QUANTIFICATION OF CLIMATE FOR TOURISM AND RECREATION UNDER CLIMATE CHANGE CONDITIONS – THE EXAMPLE OF ATHENS

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EXTENDED 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 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.
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. PET is defined to be the physiological equivalent temperature at any given place (outdoors or indoors). It is equivalent to the air temperature at which, in a typical indoor setting, the heat balance of the human body (work metabolism 80 W of light activity, added to basic metabolism; heat resistance of clothing 0.9 clo) is maintained with core and skin temperatures equal to those under the conditions being assessed.

The future simulations concerning PET and CTIS for the area for Athens have been exemplary used, in order climate information is considered by tourism industry and local authorities for tourism planning.

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

1. INTRODUCTION

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 and de Freitas 2001; Matzarakis et al. 2004, 2007; Amelung et al. 2007).
Usually, the discussion about climate change and its implications for tourism and other branches is still ongoing and the aim of this paper is to quantify the expected bio-climatological and relevant tourism and recreation (including health) climatological factors. This can be performed by the use of climate tourism indices such as 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 climatic conditions and extremes, based on regional climate simulations, can affect the decision making for vacation 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, 2007a).

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 (average height of a standing person's gravity center in Europe). 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. 2007a).

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 2007a). 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, relative humidity > 93 %, precipitation < 1 mm as well as precipitation > 5 mm, and snow cover > 10 cm are taken into consideration (Matzarakis 2007a; 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 2007b; 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

Information for each parameter is presented as percentage occurrence within ten days periods (decas). Since the presented results are based on model projections and thus affected by the models' uncertainties, a temporal resolution finer than 1 month is not considered useful. The analyzed bioclimatic parameters are presented in frequencies on a percentage basis. Each coloured column describes the corresponding frequency of any parameter. A frequency of 100 % indicates that each day in a month is characterized by the respective condition listed on the right hand side (Figure 1). 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. The resolution used for this study is 18 km.

3. RESULTS AND DISCUSSION

Concerning 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. 1, 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. 1 (middle graph) for the near future (2021-2050) and in Fig. 1 (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. 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 distribution of PET classes for the present climate (Fig. 2, 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.

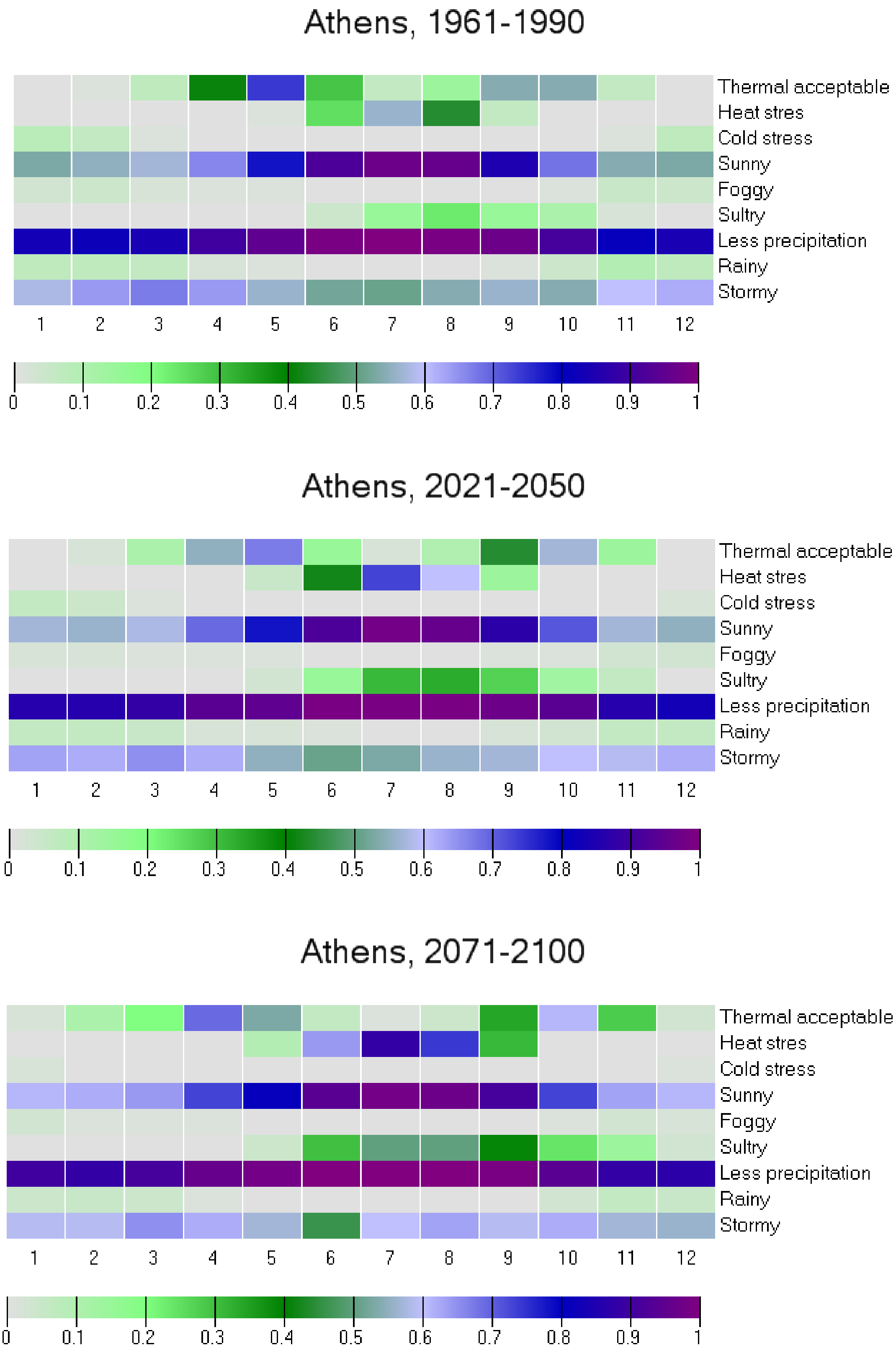

Figure 2. Climate-Tourism-Information-Scheme for Athens during the reference period 1961-1990 (upper graph) and the future projection periods 2021-2050 (middle graph), 2071-2100 (lower graph), Data: CLM-A1B.

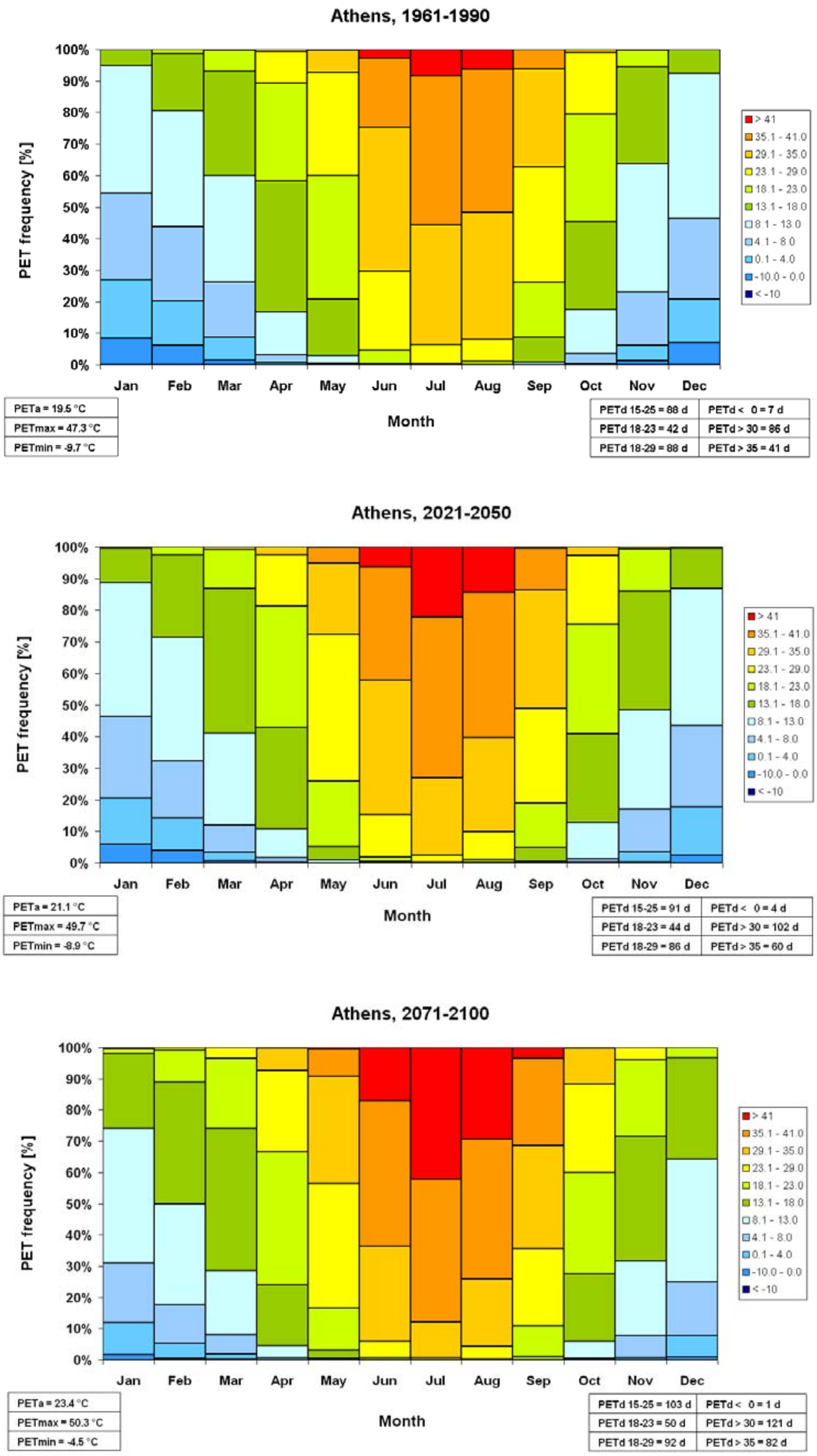

Figure 1. Monthly frequency distribution of PET for Athens during the reference period 1961-1990 (upper graph) and the future projection periods 2021-2050 (middle graph), 2071-2100 (lower graph), Data: CLM-A1B.

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. 2, 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. 2, middle graph). These changes will be further increased by the end of the 21st century (Fig. 2, 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.

4. CONCLUSIONS

Climate builds not only a resource for tourism as a driver but can be a limitation, because of extreme events and the related issues. 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. All this concept can be included in an information scheme presenting the climate information in an easy understandable way for end users. 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.

REFERENCES

2. Amelung B., Blazejczyk K., Matzarakis A. (eds.) (2007), Climate Change and Tourism: Assessment and Coping Strategies, Maastricht – Warsaw – Freiburg.
3. Christensen J.H., Carter T.R., Rummukainen M., Amanatidis G. (2007), Evaluating the performance and utility of regional climate models: the prudence project, *Climatic Change*, **81**, 1–6.
4. De Freitas C.R. (2003), Tourism climatology: evaluating environmental information for decision making and business planning in the recreation and tourism sector, *Int. J. Biometeorol.*, **48**, 45–54.
5. Frei, C., J.H. Christensen, Deque M., Jacob D., Jones R.G., Vidale P.L. (2003), Daily precipitation statistics in regional climate models: Evaluation and intercomparison for the European Alps, *J. Geophys. Res*., **108**, 4124, DOI:10.1029/2002JD002287.
6. Giorgi F, Mearns L.O. (1999), Introduction to special section: Regional climate modeling revisited, *J. Geophys. Res*., **104**, 6335–6352.
7. Hagemann S., Machenhauer B., Jones R., Christensen O.B., Deque M., Jacob D., Vidale P. L. (2004), Evaluation of water and energy budgets in regional climate models applied over Europe, *Climate Dynamics*, **23**, 547–567.
8. Hohenegger C., Brockhaus P., Schär C. (2008), Towards climate simulations at cloud-resolving scales, *Meteorologische Zeitschrift*, **17**, 383-394.
9. Höppe P. (1993), Heat balance modeling, *Experientia*, **49**, 741–746.

10. Höppe P. (1999), The physiological equivalent temperature – a universal index for the biometeorological assessment of the thermal environment, *Int. J. Biometeorol.*, **43**, 71-75.
11. IPCC (2001) Climate Change 2001: The Scientific Basis. Contribution of the Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (Houghton J.T. et al., eds), Cambridge and New York 2001.
12. IPCC (2007) 2007 Climate Change 2007: The Scientific Basis, Contribution of the Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Solomon, S., Qin D., et al., (eds)), Cambridge University press
13. Jacob D., Bäring L., Christensen O.B., Christensen J. H., De Castro M., Deque M., Giorgi F., Hagemann S., M. Hirschi, R. Jones, E. Kjellström, G. Lenderink, B. Rockel, E. Sanchez, Schär C., Seneviratne S., Somot S., Van Ulden A., Van Den B., Hurk, A. (2007), An inter-comparison of regional climate models for Europe: model performance in present-day climate, *Climatic Change*, **81**, 31–52.
14. Lin T.P., Matzarakis A. (2008), Tourism climate and thermal comfort in Sun Moon Lake, Taiwan, *Int. J. Biometeor.*, **52**, 281-290.
15. Matzarakis A, de Freitas C.R. (eds.) (2001), Proceedings of the First International Workshop on Climate, Tourism and Recreation, International Society of Biometeorology, Commission on Climate Tourism and Recreation. December 2001. http://www.mif.uni-freiburg.de/isb
16. Matzarakis A. (2010), Climate Change: Temporal and spatial dimension of adaptation possibilities at regional and local scale, In: Schott, C. ed. Tourism and the implications of Climate Change: Issues and Actions. Emerald Group Publishing 237-259.
17. Matzarakis A. (2006), Weather and climate related information for tourism, *Tourism and Hospitality Planning & Development*, **3**, 99-115.
18. Matzarakis A. (2007a), Assessment method for climate and tourism based on daily data, *In*: A. Matzarakis, C. R. de Freitas, D. Scott (Eds.), Developments in Tourism Climatology, 52-58.
19. Matzarakis A., de Freitas C.R., Scott D. (eds.) (2004), Advances in tourism climatology, Ber. Meteorol. Inst. Univ. Freiburg Nr. 12.
20. Matzarakis A., de Freitas C.R., Scott D. (eds.), (2007), Developments in Tourism Climatology, ISBN 978-3-00-024110-9.
21. Matzarakis A, Mayer H. (1996), Another kind of environmental stress: thermal stress, WHO Collaborating Centre for Air Quality Management and Air Pollution Control, Newsletters, 18, 7–10.
22. Vidale P.L., Lüthi D., Frei C., Seneviratne S. I., Schär C. (2003), Predictability and uncertainty in a regional climate model, *J. Geophys. Res*., **108**, 4586, DOI:10.1029/2002JD002810.
23. Zaninovic K., Matzarakis A. (2009), The Biometeorological Leaflet as a means conveying climatological information to tourists and the tourism industry. *Int. J. Biometeorol*., **53**, 369-374.