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ORIGINAL ARTICLE

Future heat-related climate change impacts on tourism industry in Cyprus

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Abstract Tourism is a vital sector of Cyprus economy, attracting millions of tourists every year and providing economic growth and employment for the country. The aim of this study was to investigate the impacts of projected climate change in the tourism industry in Cyprus (Republic of Cyprus) using both "Tourism Climate Index" (TCI) and "Beach Climate Index" (BCI). TCI refers to tourism activities mainly related to sightseeing, nature-based tourism, and religious tourism etc., while BCI represents beach tourism that constitutes 85 % of tourism activities in Cyprus. The projections of climate change impacts in tourism are performed for 2071–2100 period, using regional climate model output employing the A1B greenhouse gas emissions scenario. The 1961–1990 period is used as the control run to compare the respective results of the future projections. The significant warming anticipated in the distant future (increases in annual and summer temperatures close to 4 °C) will have adverse impacts on Cyprus tourism industry regarding sightseeing tourism. TCI results for the distant future period show only acceptable conditions for general tourism activities during summer in contrast with the good/very good conditions in the present climate. Conversely, this type of tourism seems to be benefited in shoulder seasons, i.e., during spring and autumn; TCI and hence tourist activities improve in the distant future in relation to the present climate. On the other hand, concerning beach tourism, future projections indicate that it will not be negatively affected by future climate change and any changes will be positive.

Keywords Regional climate models · Climate change impacts · Tourism Climate Index · Beach Climate Index · Tourism industry · Cyprus

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Introduction

Climate has a strong influence on the tourism and recreation sector and in some regions represents the natural resource on which the tourism industry is predicated. Most types of tourism are closely linked to climate (Alcamo et al. 2007), in terms of the climate of the source country of tourists (e.g., the perception of unreliable summers in, for example, northern Europe), the destination country for tourists (e.g., the perception of reliable summers in the Mediterranean), and climate seasonality (the seasonality contrast that drives demand for summer vacations in the northern hemisphere). In a climate change world, conditions for tourism as described by the Tourism Comfort Index are expected to improve in northern and western Europe (Alcamo et al. 2007; Amelung and Viner 2006; Hanson et al. 2006; Nicholls and Amelung 2008). It has been indicated that an arbitrary climate change scenario of 1 °C would lead to a gradual shift of tourist destinations further north and up the mountains affecting the preferences of the sun and beach lovers from western and northern Europe (Alcamo et al. 2007; Giannakopoulos et al. 2011; Hamilton et al. 2005). In the south and southeast parts, the Mediterranean, one of the most visited beach-based tourist destinations worldwide, several research works have shown that higher temperatures could lead to a gradual decrease in tourism attractiveness during peak season (summer) but an increase during shoulder seasons' tourism (spring and autumn) due to the improvement of the climatic suitability (Hamilton et al. 2005; Amelung and Viner 2006; Amelung et al. 2007; Nicholls and Amelung 2008; Hein et al. 2009; Rutty and Scott 2010; Amelung and Moreno 2012; Amengual et al. 2014). Furthermore, heat waves are very likely to affect tourist decisions regarding the travel destination or the length of stay due to tourist discomfort, especially for those population groups that are sensitive to such events (e.g., elderly). The increase in sea surface temperature (SST) due to the increase in air temperature will contribute to the extension of the swimming season. The above could result in the lengthening and the flattening of the tourism high season in the coming decades (Amelung and Viner 2006; Alcamo et al. 2007; Nicholls and Amelung 2008; Dubois and Cauchy 2014). Finally, a decrease in precipitation and the elongation of dry periods could exacerbate problems in water stress tourist regions, which already cannot satisfy the increased water demand from the tourism sector in summer for drinking water as well as for recreational facilities (swimming pools, golf courses) (Ehmer and Heymann 2008). Papadaskalopoulou et al. (2015) testified that the expected small decrease in precipitation of approximately 5 % at the areas where the main dams of Cyprus are located for the future period 2021–2050 could result in a substantial decrease in the future total dam inflow of 23 %.

Such changes in climatic suitability could potentially have substantial influences on the volumes, spatial distributions, and timing of travel within Europe. Additionally, these alterations to tourism flows have important consequences on the operation of the European tourism industry, from the planning, location, development of new accommodations, transportation routes, and attractions to the staffing and operation of existing enterprises (Nicholls and Amelung 2008). Also, it is significant to be mentioned that the ability of tourism businesses to successfully adapt to these new conditions depends heavily on the adoption of a proactive rather than reactive behavior in relation to climate change future impacts, on their organizational flexibility and on the mobility of their capital investments taking advantage of the new opportunities for tourism (Nicholls and Amelung 2008; Moreno and Amelung 2009).

Cyprus lies at the eastern end of the Mediterranean Sea (Fig. 1) and experiences mild winters and hot dry summers. The average daytime temperature in winter ranges from 12 to 15 °C, while in summer the maximum temperature ranges from 32 to 40 °C in coastal and inland regions, respectively. Meteorological observations for the period 1892–2010 show an increase in the annual mean air temperature of about 1.4 °C in Nicosia and 2.3 °C in Limassol and also rise in the number of hot days and warm nights and decline in the number of frost nights. Additionally, rainfall has fallen by 17 % since the beginning of the twentieth century; however, there has been an increase in heavy rainfall which falls in a period of 1 h for the period 1930–2007 (CYPADAPT 2012).

The projected climate warming and its impacts, negative or positive, on the tourism industry of Cyprus are the object of this study. In addition, studies of the current and/or future spatial and temporal distribution of climate resources for general tourism as well as for summertime tourism in Cyprus are extremely scarce. In fact, only one article was identified (Olya and Alipour 2015) where authors studied the spatial risk analysis of excessive rainfall on North Cyprus' tourism using, among other methods, the Tourism Climate Index. In the light of this information, the purpose of this study is also to investigate potential changes in climatic attractiveness for Cyprus' major tourism areas over the coming century. Additionally, this research's intention is to consider the likely implications of these climate change impacts on flows of tourists as well as for tourism planning, development, and management.

Materials and methods

Cyprus tourism and climate features

Tourism is a vital economic sector of Cyprus. Every year, approximately 2 million tourists visit Cyprus providing economic growth and employment for the country. In 2014, tourist arrivals reached about 2.4 millions (CYSTAT 2015a), while tourism revenue amounted to 2.44 billion Euros contributing approximately 14 % to Cyprus' GDP (CYSTAT 2015b, c).

Cyprus is a popular tourist destination due to the good climatic conditions prevailing in the island throughout the year, with plenty of sunshine and mild winters, as well as due to the short distances and the largely developed tourist infrastructure. On the other hand, among the weaknesses of the tourism sector in Cyprus, the fact is that it is considered an expensive destination (including the high travel expenses), the deterioration of the relationship between price and value, and the aging of infrastructure. The tourist arrivals in Cyprus, although they marked a significant increase during the last decades up to 2001 where they reached their peak, have remained at lower levels since (CYSTAT 2015a).

Cyprus was ranked at the 14th place in the EU-28 with 13 million nights spent by nonresidents in 2013, while at the same year Spain was the most popular EU tourist destination (252 million nights), followed by Italy (185 million nights) and France (131 million nights), which together account for almost half of the total nights spent in

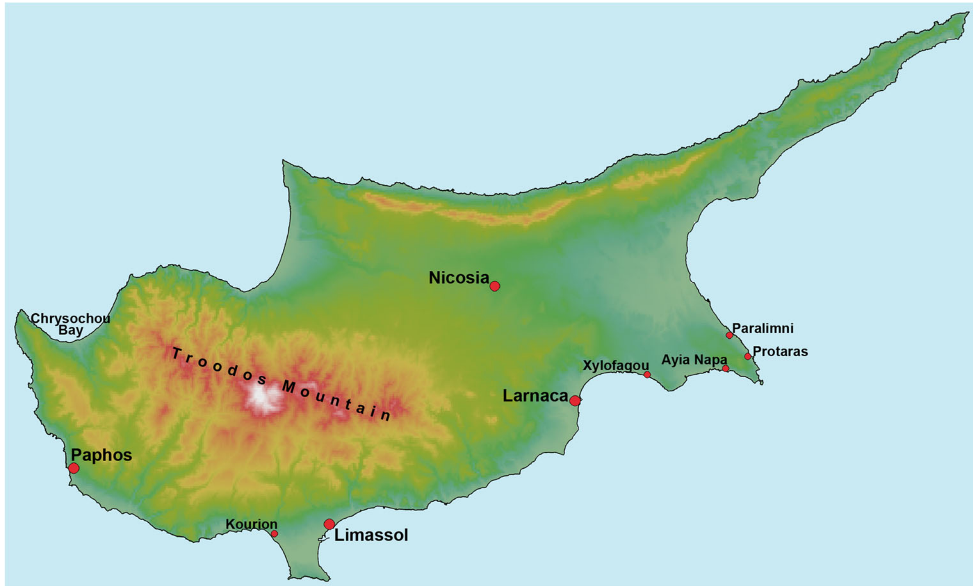


Fig. 1 Map and location of Cyprus. The analysis of the results is confined to the Republic of Cyprus' administrated part

the EU by nonresidents (Eurostat 2014). However, this indicator does not take into account the size of the host countries in population terms, which the indicator of tourism intensity does. In particular, when examining tourism intensity for 2013, Malta is ranked in the first place with Cyprus holding the second place followed by Croatia, Austria, Spain, Greece, Italy, and others (Eurostat 2014).

The overnight stays in Cyprus during the period 2000–2013 consisted of 93 % foreign tourists and 7 % of Cyprus residents (internal tourism) (CYSTAT 2014). Regarding the source countries of foreign tourists during the period 2000–2014, arrivals of tourists from the UK constituted the main source of international tourism with 50 % of total tourist arrivals, followed by Russia (10 %), Germany (6 %), Greece (5 %), and Sweden (4.5 %) (CYSTAT 2015a).

Considering that tourists visiting a place for leisure are more sensitive to changes in climate compared to those traveling for business purposes or to see friends and relatives (Fagence and Kevan 1997), the statistics on the purpose of tourists visiting Cyprus are examined. In particular, it is estimated that in the period 2001-2011 on average 85 % of the tourists visited Cyprus for leisure, 9 % for visiting relatives and friends. and the rest 6 % for business purposes (e.g., conferences, meetings etc.) (CYSTAT 2012). The great share of tourists visiting Cyprus for leisure indicates that Cyprus tourism is quite sensitive to climate change, as far as the purpose of traveling is concerned.

During the last decades, Cyprus has developed its tourist accommodation infrastructure to a great extent in order to meet the needs of the increasing incoming tourism. According to the Cyprus Tourism Organization, in 2013 94 % of beds were established at the coastal cities of Famagusta (Greek area–Ayia Napa, Paralimni), Paphos, Larnaca, and Limassol, 3.3 % at the capital of Nicosia which is located inland, and 2.7 % at the villages of the mountain Troodos (Hill Resorts) (CTO 2014). The preferences of tourists regarding the location of their stay for the period 2001–2011 were also allocated between the coastal cities of Famagusta (33 %), Paphos and Polis (33 %), Limassol (15 %), and Larnaca (9.5 %) as well as to Nicosia (5 %) (CYSTAT 2012). The fact that the locations where the tourist infrastructure is concentrated and which tourists prefer for their stay are on the vast majority, the coastal cities of Cyprus, may provide a good indicator that tourism in Cyprus is strongly dependent on beach tourism, which makes it more sensitive to changes in the climatic parameters affecting this type of tourism.

Countries with high seasonality in tourism are considered more sensitive to changes in climate, as they strongly depend on climatic parameters (e.g., sun and high temperatures or low temperatures and snow) for the promotion of their tourist products. Cyprus is generally characterized by high seasonal variation in tourism with high distribution of tourist arrivals and nights spent in summer and low in winter. This is attributed to the fact that the main tourist product of Cyprus is based on the "3S" (sea, sand and sun) model, thus creating an uneven distribution of tourist flow. In fact, the seasonality in Cyprus' tourism was above the EU average in 2014, as well as for seven other EU countries of the Mediterranean, such as France, Greece, Italy, and Croatia but also for Denmark, Bulgaria, and the Former Yugoslav Republic of Macedonia (Eurostat 2015a), all of them presenting one peak in tourist demand during the summer months. Among these countries, Croatia recorded the highest seasonality with 25–35 % monthly share during the months of July and August and the highest slowdown during winter (Eurostat 2015a).

In Cyprus, tourist arrivals during the period 2000–2014 may be divided in two seasons. The season from May to October where the monthly share of tourist arrivals is above 10 %, with the highest shares of the year being recorded in July and August (14–16 %), and the season from November to April where the monthly share is 2–6 %, with the winter months reaching the lowest shares (Eurostat 2015b). Malta, on the other hand, although presents similar monthly shares to Cyprus during summer, is classified at the group of countries with low seasonal variation, as it has a smooth slowdown during winter, close to the EU average, unlike Cyprus (Eurostat 2015a). As a result, Malta is considered less sensitive to climate change compared to Cyprus, with respect to the seasonal variation of its tourism.

During the period 2000–2014, a change in the seasonality of tourism in Cyprus has been observed, with an overall increase in the monthly shares of nights spent during the summer months as well as during the shoulder months of May, September, and October, with the remaining months of the year recording an equivalent decrease, thus resulting in an increase in the seasonality of tourism (Fig. 2).

Tourism Climate Index

Tourism Climate Indexes (TCIs) are commonly used to describe the climate conditions suitable for tourism activities and are a good example of climate services products (Dubois and Dubois 2014). Indeed, TCIs can use either observational or modeled data, can be calculated at all time scales, and can be used in a planning, investing, or daily operation perspective. The most commonly used TCI was defined by Mieczkowski (1985) and despite its limitations, its formula is supposed valid for all forms of tourism. Mieczkowski (1985) was among the first to apply the general findings of human comfort to the specific activities related to recreation and tourism. He devised a tourism climatic index consisting of five subindices, describing daytime thermal comfort, daily thermal comfort, precipitation, hours of sunshine, and wind speed. The mapping of raw data to subindex values depends on the kind and level of tourist activity. Beach holidays require climatic conditions different from ski holidays; in his article, light activities, such as touring, are used as a reference.

The thermal comfort subindices are based on the effective temperature, which is a measure of temperature that takes the effect of relative humidity into account. The wind subindex combines information about wind speed and temperature. The other subindices are based on single variables and reflect either the empirical findings of physiological research or qualitative assessments of tourist preferences, for example, in relation to precipitation. A standardized rating system, ranging from 5 (optimum) to 0 (extremely unfavorable), was devised to provide a common basis of measurement for each of the subindices. Mieczkowski proposed the following equation for calculating the TCI for outdoor recreational activities:

$$\mathrm{TCI} = 2(4\mathrm{CID} + \mathrm{CIA} + 2\mathrm{R} + 2\mathrm{S} + \mathrm{W})$$

in which CID, CIA, R, S, and W are the indexes of daytime comfort, daily comfort, precipitation, sunshine, and wind speed, respectively. The weights used in the equation are

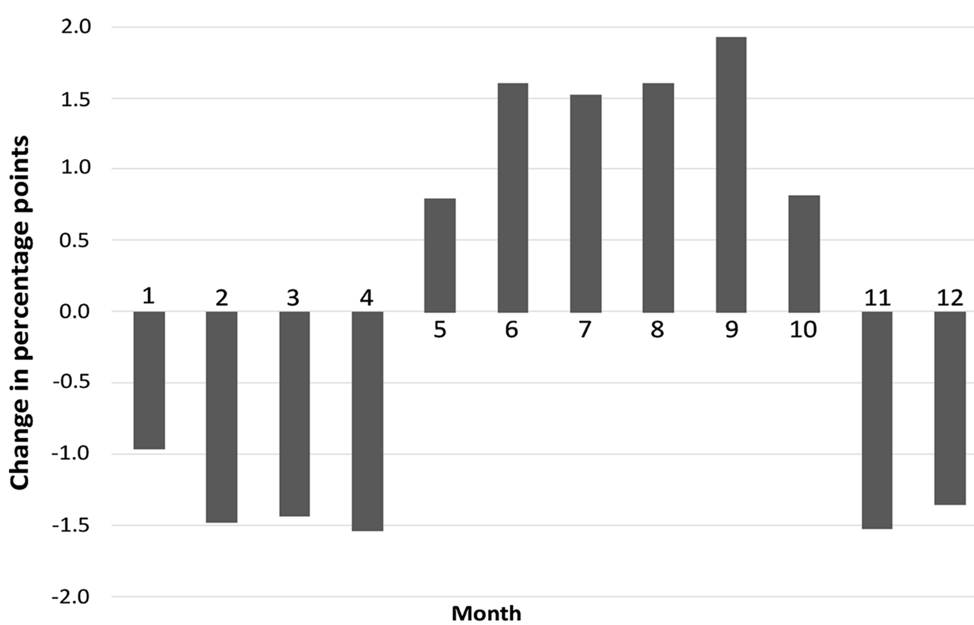


Fig. 2 Change in the yearly distribution of the monthly shares of nights spent in Cyprus, 2000–2014 (percentage points) (*Source* Eurostat 2015b)

ultimately subjective, although they do have a basis in scientific knowledge. In the equation proposed by Mieczkowski (1985), the highest weight is given to the daytime comfort index (40 %) to reflect the fact that tourists are generally most active during the day. The amount of sunshine and the amount of precipitation are given the second highest weights (20 %), followed by daily thermal comfort and wind speed (10 %). In order to use the original rating scheme for precipitation which is based on mean monthly values, the daily values where simply multiplied by 30. An alternative methodology would be to change the original scheme by simply dividing the monthly values by 30 to obtain a rating scheme based on daily values (Perch-Nielsen et al. 2010). After summing the weighted individual components, the result is multiplied by two so that the maximum TCI score is 100. Mieczkowski proposed a classification of TCI scores, with values in excess of 30 corresponding to "unfavorable" conditions, scores exceeding 40 corresponding to "marginal" conditions, and values in excess of 50 corresponding to "acceptable" conditions. Additionally, values in excess of 60 corresponding to "good" conditions, scores exceeding 70 representing "very good" climatic conditions, levels of over 80 corresponding to "excellent" conditions, and scores of 90 or more standing for "ideal" circumstances.

While being widely used as a measure of climatic attractiveness in combination with projections of climate change (Scott et al. 2004; Amelung and Viner 2006; Amelung et al. 2007; Nicholls and Amelung 2008; Hein et al. 2009; Amelung and Nicholls 2014; Olya and Alipour 2015), the TCI presents a number of limitations. A critical limitation of the TCI is that it is as an "expert-based" index meaning that it was secondarily derived from the biometeorology literature and Mieczkowski's subjective opinion and was not validated against tourists' stated preferences or visitation data. Other weakness is that the TCI does not take into account potential overriding effects of rain when rating the climate asset (de Freitas et al. 2008).

Beach Climate Index

Based on the work of Mieczkowski (1985), Morgan et al. (2000) developed a user-based climate index to assess the climate suitability of coastal destinations specific for beach recreation. In fact, Morgan's BCI contains the same elements as Mieczkowski's TCI except for the daily thermal component. The main difference between the two indices is the rating and weighting schemes. Morgan et al. (2000) based their schemes on the stated preferences of actual beach users, while Mieczkowski (1985) based his schemes heavily on expert judgment. Similar to Mieczkowski's TCI, Morgan et al.'s BCI is made up of smaller components (subindices) that, after weighting, add up to a maximum score of 100 (ideal conditions). The resulting equation is as follows (Morgan et al. 2000):

$$\mathrm{BCI} = 0.18\mathrm{TS} + 0.29\mathrm{P} + 0.26\mathrm{W} + 0.27\mathrm{S}$$

in which BCI is the Beach Climate Index, TS, P, W, and S are the components of thermal sensation, precipitation, wind, and sunshine, respectively. Each of the four components is itself represented by an index, with values ranging from 0 to 100. In the equation proposed by Morgan, the highest weight is given to the precipitation index (29 %) to reflect the negative impact that this element has on outdoor activities. Wind speed and the amount of sunshine are given the second highest weights (26 and 27 %, respectively), followed by thermal sensation (18 %).

The final Beach Climate Index (BCI) can attain values ranging from 0 to 100. Morgan et al. (2000) divides this range as suggested by Mieczkowski (1985), with values below 40 seen as unfavorable, the range between 40 and 60 as acceptable, values from 60 to 70 as good, between 70 and 80 as very good, and scores above 80 as excellent for beach tourism.

Although BCI has more sound rating and weighting schemes compared to TCI, it has also some limitations that have to be mentioned. Firstly, rating and weighting schemes were based on the climate preferences of northern European tourists (Morgan et al. 2000). The generalization of these results may be limited due to possible intercultural differences in climate preferences among tourists (Moreno and Amelung 2009; de Freitas et al. 2008); however, this is not the case for Cyprus due to fact that the majority of tourists derived from northern countries. Also, continuing with BCI limitations, climate preferences may also change in time owing to acclimatization or adaptation of humans to a warmer climate (de Freitas et al. 2008). Lastly, BCI, similarly with TCI, does not take into consideration the overriding effects of precipitation when rating the climate benefit (Moreno and Amelung 2009).

Regional climate modeling

Calculations for both TCI and BCI were based on the daily output of the RACMO2 regional climate model (RCM). This model was developed within the framework of the EU project ENSEMBLES (http://ensembles-eu.metoffice.com), in which the National Observatory of Athens participated.

RACMO2 was developed by the Koninklijk Nederlands Meteorologisch Instituut, in the Netherlands, widely known as KNMI. The KNMI-RACMO2 regional climate model (Lenderink et al. 2003, 2007; van den Hurk et al., 2006) is forced with output from a transient run conducted with the ECHAM5 global climate model. The RCM model uses 40 vertical levels on a horizontal 95 × 85 (lat × lon) grid and has a horizontal resolution of 25 km.

Table 1 Projected changes and the 95th percentile confidence interval of climate for 2071–2100 (distant future) compared to 1961–1990 (control period)

	Western regions	Mountain regions	Inland regions	Southern regions	Southeastern regions
TXa (°C)	(+)3.6	(+)4.3	(+)4.0	(+)3.8	(+)3.6
	± 0.30	±0.35	±0.32	±0.30	±0.25
TXDJF (°C)	(+)3.4	(+)3.7	(+)3.5	(+)3.6	(+)3.4
	±0.40	±0.50	±0.45	±0.40	±0.35
TXMAM (°C)	(+)3.7	(+)4.6	(+)4.3	(+)4.2	(+)3.9
	±0.40	±0.60	±0.60	±0.60	±0.35
TXJJA (°C)	(+)3.7	(+)4.4	(+)4.1	(+)4.0	(+)3.7
	±0.40	±0.45	±0.33	±0.40	±0.25
TXSON (°C)	(+)3.8	(+)4.2	(+)4.1	(+)4.1	(+)3.8
	±0.50	±0.60	±0.60	±0.60	±0.45
PRa (mm)	(–)85–100	(–)115	(–)55	(–)85–100	(–)55
	(±30)	(±35)	(±30)	(±30)	(±30)
PRDJF (mm)	(–)60–75	(–)80	(–)40	(–)60–75	(–)40
	(±25)	(±30)	(±20)	(±25)	(±20)
TX > 35 °C	(+)30	(+)60	(+)60	(+)50	(+)55
	±2	±5	±4	±4	±2
TN > 20 °C	(+)80	(+)75	(+)75	(+)70	(+)75
	±7	±5	±5	±7	±7

where *TXa* average annual maximum temperature (Tmax), *TXDJF* average winter Tmax, *TXMAM* average spring Tmax, *TXJJA* average summer Tmax, *TXSON* average autumn Tmax, *PRa* annual total rainfall, *PRDJF* average winter rainfall, TX > 35 °C = number of heat wave days (maximum temperature > 35 °C), TN > 20 °C = number of tropical nights (minimum temperature > 20 °C). Projections carried out by the RACMO2 regional climate model developed at KNMI (Netherlands) within the framework of the EU ENSEMBLES project. The 95th percentile confidence intervals are calculated by bootstrapping the 30-year differences of each index between the two study periods (Mudelsee and Alkio 2007)

In the present study, the control run represents the base period 1961–1990 and is used as a reference for comparison with future projections for the period 2071–2100 (distant future). The distant future period is specifically chosen due to the significant warming projected which may negatively affect the tourism industry (Table 1). Finally, the future period simulations of the model are based on the IPCC SRES A1B scenario (Nakicenovic et al. 2000), which provides a good midline estimate for carbon dioxide emissions and economic growth (Alcamo et al. 2007).

KNMI RACMO2 RCM has been extensively validated all over Europe (Mediterranean region also included) in the course of EU project ENSEMBLES. The selection of this specific model was based on an assessment performed within the ENSEMBLES project. The ability of all the models to simulate the present climate was assessed, and KNMI-RACMO2 was found to more accurately simulate mean climate and extremes for the Mediterranean region (ENSEMBLES 2010; Christensen et al. 2010). Furthermore, Kostopoulou et al. (2012) have performed a regional evaluation of various models (KNMI RACMO2 included) for the Balkan Peninsula focusing on climate extremes. According to this study, RACMO2 manages to reproduce patterns of extreme temperature and precipitation with reasonable accuracy when compared to the E-OBS gridded observational dataset.

Results

Future climate projections

The projected climatic changes in Cyprus for the distant future period (2071–2100) show a remarkable increase in air temperature as well as an increase in the frequency and intensity of extreme weather events (heat waves) (Table 1). A quantification of uncertainty in RCM projections is attempted by bootstrapping the 30-year differences of each index between the two study periods (Mudelsee and Alkio 2007). Bootstrapping works with artificially produced resampled sets (by means of a random number generator) of the difference index sample. In our study, each sample consists of 30 values which are resampled 1000 times with replacement. In each resample, the method calculates the mean of each sample and the 95th percentile confidence intervals are then computed from the resulting series. Thus, in the analysis performed, each mean parameter change is presented with a (±α) value which represents the confidence range value to add or subtract from the mean difference to get the limits. This is used as a measure to assess confidence in our results as presented in Table 1.

In particular, a relatively strong warming of about 3.6 °C (±0.30) is expected for western (Paphos) and southeastern regions (Larnaca and Famagusta), while in southern (Limassol) and inland (Nicosia) areas, the increase is higher, 3.8 °C (±0.30) and 4.0 °C (±0.32), respectively. Mountain areas of Troodos present the highest increase in the average annual maximum temperature of about 4.3 °C (±0.35) (Table 1). In addition, seasonal temperatures present significant increases. During spring and autumn (shoulder season for summer tourism), the mean temperature increase in Cyprus is expected to be 4.1 °C (±0.50) and 4.0 °C (±0.60), respectively, while during high season (summer), the increase is anticipated at about 4.0 °C (±0.40). For winter (low season), the mean temperature increase is expected at about 3.5 °C (±0.40). As concerns rainfall, Table 1 testifies that annual total precipitation is expected to decrease about 85–100 mm (±30) in western and southern areas, 115 mm (±35) in mountain areas, and 55 mm (±30) in inland and southeastern regions. In addition, reductions in rainfall are also projected for winter in the distant future. More precisely, in western and southern areas, the decrease is expected at about 60–75 mm (±25), in mountain areas at about 80 mm (±30), while in inland and southeastern regions, the decline is anticipated at about 40 mm (±20) (Table 1). The climate change signal is clear and robust since the uncertainties, especially for temperature, are much smaller than the changes.

In addition to these projected changes in temperature and precipitation by the end of the century, Cyprus' climate is likely to be exacerbated by the increasing extreme weather events such as heat wave. Table 1 testifies that in the distant future, western regions of Cyprus are expected to have one additional month of heat wave days ($TX > 35$ °C), while the remaining areas are expected to have approximately 2 months of extreme warming. Moreover, the number of tropical nights ($TN > 20$ °C) is anticipated to substantially increase about 70–80 days (±5–7).

Along with the increase in air temperature, an increase in sea surface temperature (SST) is also expected, at a lower rate though (Nicholls et al. 2007). In fact, sea warming already takes place as observations indicate a strong eastward increasing sea surface warming trend in the Mediterranean basin, with the Levantine Basin where Cyprus belongs, recording a warming rate of 0.04–0.06 °C per year during the last 2–3 decades (Skliris et al. 2011; Samuel-Rhoads et al. 2012). Future climate change simulations with the use of high-resolution coupled atmosphere–ocean regional climate models based on the A1B emissions scenario, show that the SST of Cyprus is expected to further increase by 2 °C until 2050 (Dubois and Cauchy 2014).

Tourism Climate Index

During summer, in the control period, Cyprus presents "good" conditions except for Famagusta and western regions which present "very good" conditions for tourism activities (Fig. 3a). As far as future changes are concerned (Fig. 3b), all areas of Cyprus show a significant decrease in TCI resulting in "acceptable" conditions during summer months.

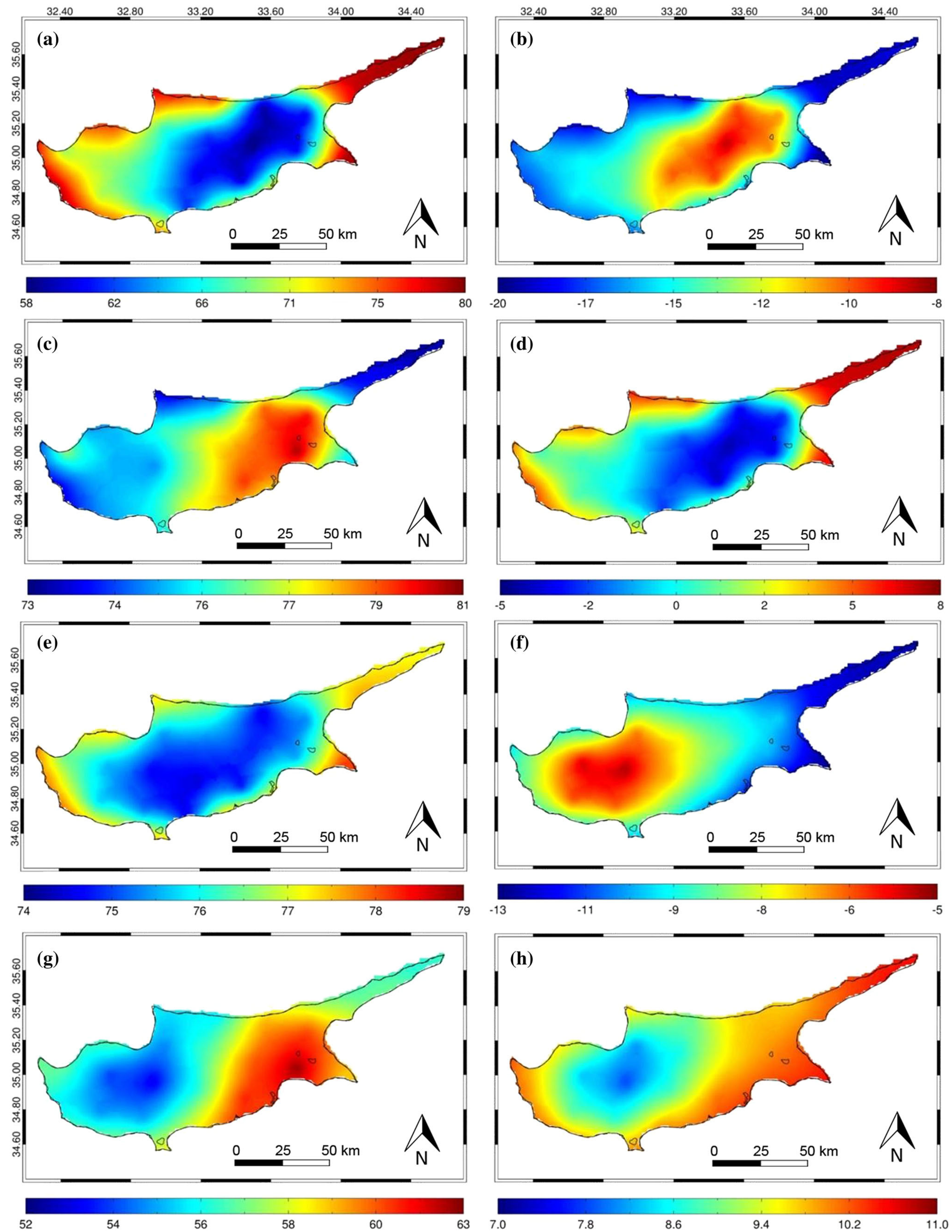
To investigate the possible shift of optimal climatic conditions, and thus tourists' preference, from the present peak demand season (summer) to the shoulder seasons (spring and autumn), the average spring TCI and the average fall TCI were examined. Figure 3c depicts that in the control period, TCI during spring is highly elevated and all areas of Cyprus are classified as "very good" for tourist activities. Concerning future changes, Fig. 3d illustrates that almost all areas of Cyprus continue to present "very good" conditions, while western regions and Famagusta present "excellent" conditions for tourism activities. Regarding autumn, Fig. 3e illustrates that in the control period, similarly with spring, all regions of Cyprus are classified as "very good" for general tourism activities. On the contrary, in the future, the projected significant increase in temperature reduces the climatic attractiveness of Cyprus' areas (more inland and southeastern regions) classifying them as "good" (Fig. 3f).

Last but not least, low season tourism during winter presents a significant growth potential as Fig. 3g, h depicts. Although in the control period the attractiveness of Cyprus' regions is low, "acceptable" in the majority and "good" only in inland and southeastern areas (Fig. 3g), in the distant future period Cyprus areas ascend to higher classes of attractiveness (Fig. 3h). More precisely, southeastern and inland regions are classified as "very good", while the remaining areas are classified as "good" (Fig. 3h).

The overall findings of the analysis of TCI for both control period and future changes due to climate change are summarized in Table 2.

Beach Climate Index

As already mentioned, almost 85 % of visits in Cyprus are for recreational purposes. In addition, 90 % of the tourists visiting Cyprus prefer the coastal cities for their stay. The assessment of both previous indicators shows that Cyprus tourism is strongly dependent on beach tourism. Consequently, through the analysis of BCI, the investigation of the effects of the warmer climate on tourism will be



(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
32.40 32.80 33.20 33.60 34.00 34.40
35.60 35.40 35.20 35.00 34.80 34.60
0 25 50 km
N
58 62 66 71 75 80
-20 -17 -15 -12 -10 -8
73 74 76 77 79 81
-5 -2 0 2 5 8
74 75 76 77 78 79
-13 -11 -9 -8 -6 -5
52 54 56 58 60 63
7.0 7.8 8.6 9.4 10.2 11.0

◀ **Fig. 3** **a** Average summer Tourism Climate Index (TCI) for control period, **b** Changes in average summer TCI in the distant future (Future–Control period), **c** average spring TCI for control period, **d** Changes in average spring TCI in the distant future, **e** Average fall TCI for control period, **f** Changes in average fall TCI in the distant future, **g** Average winter TCI for control period, **h** Changes in average winter TCI in the distant future

focused directly on beach tourism which is the most relevant. Moreover, it will be confined to the coastal zone of Cyprus from west (Paphos District) to south (Limassol District) and southeast (Larnaca and Famagusta District-Greek part).

For the high season of Cyprus tourism, BCI shows that "excellent" conditions for beach holidays are found at the coastal area which extends from Limassol salt lake (Limassol District) to Xylofagou (Larnaca District) as well as the area of Chrysochou bay (Paphos District) (Fig. 4a). The remaining coastal area, which includes the Cyprus tourism "hot spots" namely Paphos and Famagusta (Ayia Napa, Protaras and Paralimni), presents "very good" conditions (Fig. 4a). Future projections of BCI concerning high season of Cyprus tourism depict that "very good" and "excellent" conditions for beach tourism in the aforementioned coastal regions are not expected to change despite the projected warming (Fig. 4b).

Concerning shoulder seasons—spring, autumn—the BCI index distribution for present time is illustrated in Fig. 4c, e. In particular, Fig. 4c shows that during spring, the coastal area between Kourion (Limassol) to Famagusta as well as the area of Chrysochou bay present "very good" conditions. Also, Paphos coastal zone presents "good" conditions for beach holidays. On the other hand, Fig. 4e shows that during autumn, "very good" conditions are presented for Limassol to Xylofagou coastal area as well as Chrysochou bay while the Paphos and Famagusta coastal zone present "good" conditions. Future projections for both spring and autumn show that the classification of coastal areas will remain in the same classes as in the present-day climate (Fig. 4d, f).

Finally, regarding low season tourism in Cyprus, BCI shows that in the reference period, coastal zone from Limassol to Larnaca presents "good" conditions, while Paphos and Famagusta coasts are classified in lower satisfaction class that is "acceptable" (Fig. 4g). Future projections for low season beach tourism in Cyprus testify that classification remains to the same satisfaction levels as the reference period (Fig. 4h).

The overall findings of the analysis of the BCI for both control period and future climate changes are summarized in Table 3.

Discussion and conclusions

From the aforementioned TCI results, it can be concluded that in the distant future (2071–2100), the considerable warming which is projected during summer (when the majority of tourists visit Cyprus) will have a negative impact on the tourism industry of Cyprus. Actually, all

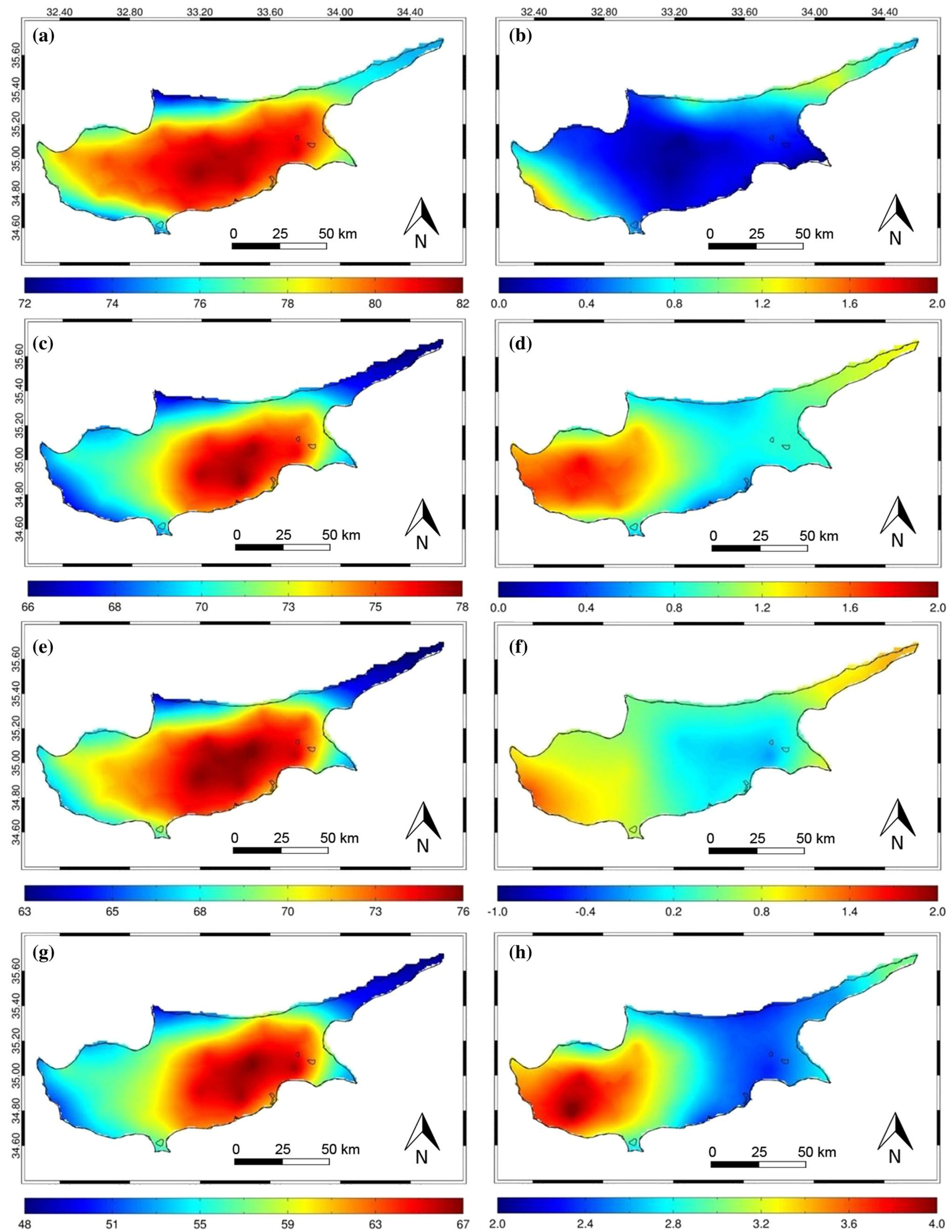
Table 2 Regions' classification as regards general tourism activities for control and future period in Cyprus

		ASuT	ASpT	AFT	AWT
Western Regions	Control	Very good	Very good	Very good	Acceptable
	Change	Acceptable	Very good	Good	Good
Mountain Regions	Control	Good	Very good	Very good	Acceptable
	Change	Acceptable	Very good	Good	Good
Inland Regions	Control	Good	Very good	Very good	Good
	Change	Acceptable	Very good	Good	Very good
Southern Regions	Control	Good	Very good	Very good	Acceptable
	Change	Acceptable	Very good	Good	Good
Southeastern Regions	Control	Good[a]	Very good	Very good	Good
	Change	Acceptable	Very good[b]	Good	Very good

where *ASuT* average summer TCI, *ASpT* average spring TCI, *AFT* average fall TCI, *AWT* average winter TCI. The red color indicates decreases in future conditions for tourism activities compared to present-day climate, while the green indicates increase. Gray indicates no change in future conditions

[a] Except for Famagusta where present "very good" conditions

[b] Except for Famagusta where present "excellent" conditions


(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
32.40 32.80 33.20 33.60 34.00 34.40
35.60 35.40 35.20 35.00 34.80 34.60
0 25 50 km
N
72 74 76 78 80 82
0.0 0.4 0.8 1.2 1.6 2.0
66 68 70 73 75 78
0.0 0.4 0.8 1.2 1.6 2.0
63 65 68 70 73 76
-1.0 -0.4 0.2 0.8 1.4 2.0
48 51 55 59 63 67
2.0 2.4 2.8 3.2 3.6 4.0

◀ **Fig. 4** **a** Average summer Beach Climate Index (BCI) for control period, **b** Changes in average Summer BCI in the distant future (Future–Control period), **c** Average spring BCI for control period, **d** Changes in average spring BCI in the distant future, **e** Average fall BCI for control period, **f** Changes in average fall BCI in the distant future, **g** Average winter BCI for control period, **h** Changes in average winter BCI in the distant future

areas of Cyprus are classified slightly "acceptable" concerning future period from "good" to "very good" conditions in the reference period.

The decreases found in future summer TCI results are mostly associated with temperature increases projected for all areas (Table 1), since TCI overemphasizes the thermal component giving it the highest weighting in the calculations. This TCI feature has been criticized in previous studies since TCI is not suitable for beach holidays tourism preferences due to its low temperature thresholds mostly suitable for general sightseeing activities (Gomez-Martin 2005; Scott et al. 2008). Nevertheless, TCI remains a widely used index for tourist perceptions of climate suitability.

In addition, autumn tourism will be negatively affected by warming in Cyprus. All areas of Cyprus are classified as "good" compared to "very good" in the control period. On the other hand, winter tourism (sightseeing, sport tourism etc.) is anticipated to be benefited by warmer climate. Specifically, during winter, almost all areas of Cyprus are expected to be classified as "good" in the distant future compared to "acceptable" in the reference period. In addition, the warming will continue to benefit spring tourism providing "very good" conditions for all tourist activities.

Overall in the future, the adverse effect of climate change in TCI will be more pronounced during summer when the greatest reduction will be marked, followed by a smaller reduction during fall, while in winter the change in TCI will be positive and in spring there will be no significant change. Subsequently, a shift in tourist's preferences before and after summer due to the improved weather conditions in Cyprus could take place, thus alleviating the tourist's displeasure due to the extensive warming during summer. Additionally, the likely reduction in tourism during the hotter months may be compensated by the diversification of the tourism product to less climate-sensitive activities (Scott et al. 2008) in order to reduce the tourism seasonality effect.

However, this could also result in a northward shift of Cyprus' summer tourism flows for seaside holidays to other countries with cooler climates which will still provide appropriate climatic conditions. To enhance adaptive capacity toward this impact, it is recommended to take action to combat the emerged competitiveness from other destinations, which will be favored by climate change, like the tourist destinations of the North Sea and Baltic regions and the northern Atlantic coast of Spain, as the Mediterranean region is expected to be gradually affected by particularly high temperatures during summer (Ehmer and Heymann 2008). Most importantly, the greater competitiveness will be faced by countries, the tourism of which is not climate dependent and that is characterized by low seasonality, as for example, the countries that their tourism sectors largely depend on city tourism (e.g., France, Italy).

The Cyprus Tourism Organization (CTO) has undertaken several initiatives toward lengthening the tourist season and diversifying its tourist product, with an ultimate aim to establish Cyprus as an "all year round" tourist destination. In particular, less climate-dependent tourist products are identified and promoted, such as tourist products based on conferences, sports, golf, health, culture, weddings, and honeymoon trips, with the development of the necessary infrastructure and their promotion to the relative target markets (CTO 2011). Currently, the most important share among these products is achieved by conference tourism, which accounts for 6 % of tourism

Table 3 Regions' classification as regards beach tourism attractiveness for control and future period in Cyprus' coastal areas

		ASuB	ASpB	AFB	AWB
Paphos	Control	Very good	Good	Good	Acceptable
	Change	No change	No change	No change	No change
Chrysochou bay	Control	Excellent	Very good	Very good	Acceptable
	Change	No change	No change	No change	No change
Limassol	Control	Excellent	Very good	Very good	Good
	Change	No change	No change	No change	No change
Larnaca	Control	Excellent	Very good	Very good	Good
	Change	No change	No change	No change	No change
Famagusta (Ayia Napa, Protaras, Paralimni)	Control	Very good	Very good	Good	Acceptable
	Change	No change	No change	No change	No change

ASuB average summer BCI, *ASpB* average spring BCI, *AFB* average fall BCI, *AWB* average winter BCI preferences. At this point, it is worth making a special reference to golf tourism, the promotion of which is particularly emphasized in Cyprus, as it constitutes a significant potential market, which could also contribute to the reduction in tourism seasonality. The operation of golf courses implies the consumption of large amounts of water for irrigation which creates conflicts with the sectors of water resources and agriculture, as Cyprus faces significant water stress problems, which are expected to be intensified in the future due to climate change. Therefore, the development of golf tourism is considered a maladaptation measure, unless non-freshwater resources are used for irrigation, such as reclaimed wastewater.

To address the shortcomings of TCI related to beach holidays, we have additionally explored BCI results.

Contrary to TCI outcomes, BCI indicates that the anticipated extreme warming will not adversely affect the Cyprus beach tourism in the distant future. As a matter of fact, any changes will be positive. Although summer is anticipated extremely hot at coastal regions, it appears that in the distant future, it will continue to offer "very good" and "excellent" conditions for tourists to carry out their beach activities. Moreover, "very good" conditions are anticipated for both spring and autumn for beach tourism in Cyprus. Finally, winter tourism seems to benefit since the higher increase in the BCI is anticipated for this period providing "acceptable" conditions for beach tourism at western coastal areas and "good" conditions for southern and southeastern coastal areas.

Overall, from the analysis of both TCI and BCI, it can be concluded that the extreme warming which is projected for the distant future in Cyprus (mainly during the summer) will have adverse impacts on tourism activities such as sightseeing, medical tourism, and alternative tourism. In addition, such tourism activities seem to benefit before and after summer, in other words, during spring and autumn where warming and extreme events will not be so intense. Conversely, regarding beach tourism, this does not appear to be negatively affected by the anticipated warming even during summer. In addition, apart from summer, both spring and autumn are expected to provide very good conditions for beach tourism activities.

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