Tourism climatic conditions of Hungary – present situation and assessment of future changes

Attila Kovács[1*], **Ákos Németh**[2], **János Unger**[1], and **Noémi Kántor**[1]

[1]*Department of Climatology and Landscape Ecology, University of Szeged,*
2 Egyetem str., H-6722 Szeged, Hungary

[2]*Hungarian Meteorological Service,*
P.O. Box 38, H-1525 Budapest, Hungary

[*]*Corresponding author E-mail: kovacsattila@geo.u-szeged.hu*

Abstract—This paper provides insight into the tourism-related outcomes of the Hungarian CRIGiS project, which was conducted in 2015. Based on tourism climatic indicators, this study aims at assessing the exposure of tourism sector to climate change. The widely known Tourism Climatic Index (*TCI*) is applied for the quantification of the climatic potential in Hungary in its original and modified form. This adjusted index version is suitable to reflect the seasonally different thermal perception patterns of Hungarian residents. These indicators were calculated based on past observations, and on the other hand, they rely on the outputs of regional climate model projections. The spatial distribution of the index values in Hungary is presented on a monthly basis and on district level, which is an administrative territorial unit in Hungary. The results indicate that, according to both versions of *TCI*, tourism climate conditions will likely to improve in the shoulder seasons and deteriorate in summer, remaining still at least acceptable for outdoor tourism purposes. The project outcomes are available for public use in the National Adaptation Geo-information System (NAGiS) developed in Hungary.

Key-words: climate change, tourism climatic potential, Tourism Climatic Index, spatial pattern, subjective thermal perception, districts of Hungary

1. Introduction

Climate constitutes an essential natural resource for tourism industry – it can promote or constrain certain tourist activities and tourism development (*de Freitas,* 2003; *Gómez Martín,* 2005; *Scott* and *Lemieux,* 2010; *Scott et al.,* 2012). Climate is an important driver of tourist motivation (*Crompton,* 1979; *Morgan et al.,* 2000; *Kozak,* 2002; *Hübner* and *Gössling,* 2012) as well as of destination choice and other decision-making mechanisms, either before trip or under holiday (*Hamilton* and *Lau,* 2005; *Gössling et al.,* 2006; *Scott et al.,* 2008, 2012; *Moreno,* 2010; *Scott* and *Lemieux,* 2010). In addition, climate has a significant impact on overall attractiveness of a target area (*Hu* and *Ritchie,* 1993; *Kozak,* 2002; *Moreno,* 2010). Tourism industry and destination products are highly sensitive to climate variability and climate change. The impacts of climate change are expected to vary geographically and seasonally (*IPCC,* 2014).

Climate change will directly affect tourism sector by altering the temporal and spatial distribution of climate resources for tourism, and thus, the main domestic and international tourism flows and expenditures (*Scott et al.,* 2004, 2012; *Rutty* and *Scott,* 2014). Climatic resources – considering their global level distributions – are projected to shift towards higher latitudes. Namely, northern parts (of Europe and America) are expected to improve of climate conditions, while southern regions (Mediterranean and Caribbean) are likely to become 'too hot' in summer. On the other hand, spring and autumn months will likely to improve in the latter case. As a result, northern European tourists might stay in their home country or neighboring areas in summer due to climate change. These features were emphasized or concluded by many research studies in the field of tourism climatology (*Morgan et al.,* 2000; *Scott* and *McBoyle,* 2001; *Scott et al.,* 2004; *Hamilton et al.,* 2005; *Amelung* and *Viner,* 2006; *Amelung et al.,* 2007; *Nicholls* and *Amelung,* 2008; *Hein et al.,* 2009; *Perch-Nielsen et al.,* 2010; *Amengual et al.,* 2012; *Amelung* and *Moreno,* 2012). However, some studies have questioned these results, because they have not considered what tourists perceive to be thermally unacceptable for their activities.

According to *Rutty* and *Scott* (2010), it is unlikely that the above mentioned southern regions will become 'too hot' for coastal tourism for the next decades. They concluded this assertion according to a survey of university students conducted in northern Europe, which examined their climate preferences for beach and urban tourism concerning the Mediterranean region. *Moreno* and *Amelung* (2009) similarly concluded that relatively modest shifts in climatic attractiveness will likely to be found over the coming 50 years, and the Mediterranean region is likely to remain Europe's prime region for summer vacation. They used the Beach Climate Index of *Morgan et al.* (2000), which was developed by using interviews with tourists. Using questionnaires with northern travellers, *Moreno* (2010) found that large majority of tourists would

still travel to the Mediterranean even if ideal coastal weather conditions were occur in their home country as a result of climate change.

These are only three examples, which question the main research opinion – i.e., the tourist activities may decrease in the Mediterranean because of the projected warming tendencies –, subjective reactions of people actually may not follow the projected trends concluded from purely objective investigations. In fact, direct consultation with travellers on their climate assessments (perception, preferences, and tolerances) is more important than ever, as emphasized by a large number of studies (e.g., *Gómez Martín,* 2005, 2006; *de Freitas et al.,* 2008; *Scott et al.,* 2008; *Gössling et al.,* 2012). These investigations, with focusing on human assessments, allow us on the one hand to explore tourists perception and preferences of weather parameters, to define the 'ideal' or 'unfavorable' climatic conditions and to determine the perceived importance of different climate parameters, or even to explore the role and importance of climate (or climate change) as a destination attribute. On the other hand, several studies analyse tourism climate potential of destination areas with climate evaluation tools (indices, rating systems). Travellers' assessment patterns should be incorporated into these tools.

Understanding the way climate change affects tourism industry and the subjective assessments and behavioral reactions of tourists remains limited. Effectiveness of adaptation to climate change and adaptive capacity of tourists remain largely unexplored as well (*Scott et al.,* 2009, 2012; *Gössling et al.,* 2012). By identifying the quantitative impacts of climatic conditions and climate change on tourism, we can facilitate the development of objective strategies, decision-making processes, and planning for climate change adaptation. Several tourism climatological evaluation tools have been developed to quantify the climate potential and climate change impacts on tourism sector; however, they are most regardless of local residents' or tourists' climatic assessments. It is widely accepted in the field of tourism (bio)climatology that the tourism climate evaluation tools should be adjusted to the local residents' or tourists' subjective assessments (*de Freitas,* 2003; *Scott et al.,* 2004, 2008; *de Freitas et al.,* 2008). To prepare targeted and sustainable adaptation strategies in response to climate change, it is indispensable to reveal climate potential with empirically tested approaches.

This study provides insight into the results related to tourism climate potential of the project '*Vulnerability/impact studies with a focus on tourism and critical infrastructures*' (*CRIGiS,* 2016). This project was conducted in 2015, with the main aim to develop methodologies that could be used to objectively quantify the effects of climate change in exposure, vulnerability, and adaptation capacity for various sectors in Hungary. In the frame of the project, the exposure of the tourism sector to the climate change was quantified. For this purpose, we applied the widely used Tourism Climatic Index in its original form (*TCI*; *Mieczkowski,* 1985) and in its modified form that is adjusted to the Hungarians'

subjective thermal assessments (*mTCI*; *Kovács et al.,* 2016), as well as the recently developed so-called second generation tourism climatic index – Climate Index for Tourism (*CIT*; *de Freitas et al.,* 2008). In this paper, we present some outcomes on the basis of *TCI* and *mTCI* patterns.
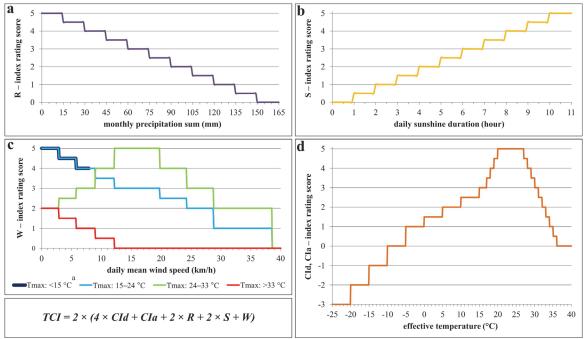

2. Methods

2.1. Tourism Climatic Index

TCI is a widely used measure that evaluates the suitability of a particular climate for general outdoor tourism activities like sightseeing and shopping or other light physical activities (e.g., *Mieczkowski,* 1985; *Scott et al.,* 2004; *Amelung* and *Viner,* 2006; *Amelung et al.,* 2007; *Farajzadeh* and *Matzarakis,* 2009; *Hein et al.,* 2009; *Perch Nielsen et al.,* 2010; *Amelung* and *Moreno,* 2012; *Amelung* and *Nicholls,* 2014; *Roshan et al.,* 2016).

In Hungary, *TCI* has been used only by a few studies so far. *Németh* (2013) quantified climate potential for Lake Balaton Region for the climate normal periods 1961–1990, 1971– 2000, and 1981–2010. *Kovács et al.* (2015) analyzed the annul course of *TCI* for Budapest (the capital of Hungary) and Siófok (the main resort on the shore of Lake Balaton) for the period 1996–2010. *Hódos* (2014) presented first time the spatial distribution of *TCI* in the region of Hungary. She determined *TCI* per month for the Carpathian Region (44–50°N and 17–27°E) for the normal periods 1961–1990, 1971–2000, 1981–2010, and 2001–2010. The changes between the periods 1981–2010 and 1961–1990 were also analyzed. The study region covered the target area of the CarpatClim project, which final outcome was a 0.1° spatial resolution, quality controlled, homogenized, cross border harmonized, and gridded dataset on daily scale for several basic meteorological variables and derived climate indicators from 1961 to 2010 (*Szalai et al.,* 2013). For homogenization the MASH (Multiple Analysis of Series for Homogenization; *Szentimrey,* 2011), for interpolation the MISH (Meteorological Interpolation based on Surface Homogenized data basis; *Szentimrey* and *Bihari,* 2007) procedure were applied; both of them were developed at the Hungarian Meteorological Service.

The original form of the *TCI* consists of five sub-indices, which in turn are based on monthly values of seven basic climate parameters (*Table 1*). From the seven basic parameters, three ones – monthly precipitation sum, daily sunshine duration, and daily mean wind speed – are rated in itself with different score values, from zero (unfavorable) to five (optimal), forming sub-indices *R*, *S,* and *W*, respectively (*Table 1, Fig. 1*). In the case of *R*, the rating system is monotonically decreasing with the increase of precipitation sum (*Fig. 1a*), while the score values of *S* ascend monotonically as the number of sunshine hours increases (*Fig. 1b*). In the case of *W*, four distinct rating systems were introduced by *Mieczkowski* (1985) depending on specific air temperature ranges (*Fig. 1c*).

Table 1 The sub-indices of Tourism Climatic Index, their rating score ranges, and their weights (based on *Mieczkowski,* 1985)

Monthly values of basic climate parameters		*TCI* sub-indices	Scores	Weight
daily maximum temperature (°C)	daytime effective temperature (°C)	*CId* – daytime comfort index	−3 to +5	40%
daily minimum relative humidity (%)				
daily mean temperature (°C)	daily effective temperature (°C)	*CIa* – daily comfort index	−3 to +5	10%
daily mean relative humidity (%)				
monthly precipitation sum (mm)		*R* – precipitation index	0 to +5	20%
daily sunshine duration (hour)		*S* – sunshine duration index	0 to +5	20%
daily mean wind speed (km/h)		*W* – wind speed index	0 to +5	10%

$$TCI = 2 \times (4 \times CId + CIa + 2 \times R + 2 \times S + W)$$

[a] For wind speed above 8 km/h, wind chill nomogram should be used (see *Mieczkowski,* 1985)

Fig. 1. Rating score systems for each sub-index in the Tourism Climatic Index (based on the rating systems of *Mieczkowski,* 1985).

The remaining two sub-indices of *TCI* were designated to describe the thermal comfort conditions – one of them refers to the whole day (*CIa* – daily comfort index), while the other characterizes the thermal conditions at the warmest period of the day (*CId* – daytime comfort index). Correspondingly, *CIa* is derived from the daily mean values of air temperature and relative humidity, while *CId* rates the combined effect of the daily maximum air temperature and minimum relative humidity (*Table 1*) (*Mieczkowski,* 1985). In fact, the rating system of *CIa* and *CId* relies on one of the earliest thermal indices, the so-called Effective Temperature (*ET*). *ET* is a simple empirical index, which expresses the combined effect of air temperature and relative humidity on thermal comfort (*Houghten* and *Yaglou,* 1923). *Mieczkowski* (1985) defined the *ET* range of 20–27 °C as optimal zone with a rating score of five; then reduced the points gradually on both sides of the optimal zone according to an arbitrarily assigned set of ordinal values (*Fig. 1d*).

It is worth noting that in contrast to the score values of *R, S,* and *W, Mieczkowski* (1985) assigned minus score points to the lowest *ET* values (i.e., to the coldest environmental conditions) (*Fig. 1*) in the case of *CIa* and *CId*.

Finally, each sub-index is weighted with certain factors that express their relative importance within the overall climate evaluation (*Table 1*). The value of *TCI* is obtained as the weighted sum of the sub-indices (*Mieczkowski,* 1985):

$$TCI = 2(4CId + CIa + 2R + 2S + W). \qquad (1)$$

The *TCI* measures the climate's overall suitability for tourism activities on a scale of minus twenty to hundred, with higher values indicating more favorable climate potentials for outdoor activities (*Mieczkowski,* 1985; *Table 2*).

Table 2. Tourism climatic index rating system (*Mieczkowski,* 1985)

TCI scores	Descriptive categories
90 – 100	ideal
80 – 89	excellent
70 – 79	very good
60 – 69	good
50 – 59	acceptable
40 – 49	marginal
30 – 39	unfavorable
20 – 29	very unfavorable
10 – 19	extremely unfavorable
–20 – 9	impossible

2.2. Modified form of Tourism Climatic Index

Although *TCI* has been the most widely applied tourism climate index over the past 30 years (*Scott et al.,* 2012), a number of limitations have been identified or emphasized by several research studies (e.g., *Scott et al.,* 2004; *Amelung* and *Viner,* 2006; *de Freitas et al.,* 2008; *Farajzadeh* and *Matzarakis,* 2009; *Moreno* and *Amelung,* 2009; *Perch-Nielsen et al.,* 2010; *Kovács* and *Unger,* 2014a). The modified form of *TCI* used in CRIGiS project overcomes two of the major shortcomings of the index.

One of the main limitations of the index is that its thermal components are theoretically unsound according to the recent human thermo-physiological knowledge. In fact, the thermal comfort sub-indices, *CId* and *CIa*, rely on *ET*, which is based on air temperature and humidity data only. However, several biometeorological studies have indicated that the thermophysiological effect of the atmospheric environment on the human body depends on the combination of four climate parameters (air temperature, air humidity, wind velocity, and thermal radiation) and on personal factors, such as clothing and human activity (*Jendritzky,* 1993; *Matzarakis* and *Mayer,* 1996; *Höppe,* 1999; *Mayer,* 2008). Several studies have proposed modification of the *TCI*'s thermal comfort sub-indices (*Scott* and *McBoyle,* 2001; *Scott et al.,* 2004; *Amelung* and *Viner,* 2006; *Perch-Nielsen et al.,* 2010). Instead of using effective temperature, *Kovács et al.* (2016) proposed the integration of the Physiologically Equivalent Temperature (*PET*) into the thermal comfort sub-indices of the *TCI*. The advantage of the biometeorological index *PET* is that it considers the physiological effect of both climate and human factors (*Höppe,* 1999; *Kántor et al.,* 2016a).

The other essential shortcoming of *TCI* is that the rating and weighting schemes of each of its sub-indices are arbitrary – they were defined according to Mieczkowski's personal expert opinion, which was based on former, obsolete (biometeorological) literature. These rating systems had never been tested empirically against the perceptions and preferences of real tourists (*Mieczkowski,* 1985; *Scott et al.,* 2004; *Amelung* and *Viner,* 2006; *de Freitas et al.,* 2008; *Farajzadeh* and *Matzarakis,* 2009; *Moreno* and *Amelung,* 2009; *Perch-Nielsen et al.,* 2010).

Adaptation of some tourist climate evaluation tools has already begun in Hungary. The process focused mainly on the adjustment of the thermal parts of *TCI* by incorporating *PET* (*Kovács* and *Unger,* 2014a, 2014b) and making the score-system suitable to express the subjective thermal assessment patterns of the Hungarian population (*Kovács et al.,* 2016).

From the different aspects of subjective thermal evaluation, in this paper we are focusing on the most evident assessment – the thermal perception (thermal sensation). A new *PET* rating system is developed and integrated into the thermal sub-indices of the *TCI*, which reflect the thermal perception patterns of Hungarian residents. This modification improves the credibility of the

thermal rating scores of *TCI,* and thus, enhances the potential of *TCI* to evaluate the thermal aspect of climate.

In order to reveal the subjective thermal assessment patterns, we used questionnaire surveys and simultaneous meteorological measurements in open air urban environments. We utilized data from a 3-year-long outdoor thermal comfort campaign, conducted on 78 days in 2011, 2012, and 2015 in six public spaces of Szeged, Hungary. Corresponding to the outdoor activities of people in this climate zone, the interviews and the meteorological measurements were carried out during spring, summer, and autumn. (More information on the Hungarian thermal comfort surveys is available in *Kántor et al.,* 2011, 2012, 2016b; *Kovács et al.,* 2016; *Kántor,* 2016.)

In frame of the surveys we recorded the thermal perception of people on a 9-point scale (thermal sensation vote, *TSV*). The applied *TSV* scale ranged from –4 to 4, corresponding to the perception of very cold to very hot. Then the thermal sensation votes were paired with the measured atmospheric parameters according to the exact time when the *TSV* data were recorded. From the meteorological data (air temperature, relative humidity, wind velocity, and mean radiant temperature), *PET* values were calculated with the RayMan software (*Matzarakis et al.,* 2010). Then we used the obtained 5805 *TSV–PET* datapairs to reveal the subjective thermal sensation patterns of Hungarians in different seasons.

In order to develop a new *PET* rating system, at first, *TSV* responses were plotted against *PET*. Instead of the usage of the actual TSVs, mean thermal sensation votes (*MTSV*) were used, which were calculated according to 1°C-wide bins of *PET* values (*Fig. 2*). It should be emphasized that MTSVs were weighted with the number of cases per *PET*-bin, similarly to the method of *Nakano* and *Tanabe* (2004) and *Yang et al.* (2013). Then, we performed regression analyses between the subjects' MTSVs and *PET*. The analyses were implemented separately for each evaluated season. The number of data pairs were 2792 in spring, 1097 in summer, and 1916 in autumn.

In every season, statistically significant regression equations (p = 0.000) were obtained, and quadratic model was found to increase the value of determination coefficient (R^2) compared to linear regression. Thus, we present only the quadratic functions in this study and use them for further analysis. The slope of the regression lines represents the 'thermal sensitivity' of subjects against the changes of *PET*. All of the obtained equations indicate that Hungarians react more sensitively to one unit increment of *PET* in the cooler parts of the *PET*-scale, than in the warmer end, revealing an enhanced heat tolerance (*Fig. 2*).

The presented seasonal *MTSV* vs. *PET* quadratic regression functions formed one of the main pillars of the next step of our study, that is, the development of a *PET*-based rating system for *TCI*. Beside the regression equations, we defined a new relationship, where sub-index rating scores from

zero (unfavorable) to five (optimal) were assigned to *PET* values. For providing full details on the conceptual and methodological aspects of the modification and adjustment of *TCI*, see *Kovács et al.* (2016).
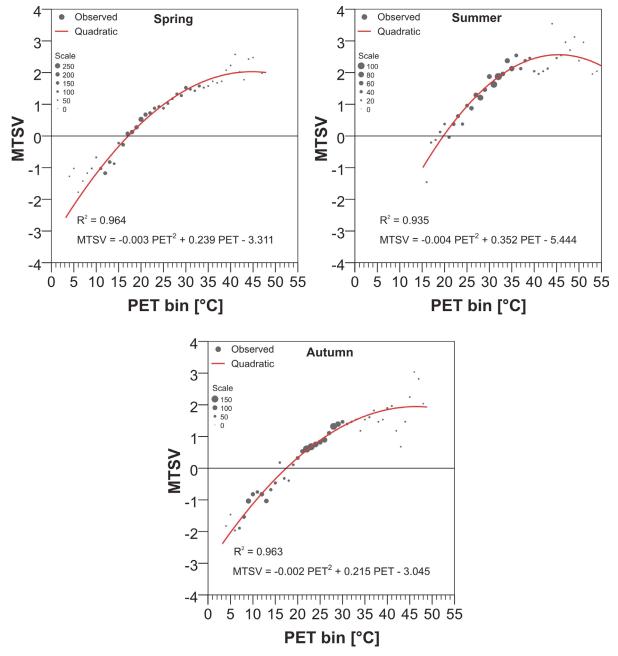

Fig. 2. Quadratic regression between the mean thermal sensation votes of Hungarians vs. the physiologically equivalent temperature (*PET*) in spring, summer, and autumn.

Fig. 3 illustrates the derived seasonal relationships between *PET* and the rating scores. Each *PET* value takes a score between zero and five. These relationships

are utilized in the new *CId* and *CIa* thermal comfort sub-indices to rate *PET* values (instead of to rate the *ET* values with the scores in the case of the original *TCI*, see *Fig. 1*). In practice, the new *CId* and *CIa* sub-indices are derived utilizing daytime maximum and daytime average *PET* values. The rating systems of the precipitation (*R*), sunshine (*S*), and wind speed (*W*) sub-indices were not modified and are used in accordance with the rating methods of *Mieczkowski* (1985) (*Fig. 1*).
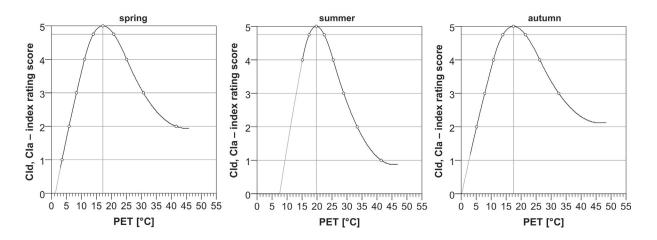

Fig. 3. The derived *PET* rating scores for the thermal sub-indices (*CId* and *CIa*) of modified *TCI* in different seasons based on the thermal sensation votes of Hungarians.

2.3. *Quantifying the impact of climate change on tourism potential*

The CRIGiS project, which constitutes the base of the present study, was the part of a broader program called '*Adaptation to Climate Change*' (*ACC,* 2016). Beyond establishing assessment methodologies, the program aimed at installing a system providing reliable database for supporting development of domestic adaptation activities to climate change. The implementation of the program started with the establishment of the National Adaptation Geo-information System (NAGiS) (*NAGiS,* 2016). The NAGiS aimed at supporting strategic planning and decision-making on the adaptation to climate change through development and operation of a multipurpose, geo-information database, which could merge several data sources derived from diverse sectors, such as hidrology, agriculture, and natural ecosystems. The CRIGiS project was initiated to extend the NAGiS with new data layers to further sectors. This extension includes indicators of exposure, sensitivity, and adaptive capacities in the tourism sector, as well as in the critical infrastructure sectors. One of the main goals of the tourism-related part of CRIGiS was to allow the outcomes usable for analyses aiming to estimate the effects of climate change on tourism potential. Such investigations can contribute to help in impact assessments and

resilience tests related to climate change in tourism sector. Ultimately, the results can be usable promoting sustainable tourism development.

The new, tourism-related data layers (i.e., original and modified *TCI*) were established for different time periods. First of all, based on observational data, they were calculated for the period of 1961–1990. On the other hand, future values of these indices were obtained from regional climate model projections for the periods of 2021–2050 and 2071–2100. The observational data were derived from the database used in CarpatClim project (as well as in *Hódos,* 2014), homogenized and interpolated with the methods MASH and MISH. However, the target area was extended to the whole area of Hungary (covering 45.8–48.6°N and 16–27°E). The climate projections were provided by the ALADIN-Climate, a regional climate model (RCM) applied at the Hungarian Meteorological Service (*Csima* and *Horányi,* 2008). The model run relied on A1B emission scenario described in the Special Report on Emissions Scenarios (SRES; *Nakicenovic et al.,* 2000), which concerns average future changes in socioeconomic conditions and population.

The climate projections did not contain information about the future values of sunshine duration, which are, however, required to calculate *TCI* and *mTCI*. Thus, sunshine duration was obtained from daily cloud cover data according to the method suggested by *Monteith* (1965) and adopted by several studies calculating *TCI* from climate model data (*Amelung,* 2006; *Perch-Nielsen et al.,* 2010; and *Mailly et al.,* 2014).

The original *TCI* values were determined according to the rating schemes and formula of *Mieczkowski* (1985) (see *Section 2.1.*). For the modified *TCI*, daily values of the observational and model data were applied instead of monthly values; moreover, calculation of *PET* required daily averages of total cloudiness as well. We determined daily *PET* values from air temperature, relative humidity, wind velocity, and cloud cover data by utilizing RayMan. For the new *CId* sub-index of *TCI* (which relies on daily maximum *PET*), the daily maximum temperature, daily minimum relative humidity, daily average wind speed, and daily average cloud cover data were used. For the new *CIa* sub-index (which relies on daily average *PET*), daily average temperature, relative humidity, wind speed, and cloud cover data were used. From the daily maximum PETs, daily average PETs, and the other necessary variables (precipitation, sunshine duration, and wind speed), monthly averages were taken and then monthly *mTCI* values were calculated.

For future exposure analysis, the so-called delta-method was applied. This means that the changes between the modeled future outcomes (2021–2050, 2071–2100) and the past model data (1961–1990) were determined, and the differences between them were added to the observational data (1961–1990). The reason for using delta method was to filter the systematic errors of model results. It should be emphasized that this method was used not for the raw model results but for the exposure assessment outcomes (i.e., for *TCI* and *mTCI* data).

The outcomes, therefore, combined past 'exposure observations' and changes occurring in the 'exposure' (*Fig. 4*).

Fig. 4. Process of determining tourism climate indicators based on observations and model data.

The climate indicators were calculated on a 0.1°×0.1° (about 10 km) horizontal resolution grid of the observational and climate model data, for a total of 1104 grid points in Hungary. In order to display of tourism climate indices on maps, district averages were calculated from the grid point data as this provides more beneficial results for the users, such as tourists and tourism professionals. The district is an administrative territorial unit in Hungary. The spatial distribution of *TCI* and *mTCI* are presented on a monthly basis and on district level.

3. Results

In this paper, the results of the middle months of the seasons, April, July, and October are presented. We classified *TCI* and *mTCI* values according to the rating categories in *Table 2*, with the only exception of *TCI* values below 40, which were merged into a category 'unfavorable', if at all.

First, the results based on observational data are presented for the two indicators (*Figs. 5a–10a*). In April, according to original *TCI*, some western and northern districts are characterized with acceptable conditions (range of 50–59), while in the other parts of the country, including the whole Great Hungarian Plain, good conditions occur (60–69) (*Fig. 5a*). Modified *TCI* indicates more favorable conditions, generally by two categories: very good (70–79) conditions are found in Transdanubia and the northern regions, while the climate potential is excellent (80–89) in most parts of the Great Plain (*Fig. 6a*). Almost every district are characterized with at least excellent climatic conditions in July according to *TCI*, moreover, in most parts of the Great Plain, the climatic conditions reach the ideal category (90–100) (*Fig. 7a*). The *mTCI* pattern

usually signals less pleasant conditions by two categories, and its distribution is slightly more diverse. It is worth mentioning that this means still good or very good circumstances (*Fig. 8a*). October shows similar results as April concerning both the category level and the spatial distribution of *TCI* and *mTCI* (*Figs. 9a–10a*).

Turning our attention for future assessments through climate model results, considerable changes will not be probable for the mid-century according to *TCI* in April *(Fig. 5b)*. For the end of the century, most parts of the country will likely to be characterized with good conditions; only some mountainous districts remain acceptable, while in a few districts in the Great Plain, very good conditions are displayed (*Fig. 5c*). In the case of *mTCI*, only a slight redistribution will be probable for the mid-century (*Fig. 6b*). However, for the end of the century, large parts of the country may experience an improvement in climatic circumstances, that is, the conditions in Transdanubia and the northern districts may become excellent like in the Great Plain (*Fig. 6c*).
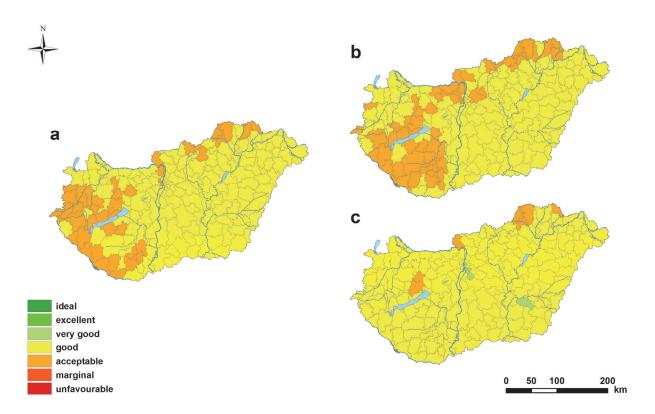

ideal
excellent
very good
good
acceptable
marginal
unfavourable

Fig. 5. Spatial distribution of *TCI* categories in April by districts for 1961–1990 (a), 2021–2050 (b), and 2071–2100 (c).
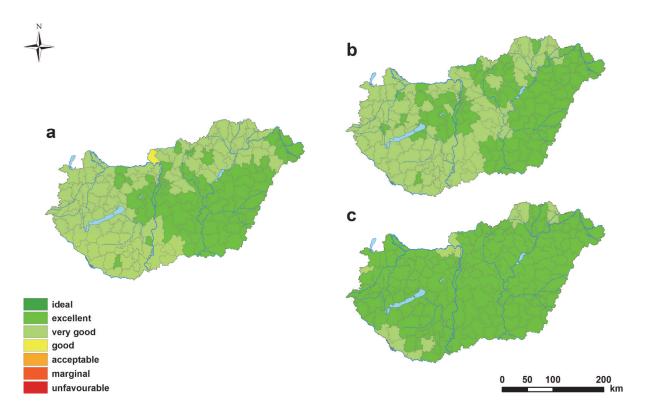
Fig. 6. Spatial distribution of *mTCI* categories in April by districts for 1961–1990 (a), 2021–2050 (b), and 2071–2100 (c).

The tendencies are similar for the future periods in the case of both indicators in July. Both of them indicate considerable changes but for unfavorable direction *(Figs. 7–8)*. According to *TCI*, ideal conditions may not occur at all, and the ratio of excellent areas may decrease for the mid-century *(Fig. 7b)*. At the end of the century, very good conditions are probable in the northern part of the country, while good conditions are displayed in the Great Plain and southwestern part of Transdanubia *(Fig. 7c)*. According to *mTCI* patterns, the ratio of the very good conditions may decrease for the mid-century, and good conditions may dominate in most parts of the country. Moreover, in the southwestern part of Transdanubia, acceptable conditions are displayed *(Fig. 8b)*. For the end of the century, *mTCI* pattern indicates acceptable conditions in greater parts of the country, mainly in the whole southwestern part of Transdanubia and southern Great Plain *(Fig. 8c)*. The spatial pattern of *mTCI* categories at the end of the century is similar to the case of *TCI* but they indicate less favorable conditions for light outdoor activities.
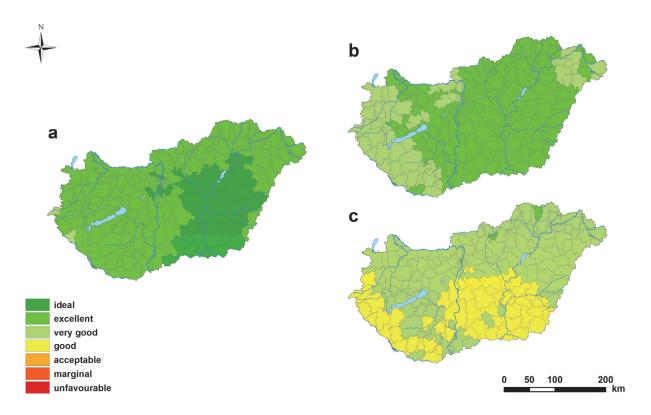
Fig. 7. Spatial distribution of *TCI* categories in July by districts for 1961–1990 (a), 2021–2050 (b), and 2071–2100 (c).
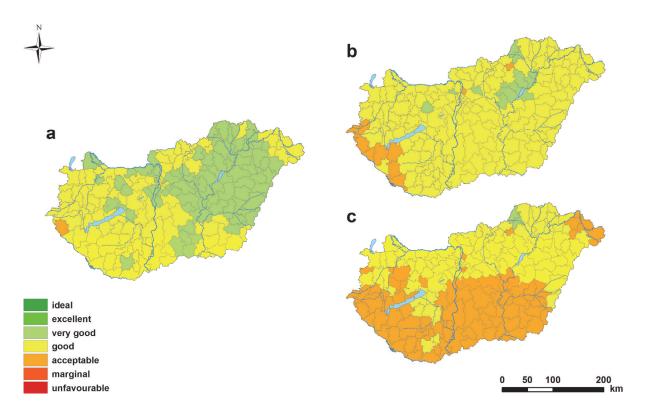

Fig. 8. Spatial distribution of *mTCI* categories in July by districts for 1961–1990 (a), 2021–2050 (b), and 2071–2100 (c).

93

In October, according to *TCI*, more remarkable improvement in climate potential is probable than in April, which already refers to the mid-century period (*Fig. 9b*). For this period, most parts of the country will likely to be characterized with good conditions, moreover, a remarkable part of the Great Plain may become very good. The improvement continues to the end of the century, moreover, at this time excellent conditions will be probable in a few southeastern districts of the Great Plain (*Fig. 9c*). The *mTCI* patterns indicate unchanged conditions or an improvement by a category (*Fig. 10*). Here, in the mid-century, already excellent conditions are indicated in most parts of the country, which was not the case in April.
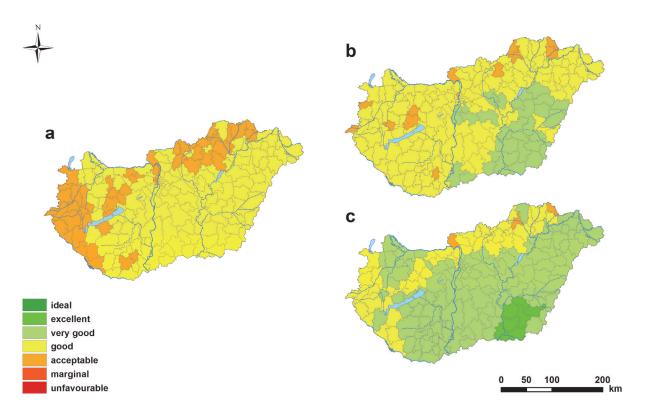

Fig. 9. Spatial distribution of *TCI* categories in October by districts for 1961–1990 (a), 2021–2050 (b), and 2071–2100 (c).
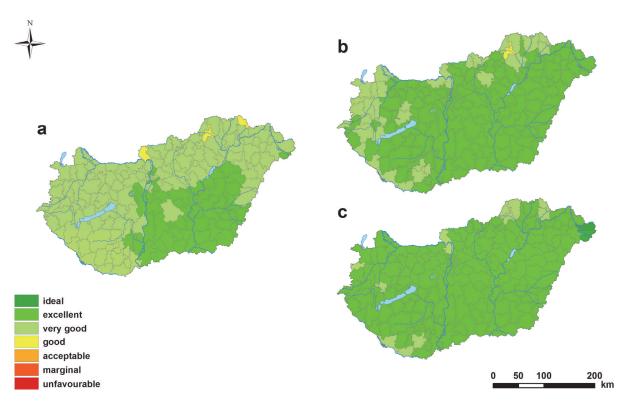
Fig. 10. Spatial distribution of *mTCI* categories in October by districts for 1961–1990 (a), 2021–2050 (b), and 2071–2100 (c).

4. Summary and concluding remarks

The study presented some tourism-related outcomes of the CRIGiS project based on the original *TCI* as well as on a modified form of *TCI*, that was adjusted to the subjective thermal assessment of Hungarian residents. According to the district-based spatial patterns of *TCI* and *mTCI* through observational data, the following outlines can be drawn for the three selected months:

– In the shoulder months (April and October), the Great Hungarian Plain as well as some northern and eastern parts of Transdanubia have more favorable climatic conditions by a category than the other parts of the country according to both indices. The *mTCI* pattern indicates more pleasant conditions than that of *TCI* generally by two categories.

– July has more favorable conditions than April and October according to *TCI*, however, *mTCI* indicates less pleasant circumstances in July compared to the shoulder months.

According to the climate model outcomes, the tourism climate potential changes for the end of the century are as follows:

95

– In April, the climatic conditions in Transdanubia and the northern parts of the country will likely to improve by a category and may become the same as in the Great Plain concerning both indices. The conditions may remain unchanged in most parts of the Great Plain.

– October shows an improvement by a category according to *TCI*, moreover, some southeastern districts in the Great Plain may expect two *TCI* categories improvement. According to *mTCI* patterns, the climatic conditions in Transdanubia and the northern parts may improve by a category and become the same as in the Great Plain.

– In July, most parts of the country may become less favorable for tourism. Both indices signal that climatic conditions are likely to deteriorate mostly at the southwestern part of the country and at the southern part of the Great Plain. The climatic conditions will still remain at least acceptable even from the Hungarian assessment point of view.

It should be borne in mind when considering the results, that the tourism climate potential of an area is associated with the features how tourism sector is affected by the present and future climatic circumstances. However, the competitiveness and economic success of tourism businesses and destinations are highly influenced by several socioeconomic mechanisms and factors (e.g., budget, accessibility and distance, presence of markets) and by natural or cultural landscape elements affecting tourist decision-making (e.g., geology, hidrology, vegetation, historical monuments, celebrations) as well (*de Freitas,* 2003; *Gómez Martín,* 2005).

Since one of the most important objectives of project CRIGiS was to develop a methodology for impact and vulnerability assessments, they were based on the outputs of a single regional climate model (RCM) simulation. Nevertheless, in a further step, the investigations have to be repeated using more RCM results to quantify the uncertainties of the projection for the users (in the absence of this, outcomes of any impact study cannot be properly interpreted).

In order to accomplish the other comprehensive goal of the project, i.e., to install a geo-information system providing reliable database, the datasets (i.e., *TCI* and *mTCI* data layers) were prepared to be compatible with the NAGiS system. Thus, the outcomes could be established in the datasets of NAGiS to be ready for use. The results are available for public use since May, 2016 (*NAGiS,* 2016).

References

ACC, 2016: Program 'Adaptation to Climate Change'. http://eea.rec.org/index.php?page=home-en (last accessed 23 May, 2016)

Amelung, B., 2006: Global (environmental) change and tourism. Issues of scale and distribution. PhD Dissertation, Universitaire Pers Maastricht. Amelung Publishers, Maastricht

Amelung, B. and *Viner, D.,* 2006: Mediterranean tourism: exploring the future with the tourism climatic index. *J. Sustainable Tour. 14,* 349–366.

Amelung, B., Nicholls, S. and *Viner, D.,* 2007: Implications of global climate change for tourism flows and seasonality. *J. Travel Res. 45,* 285–296.

Amelung, B. and *Moreno, A.,* 2012: Costing the impact of climate change on tourism in Europe: results of the PESETA project. *Climatic Change 112,* 83–100.

Amelung, B. and *Nicholls, S.,* 2014: Implications of climate change for tourism in Australia. *Tourism Manage. 41,* 228–244.

Amengual, A., Homar, V., Romero, R., Alonso, S. and *Ramis, C.,* 2012: Projections of the climate potential for tourism at local scales: application to Platja de Palma, Spain. *Int. J. Climatol. 32,* 2095–2107.

CRIGiS, 2016: Project '*Vulnerability/impact studies with a focus on tourism and critical infrastructures*'. http://www.met.hu/KRITeR/en/kezdo/ (last accessed 23 May, 2016)

Crompton, J.L., 1979: Motivations for pleasure vacation. *Ann. Tourism Res. 6,* 408–424.

Csima, G. and *Horányi, A.,* 2008: Validation of the ALADIN-Climate regional climate model at the Hungarian Meteorological Service. *Időjárás 112,* 155–177.

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.

De Freitas, C.R., Scott, D. and *McBoyle, G.,* 2008: A second generation climate index for tourism (*CIT*): specification and verification. *Int. J. Biometeorol. 52,* 399–407.

Farajzadeh, H. and *Matzarakis, A.,* 2009: Quantification of climate for tourism in the northwest of Iran. *Meteorol. Appl. 16,* 545–555.

Gómez Martín, B., 2005: Weather, climate and tourism. A geographical perspective. *Ann. Tourism Res. 32,* 571–591.

Gómez Martín, B., 2006: Climate potential and tourist demand in Catalonia (Spain) during the summer season. *Climate Res. 32,* 75–87.

Gössling, S., Bredberg, M., Randow, A., Sandström, E. and *Svensson, P.,* 2006: Tourist perceptions of climate change: A study of international tourists in Zanzibar. *Curr. Issues. Tourism 9,* 419–435.

Gössling, S., Scott, D., Hall, C.M., Ceron, J-P. and *Dubois, G.,* 2012: Consumer behaviour and deman response of tourists to climate change. *Ann. Tourism Res. 39,* 36–58.

Hamilton, J.M. and *Lau, M.A.,* 2005: The role of climate information in tourist destination choice decision-making. In (*Gössling, S.* and *Hall, C.M.* (Eds.)) Tourism and global environmental change. Routledge, London, 229–250.

Hamilton, J.M., Madisson, D.J. and *Tol, R.S.J.,* 2005: Climate change and international tourism: a simulation study. *Glob. Environ. Change 15,* 253–266.

Hein, L., Metzger, M.J. and *Moreno, A.,* 2009: Potential impacts of climate change on tourism; a case study for Spain. *Curr. Opin. Environ. Sustain. 1,* 170–178.

Houghten, F.C. and *Yaglou, C.P.,* 1923: Determining equal comfort lines. *J. Am. Soc. Heat. Vent. Eng. 29,* 165–176.

Hódos, R., 2014: A turisztikai klímapotenciál alakulása a Kárpát-régióban 1961–2010 között. Bachelor's thesis, Eötvös Loránd University, Budapest. http://nimbus.elte.hu/tanszek/ docs/BSc/2014/HodosRita_2014.pdf (last accessed 1 September, 2016) (In Hungarian)

Höppe, P., 1999: The physiological equivalent temperature – an universal index for the biometeorological assessment of the thermal environment. *Int. J. Biometeorol. 43,* 71–75.

Hu, Y. and *Ritchie, J.R.B.,* 1993: Measuring destination attractiveness: A contextual approach. *J. Travel Res. 32,* 25–34.

Hübner, A. and *Gössling, S.,* 2012: Tourist perceptions of extreme weather events in Martinique. *J. Destin. Mark. Manage 1,* 47–55.

IPCC, 2014: Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (*Field, C.B. et al.* (Eds.)). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132.

Jendritzky, G., 1993: The atmospheric environment – an introduction. *Experientia 49,* 733–738.

Kántor, N., Égerházi, L.A. and *Gulyás, Á.,* 2011: Assessments of the outdoor thermal conditions in Szeged, Hungary: perceptions and preferences of local individuals. In (*Gerdes, A., Kottmeier, C.* and *Wagner, A.* (Eds.)) Climate and Constructions International Conference. Karlsruher Institut für Technologie, Karlsruhe, 307–314.

Kántor, N., Égerházi, L.A. and *Unger, J.,* 2012: Subjective estimation of thermal environment in recreational urban spaces – part 1: investigations in Szeged, Hungary. *Int. J. Biometeorol. 56,* 1075–1088.

Kántor, N., 2016: Differences between the evaluation of thermal environment in shaded and sunny position. *Hung. Geogr. Bull. 65,* 139–153.

Kántor, N., Kovács, A. and *Takács, Á.,* 2016a: Small-scale human-biometeorological impacts of shading by a large tree. *Open Geosci. 8,* 231–245.

Kántor, N., Kovács, A. and *Takács, Á.,* 2016b: Seasonal differences in the subjective assessment of outdoor thermal conditions and the impact of analysis techniques on the obtained results. *Int. J. Biometeorol. 60,* 1615–1635.

Kovács, A. and *Unger, J.,* 2014a: Modification of the tourism climatic index to central European climatic conditions – examples. *Időjárás 118,* 147–166.

Kovács, A. and *Unger, J.,* 2014b: Analysis of tourism climatic conditions in Hungary considering the subjective thermal sensation characteristics of the south-Hungarian residents. *Acta Clim. Chorol. Univ. Szegediensis 47–48,* 77–84.

Kovács, A., Unger, J. and *Szépszó, G.,* 2015: Adjustment of tourism climatological indicators for the Hungarian population in assessing exposure and vulnerability to climate change. In (*Demiroğlu, O.C., de Freitas, C.R., Scott, D., Kurnaz, M.L.* and *Ünalan, D.* (Eds.)) Proceedings of the 4th International Conference on Climate, Tourism and Recreation – CCTR2015. Istanbul Policy Center, Istanbul, Turkey, 71–76.

Kovács, A., Unger, J., Gál, C.V. and *Kántor, N.,* 2016: Adjustment of the thermal component of two tourism climatological assessment tools using thermal perception and preference surveys from Hungary. *Theor. Appl. Climatol 125,* 113–130.

Kozak, M., 2002: Comparative analysis of tourist motivations by nationality and destinations. *Tourism Manage. 23,* 221–232.

Mailly, D., Abi-Zeid, I. and *Pepin, S.,* 2014: A multi-criteria classification approach for identifying favourable climates for tourism. *J. Multi-Crit. Decis. Anal. 21,* 65–75.

Matzarakis, A. and *Mayer, H.,* 1996: Another kind of environmental stress: thermal stress. *WHO Newsl. 18,* 7–10.

Matzarakis, A., Rutz, F. and *Mayer, H.,* 2010: Modelling radiation fluxes in simple and complex environments: basics of the RayMan model. *Int. J. Biometeorol. 54,* 131–139.

Mayer, H., 2008: KLIMES – a joint research project on human thermal comfort in cities. *Ber. Meteor. Inst. Albert-Ludwigs-Univ. Freiburg 17,* 101–117.

Mieczkowski, Z.T., 1985: The tourism climatic index: a method of evaluating world climates for tourism. *Can. Geogr. 29,* 220–233.

Monteith, J.L., 1965: Evaporation and environment. In: The state and movement of water in living organism. Proceedings of the Symposia of the Society for Experimental Biolology 19. Cambridge University Press, Cambridge, 205–234.

Moreno, A. and *Amelung, B.,* 2009: Climate change and tourist comfort on Europe's beaches in summer: a reassessment. *Coast. Manage. 37,* 550–568.

Moreno, A., 2010: Mediterranean tourism and climate (change): a survey based study. *Tour. Hosp. Plan. Dev. 7,* 253–265.

Morgan, R., Gatell, E., Junyent, R., Micallef, A., Özhan, E. and *Williams, A.T.,* 2000: An improved user-based beach climate index. *J. Coast. Conserv. 6,* 41–50.

NAGiS, 2016: National Adaptation Geo-information System. http://nater.mfgi.hu/en (last accessed 23 May, 2016)

Nakano, J. and *Tanabe, S-I.,* 2004: Thermal comfort and adaptation in semi-outdoor environments. *ASHRAE Trans. 110,* 543–553.

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grübler, A., Jung, T.Y., Kram, T., La Rovere, E.L., Michaelis, L., Mori, S., Morita, T., Pepper, W., Pitcher, H., Price, L., Riahi, K., Roehrl, A., Rogner, H-H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooijen, S., Victor, N., and *Dadi, Z.,* 2000: *IPCC special report on emissions scenarios.* Cambridge University Press, Cambridge

Németh, Á., 2013: Estimation of tourism climate in the Lake Balaton Region, Hungary. *J. Environ. Geogr. 6,* 49–55.

Nicholls, S. and *Amelung, B.,* 2008: Climate change and tourism in Northwestern Europe: Impacts and adaptation. *Tourism Anal. 13,* 21–31.

Perch-Nielsen, S.L., Amelung, B. and *Knutti, R.,* 2010: Future climate resources for tourism in Europe based on the daily Tourism Climatic Index. *Climatic Change 103,* 363–381.

Roshan, G., Yousefi, R. and *Fitchett, J.M.,* 2016: Long-term trends in tourism climate index scores for 40 stations across Iran: the role of climate change and influence on tourism sustainability. *Int. J. Biometeorol. 60,* 33–52.

Rutty, M. and *Scott, D.,* 2010: Will the Mediterranean become "too hot" for tourism? A reassessment. *Tour. Hosp. Plan. Dev. 7,* 267–281.

Rutty, M. and *Scott, D.,* 2014: Thermal range of coastal tourism resort microclimates. *Tourism Geogr. 16,* 346–363.

Scott, D. and *McBoyle, G.,* 2001: Using a 'tourism climate index' to examine the implications of climate change for climate as a natural resource for tourism. In (*Matzarakis, A.* and *de Freitas, C.R.* (Eds.)) Proceedings of the First International Workshop on Climate, Tourism and Recreation. International Society of Biometeorology, Commission on Climate, Tourism and Recreation, Halkidi, Greece, 69–88.

Scott, D., McBoyle, G. and *Schwartzentruber, M.,* 2004: Climate change and the distribution of climatic resources for tourism in North America. *Climate Res. 27,* 105–117.

Scott, D., Gössling, S. and *de Freitas, C.R.,* 2008: Preferred climates for tourism: case studies from Canada, New Zealand and Sweden. *Climate Res. 38,* 61–73.

Scott, D., de Freitas, C.R. and *Matzarakis, A.,* 2009: Adaptation in the tourism and recreation sector. In (*Ebi, K.L., Burton, I.* and *McGregor, G.R.* (Eds.)) Biometeorology for adaptation to climate variability and change. Springer Netherlands, Dordrecht, 171–194.

Scott, D. and *Lemieux, C.,* 2010: Weather and climate information for tourism. *Proc. Environ. Sci. 1,* 146–183.

Scott, D., Hall, C.M., and *Gössling, S.,* 2012: *Tourism and climate change: impacts, adaptation and mitigation.* Routledge, Abingdon

Szalai, S., Auer, I., Hiebl, J., Milkovich, J., Radim, T., Stepanek, P., Zahradnicek, P., Bihari, Z., Lakatos, M., Szentimrey, T., Limanowka, D., Kilar, P., Cheval, S., Deak, Gy., Mihic, D., Antolovic, I., Mihajlovic, V., Nejedlik, P., Stastny, P., Mikulova, K., Nabyvanets, I., Skyryk, O., Krakovskaya, S., Vogt, J., Antofie, T. and *Spinoni, J.* (2013): Climate of the Greater Carpathian Region. Final Technical Report. www.carpatclim-eu.org/ (last accessed 1 September, 2016)

Szentimrey, T. and *Bihari, Z.,* 2007: Manual of interpolation software MISHv1.02. Hungarian Meteorological Service, Budapest

Szentimrey, T., 2011: Manual of homogenization software MASHv3.03. Hungarian Meteorological Service, Budapest

Yang, W., Wong, N.H. and *Jusuf, S.K.,* 2013: Thermal comfort in outdoor urban spaces in Singapore. *Build. Environ. 59,* 426–435.