND DATA

The most relevant parameters are used in our analysis, interpreting the climate components in tourism and recreation (physical, thermal and aesthetic), that describe the so called climatic tourism potential (de Freitas, 2003; Matzarakis, 2006; 2007).

One of the most popular physiological thermal indices derived from the human energy balance (Höppe, 1993), that is the Physiologically Equivalent Temperature (PET), is chosen (Table 1) to describe the thermal component of climate. In order to calculate PET, it is necessary to determine the meteorological parameters, which are important for the human energy balance at a human-biometeorologically significant height, e.g. 1.1 m above ground, which is the average height of a standing person's gravity center in Europe (Mayer and Höppe, 1987). Dominant meteorological parameters influencing the human energy balance concern air temperature, air humidity, wind speed and mean radiant temperature of the surroundings. The thermal environment expressed in terms of PET is calculated by the radiation and energy balance model RayMan (Matzarakis *et al.*, 2007). The frequency (%) distribution of PET classes on monthly basis is presented in the bio-climate diagram (Figure 1). Each coloured column represents the frequency distribution of the PET classes that appears in a specific month; namely, a frequency of 50 % of slight heat stress (23 °C < PET < 29 °C) in a month corresponds to an occurrence of the indicated condition during 15 days of this month.

The other two components, the aesthetic and physical, can be covered by simple and easy extracted parameters and factors e.g. snow height and daily sunshine duration from data records or networks (Matzarakis, 2007). Furthermore the applied method combines meteorological and tourism related components. Thus, besides the two variables frequently used in impact assessment studies (air temperature and precipitation), PET (Höppe 1999), 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}, relative humidity > 93 %, precipitation < 1 mm as well as precipitation > 5 mm, and snow cover > 10 cm are taken into consideration (Matzarakis 2007; Lin and Matzarakis, 2008; Zaninovic and Matzarakis, 2009).

Table 1. Ranges of the physiologically equivalent temperature (PET) for different grades of thermal perception by human beings and physiological stress on human beings; internal heat production: 80 W, heat transfer resistance of the clothing: 0.9 clo (according to Matzarakis and Mayer, 1996)

PET	Thermal Perception	Grade of Physiological Stress
	very cold	extreme cold stress
4 °C		
	Cold	strong cold stress
8 °C		
	Cool	moderate cold stress
13 °C		
	slightly cool	slight cold stress
18 °C		
	Comfortable	no thermal stress
23 °C		
	slightly warm	slight heat stress
29 °C		
	Warm	moderate heat stress
35 °C		
	Hot	strong heat stress
41 °C		
	very hot	extreme heat stress

The Climate-Tourism-Information-Scheme (CTIS) (Matzarakis 2007; Lin and Matzarakis, 2008) was derived to integrate and simplify climate information for tourism. The CTIS contains detailed climate information which can be used by tourists to anticipate thermal comfort, aesthetical and physical conditions for planning their vacations. The CTIS describes frequencies of selective parameters, here relevant for tourism purpose, on a monthly scale. Thereby, the parameters are subject to certain thresholds that are exceeded and fallen below, respectively (Table 2).

Table 2. Definition of parameters used in the Climate-Tourism-Information-Scheme

Parameter	Threshold
Thermal comfort range	18°C < PET < 29°C
Heat stress	PET > 35°C
Cold stress	PET < 0°C
Sunny	Cloud cover < 4 eights
Foggy	Relative humidity > 93 %
Sultry	Vapor pressure > 18 hPa
Less precipitation	Precipitation ≤ 1mm
Rainy	Precipitation > 5mm
Stormy	Wind velocity > 8 m s^{-1}

Since the presented results are based on model projections and thus affected by the models' uncertainties, a temporal resolution finer than one month is not considered useful. The analyzed bioclimatic parameters under predefined thresholds are presented in frequencies (%) in a matrix, where the columns (12) refer to months and the rows (9) to the selected parameters described in Table 2. Thus, each coloured column depicts the corresponding frequency of each parameter listed on the right hand side (Figure 2), within a specific month. A frequency of 100 % indicates that each day in a month is characterized by the respective condition. A frequency of 50 % corresponds to an occurrence of the indicated condition during 15 days, 10 % to 3 days of the considered month etc.

Future climate change conditions are analyzed using the Climate Version of the Local Model (CLM) based on the COSMO model which is currently used – among other weather services – by the DWD (Deutscher Wetterdienst) for operational weather forecast. The regional model LM is based on the primitive hydro-thermodynamical equations describing compressible non-hydrostatic flow in a moist atmosphere without any scale approximations. The climate simulations concern the future periods 2021-2050 and 2071-2100 against the reference period 1961-1990, under A1B scenario. According to IPCC (2007), the A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil-intensive (A1FI), non-fossil energy sources (A1T) or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies). The resolution used for this study is 18 km (Christensen *et al.*, 2007; Giorgi and Mearns, 1999; Hagemann *et al*., 2004).

3. RESULTS AND DISCUSSION

The distribution of PET classes for the present climate (Fig. 1, upper graph) show that cold stress conditions (PET<8°C) occur from November to March with a maximum frequency of about 50% during the winter months (December, January, and February). The number of days with thermal comfort is 88 days per year. Thereby, the thermal comfort conditions last almost throughout the whole year, namely from March to November with a maximum frequency of 70% in May followed by 50-55% in September and October. Minimum frequencies (only 5-20%) are during the very hot summer season (July and August) and in the months of March and November.

The number of days with heat stress (PET>35°C) is about 40 days occurring during summer (June, July, and August) with a maximum frequency of about 50% in July and August. In the near future (2021-2050), the mean annual PET will increase by 1.5°C, the number of days with heat stress by 50% whereas cold stress and thermal comfort will hardly decrease (-2 to -3 days, Fig. 1, middle graph). The distribution of PET classes will be changed as well. Cold stress conditions (PET<8°C) lasting from November to March will be reduced by almost 10%, with an exception in December, where no reduction appears. Although the number of thermal comfort is declining, the frequency of thermal comfort is slightly increasing by 10% on average. Hot conditions will obviously increase, especially during summer (maximum about 20% happens in July, Fig. 1, middle graph). These changes will be further increased by the end of the 21st century (Fig. 1, lower graph). There will be hardly days with PET values below 0°C anymore. Heat stress days will be doubled and days with thermal comfort is experienced to be slightly increased compared to the present climate. The mean annual PET might increase by +4°C and higher values might be more frequent. The frequency of cold stress will be reduced almost by half.

Concerning CTIS for the reference period (1961-1990), thermal comfort appears in May with a frequency of 80% followed by the months of September and October (55%). The months of April and June also offer thermal comfortable conditions with 40 and 30%, respectively (Fig. 2, upper graph). Heat stress only occurs in the summer months (June, July, and August) with a maximum occurrence of ~55% in July. Cold stress as well as foggy days, however, hardly occurs in Athens. Sunny days appear throughout the year with maximum frequencies (90-100%) from April to October and minimum frequencies (about 55%) from November to March. Sultry or humid-warm conditions only occur in late summer with a 20-25% frequency. The frequency of dry days is maximum in summer (100%), but the other seasons have a high frequency of ~80% as well. Hence, rainy days are hardly present. Stormy days occur throughout the year with higher frequencies (60-70%) in winter and minor frequencies (~55%) in summer. Changes of parameters introduced just before are shown in Fig. 2 (middle graph) for the near future (2021-2050) and in Fig. 2 (lower graph) for the far future (2071-2100), respectively. Regarding the near future, heat stress is expected to increase by +20% in summer associated with a slight increase in its length.

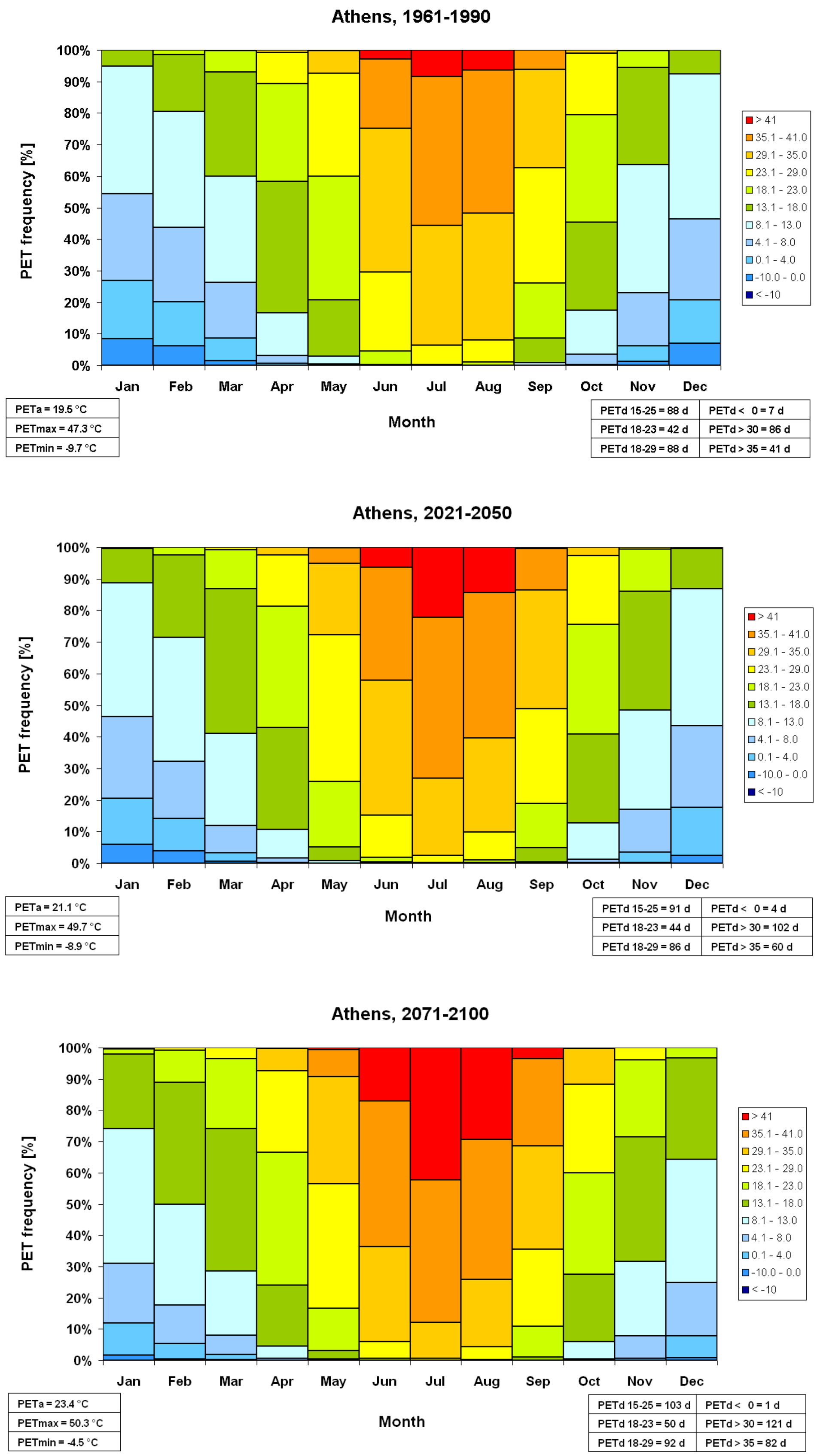

Figure 1. Monthly frequency distribution of PET for Athens, during the reference period 1961-1990 (upper graph) and the future projection periods 2021-2050 (middle graph), 2071-2100 (lower graph), Data: CLM-A1B

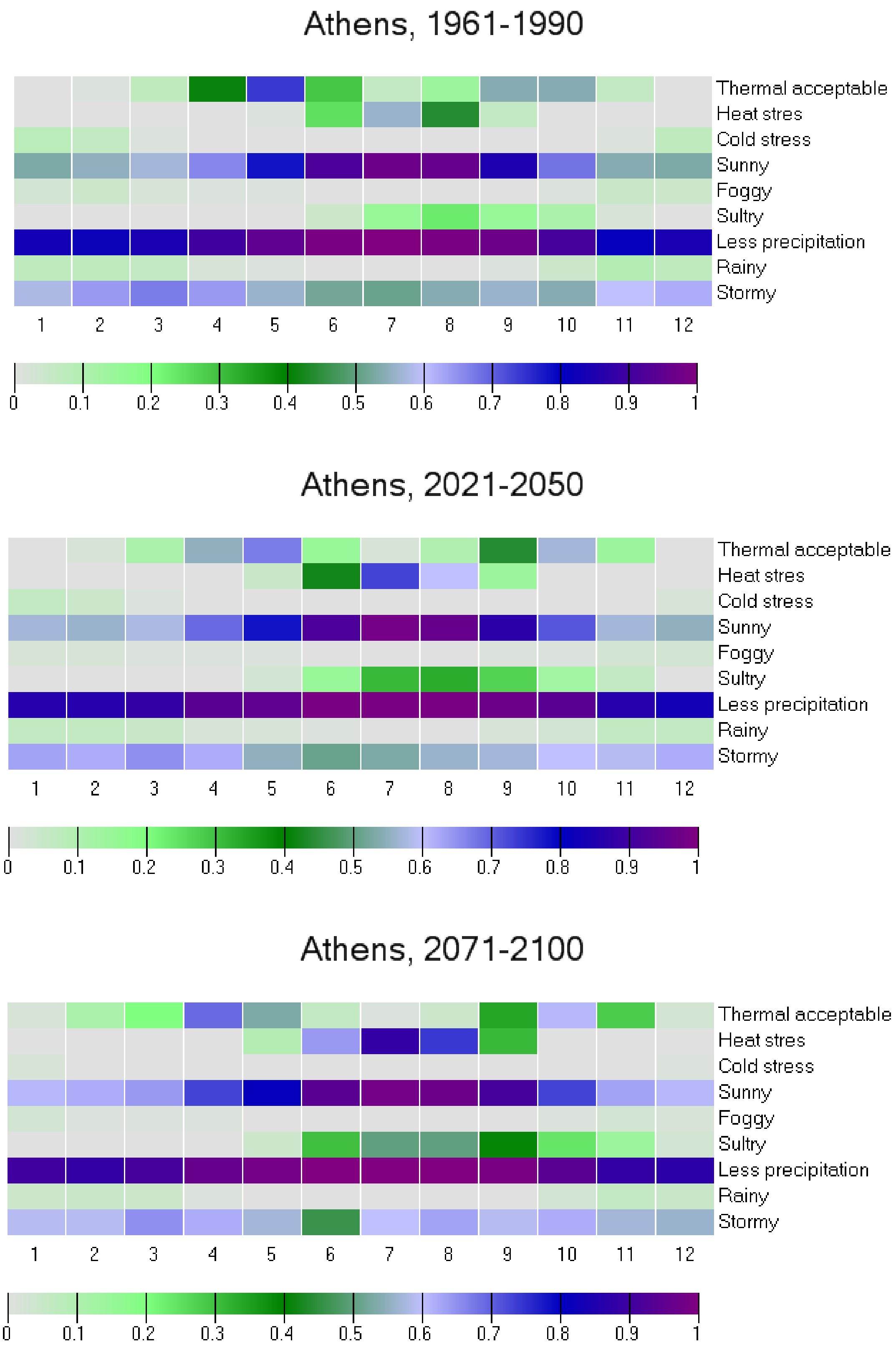

Figure 2. Climate-Tourism-Information-Scheme for Athens, during the reference period 1961-1990 (upper graph) and the future projection periods 2021-2050 (middle graph), 2071-2100 (lower graph), Data: CLM-A1B

An increasing frequency of sultry conditions is likely to be projected especially in July, August, and September (+20%). By the end of the 21st century the changes are expected to increase. Thermal comfortable conditions are likely to shift from May to April with a maximum frequency of 70% in April and from September to October. Additionally, the months of November and March will become more comfortable whereas in summer thermal comfort is not expected anymore. Heat stress, however, might last from June to September with a frequency of 60-80%, but with a less frequency in September (30%). An increase in frequency and the length of sultry conditions might be expected as well.

The results in the present study build a possibility how to transfer information about climate for tourism purposes. CTIS can be used in order to assess and quantify different destinations considering the most relevant factors of the specific destination (Endler and Matzarakis, 2011a; b; Lin and Matzarakis, 2008; Zaninovic and Matzarakis, 2009; Caliscan *et al.*, 2012; Grigorieva and Matzarakis, 2011; Matzarakis and Nastos, 2011; Shiue and Matzarakis, 2011). This can be performed by the use of still existing data and by climate modelling in order to develop strategies for the future (Scott *et al*., 2009; Matzarakis, 2010).

In addition, the here used methods based on the frequency diagrams of bioclimate (PET) and climatological (precipitation) factors and on thresholds of facets of climate in tourism (CTIS) can deliver detailed information. This builds a useful possibility for users, who are not familiar with complex terminologies of human biometeorology or climatology. The results can be used as basic climatological and bioclimate analysis of a specific destination in specific regions.

The quantification and assessment of the extreme conditions have to be performed by an appropriate way and not only in terms of air temperature, which is only one of the parameters that influence human thermal comfort and health; the other parameters concern air humidity, wind speed and radiation fluxes (expressed with the mean radiant temperature) (VDI, 1998; McGregor *et al.,* 2002; Zaninovic and Matzarakis, 2009; Didaskalou and Nastos, 2003; Didaskalou *et al.*, 2009; Bleta *et al*., 2013; Nastos and Matzarakis, 2013). The results based on the frequency diagrams and CTIS approach give an addition for the public and official responsible from urban planning and tourism the possibility to be informed about the present and expected conditions in order to develop and apply mitigation and adaptation possibilities (Matzarakis and Endler, 2010; Bartels *et al.*, 2009). These results and information can be visualized user friendly and easy understandable for non-scientists and authorities.

4. CONCLUSIONS

Climate builds not only a resource for tourism as a driver but can be a limitation. Climate is usually described by air temperature and rain conditions and sometimes by the sunshine duration at a location. Nevertheless, these parameters are less representative for the spatial and temporal climate variability of a region and do not cover all the components of climate.

For an integral assessment of climate for tourism, several issues in terms of mean, extremes and frequencies can be included in climate information for the interpretation of tourism potential. This can be achieved by the quantification of pleasant and unpleasant conditions for tourists in terms of thermal comfort or discomfort, rain conditions dividing them in several classes but also snow conditions. Fog and wind can also build relevant factors. The concept of the applied information scheme (CTIS) presenting the climate information in an easy understandable way for end users is helpful. Specific factors relevant or not relevant for a region can be included or not.

Regional climate simulations provide relevant and important information in order to extract possibilities of adaptation and protection of human life and infrastructure. Concerning Athens in the context of climate-tourism assessment, the increase of heat stress and the reduction of precipitation will be the main factors, which require special attention for the preparation and development of strategies for future tourism possibilities and limitations i.e. extension of tourism period in autumn and spring against shortening of high summer season.

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