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Potential impacts of climate change on tourism; a case study for Spain

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Despite an increased scientific understanding of the magnitude and regional variation in climate change in the coming decades, the societal costs of climate change remain difficult to quantify. This is mainly due to uncertainty surrounding future climate change and economic projections, as well as the complexities of linking physical impacts to economic processes. One of the sectors for which it has been particularly difficult to assess the impacts of climate change is the tourism industry. It is nevertheless likely that tourism will be strongly affected by climate change, as many tourist activities are dependent on weather conditions. This paper reviews recent advances in modeling the impacts of climate change on the tourism sector and presents a case study focusing on the impacts of climate change on tourism in Spain, where the tourism sector is particularly vulnerable to climate change.

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Assessing climate change impacts on tourism

Tourism is likely to be strongly affected by climate change. Many tourist activities depend on weather conditions and natural resources and most tourists have a high flexibility to adjust their holiday destinations [1]. The interest in the relationship between weather and climate on the one hand and recreation and tourism on the other started around the 1950s [2]. However, until relatively recently, climate was considered a more or less stable property of destinations. It was assumed that climate could not account for any long-term trends in tourism demand [3]. The climate change projections from the Intergovernmental Panel on Climate Change (IPCC) have led to a renewed interest in the relation between climate and the tourism sector. Particular for the tourism sector is that impacts are determined by climate change at two different sites, that is, in the countries of origin as well as the destination countries.

In recent years, a range of impact assessments has been produced. Some of these studies are global in nature [4•,5], whereas others focus on specific countries [6•] or destination types, such as ski areas [7], parks [8,9], and coastal zones [10•,11•]. Relatively few studies have specifically analyzed the potential impacts of climate change on the numbers of tourists visiting a specific country. Hamilton *et al.* [5] have developed a global model of international tourism, modeling changes in tourist flows (expressed as nights spent) and departures in different countries as a function of demography, income and climate change, using temperature change as indicator for climate change. The work of Hamilton *et al.* [5] was further refined in Hamilton *et al.* [6•], where previously developed models operating at the national scale were downscaled in order to analyze changes at the subnational level in Germany, the UK and Ireland. The resulting tourism demand models combined a climate and an 'all other factors' variable and indicated that an increasing attractiveness of the domestic climate would lead people from these countries to spend more holidays in the home country at the expense of taking holidays abroad.

One of the key aspects in analyzing the impacts of climate change on the tourism sector is expressing the impacts of climate change in a suitable physical indicator that can be used to model the attractiveness of the climate to tourists. Many of these indicators only summarize a single climatic aspect. For example, Hamilton *et al.* [5] uses temperature change as indicator for climate change. Alternatively, a composite indicator capturing a range of relevant climatic aspects can be used. The most commonly used of these indices is the Tourism Climate Index (TCI) developed by Mieczkowski [12]. The TCI incorporates several weather parameters such as temperature, precipitation and wind, and attempts to reflect destination's climate suitability for tourism, assuming that the tourist engages in light physical activities (e.g. sightseeing, shopping and relaxing). It has been widely used in studies examining the impacts of climatic factors including climate change on tourism. For example, Scott *et al.* [13] used the TCI to assess the current distribution of tourism in North America and the implications of climate change on the sector, while Amelung *et al.* [14] and Amelung *et al.* [4•] analyzed the consequences of climate change for tourism in the Mediterranean and at a global scale respectively. Several other indices have been proposed to express the suitability of climate for tourism (e.g. [15,16]), but they have, to date, not been as widely applied as the TCI index.

A second key step is to model subsequent impacts of climate change on tourist flows. A range of studies have addressed the factors driving tourist flows to countries, including such variables as climate, cultural setting, presence of historical sites, level of facilities, distance and travel costs, and so on (e.g. [17]). For example, Lyssiotou [18] examined the demand of the British for international tourism using econometric modeling and Divisekera [19] examined tourism flows between New Zealand, UK, the US and Japan. Maddison [20] estimated the demand function of British tourists with a travel cost method approach, and estimated potential changes in tourist arrivals as a function of climate change, including the variables temperature and precipitation. Morley [21] stresses that, in addition to economic variables, climate and landscape attributes should be included in the explanatory variables for tourism demand.

The state of the art in the field was summarized in the recent report 'Climate change and tourism—Responding to global challenges', commissioned by the United Nations World Tourism Organization (UNWTO), the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) [22••]. The report analyzes the relationship between climate change and tourism, identifying the main impacts in regions and activities and issues of adaptation and mitigation. The report indicates the need for further refinement of existing approaches to study the impacts of climate change including the deployment of models with greater spatial resolution.

Case study for Spain

Scope and objectives

In the following section we illustrate the role climate change can have on tourism by implementing a case study for Spain. The case study combines a number of elements inherent to climate change impact studies, including spatial variations in climate change, linking physical and economic impacts, and modeling societal responses to climate change. The paper also presents two maps indicating changes in the attractiveness of the climate for tourism at the European scale, at present and in 50 years time.

Tourism is of major economic importance in Spain, which has the greatest number of nights spent by foreign visitors of all European countries [23]. Total revenues from tourism amounted to €37 billion or 13% of GDP in 2002 [24]. Furthermore, the sector employs over 2 million people, around 13% of the national work force [24]. Tourists are attracted to Spain for its beaches, its cultural heritage, its varying landscapes and, above all, its pleasant climate compared with that of north-western Europe. The main motivation for 60% of the tourists coming to Spain is to enjoy the sun and beaches [25].

The tourism sector in Spain is vulnerable to climate change because (i) tourism is highly important to its national economy; (ii) temperature increases in most other Mediterranean countries are moderated to a larger extent by the sea; and (iii) source countries for tourists to Spain may obtain a more attractive climate in the future. In this case study, we focus both on climate change in the countries of origin, Spain and the key alternative destination countries in the Mediterranean.

Methods

The case study involves two main steps (i) an analysis of the suitability of the Spanish climate for tourism, at present and in 50 years time, based on existing climate change models and scenarios; and (ii) modeling potential changes in the number of tourists visiting Spain as a function of climate change. Climate suitability was determined using the Tourism Climatic Index (TCI; [12]). High resolution climate change scenarios [1,24] allowed for regional detail in projecting TCI. Monthly tourist flows were modeled using a newly developed log linear model. The baseline for the study is 2004, for which detailed monthly tourism data were available, and the model forecasts tourist flows for the year 2060, based on climate change forecasts for the period 2051–2080. We focus on foreign visitors, who are most mobile in terms of adapting their holiday destination to climate change.

The study analyses the tourism flows to seven regions: five regions in Spain, north-western Europe and the other European Mediterranean countries. North-western Europe is included as the main source of tourists to Spain, and the other Mediterranean countries because they are the main competing tourist destination. The Spanish regions distinguished in the paper are Andalucia, the Mediterranean coast, Central Spain, Northern Spain and the Balearic islands, each with a different climate regime. For each region, climate data were extracted for a city located within the region, assuming that it is representative for the region. For instance, Santander is located on the Atlantic coast, and represents the Spanish northern latitudes with mild temperatures during summer and abundant precipitation throughout the year. The other Spanish regions are characterized by varying levels of temperate, wet winters and hot, dry summers characteristic of the Mediterranean climate. The Canary Islands have not been included in the analysis because there were no climate forecasts available in the grid dataset that we used (see below).

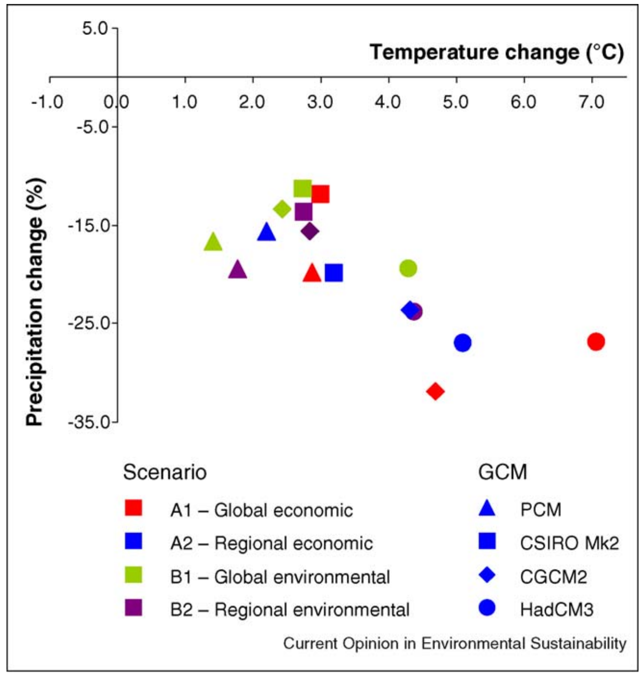
The 'other Mediterranean countries' region includes Italy, Croatia, Greece and the French Mediterranean coast (the French Regions Provences-Alpes-Côte d'Azur, Languedoc-Roussillon and Corsica). For these regions climate change has been analyzed on the basis of the projected changes for Brac (Croatia) and Lesbos (Greece), which have indicative climate regimes for the coastal Central and Eastern Mediterranean, respectively. The north-western European region includes the remainder of France, Belgium, the Netherlands, Denmark and the United Kingdom (UK). The climate for north-western Europe has been approximated by averaging climate data for three seaside resorts: Deauville (France), Scheveningen (the Netherlands) and Blackpool (the UK).

For the climate change projections, we use the TYN SC1.0 dataset, consisting of monthly climate information based on outputs from transient coupled atmosphere-ocean General Circulation Models (GCMs) [24]. The dataset has a spatial resolution of 10 arcmin longitude–latitude (for Europe approximately 16 km × 16 km), and contains mean monthly values for five climate variables from 2001 to 2100. A similar dataset of observed values (referred to as CRU TS1.2) covers 1901–2000 [25]. The dataset variables are temperature, diurnal temperature range, precipitation, cloud cover and vapor pressure. The dataset consists of 16 climate change scenarios representing combinations of four IPCC emissions scenarios described in the Special Report on Emissions Scenarios (SRES; [26]) and four GCMs, covering 93% of the range of uncertainty in global warming in the 21st century published by the IPCC [24]. The climate change scenarios project that Spain will get considerably warmer and drier, especially in summer. Figure 1 summarizes the projected change in Spanish summer climate for the 16 scenarios of the TYN SC1.0.

In order to assess the impact of climate change on tourism in this study the A1 scenario has been used. This scenario assumes favorable socioeconomic conditions for international tourism (i.e. rapid global GDP growth and a globalized world with great mobility [26]). To acknowledge the variation between GCMs and scenarios, the present analysis was performed for A1 scenarios of the extreme HadCM3 (+7.1 °C, −27% precipitation in summer) and of the more modest CSIRO-mk2 GCM (+3.0 °C, −12% precipitation in summer). Together, these two scenarios span most of the variation in climate change projections for Spain (Figure 1). In the rest of this manuscript these GCM scenario combinations will be referred to as HadCM3-A1 and CSIRO2-A1 respectively.

The suitability of the climate for tourism in this case study is expressed using the Tourism Climatic Index (TCI; [12]). Calculation of the TCI requires mean monthly data for maximum temperature, mean temperature, minimum relative humidity, relative humidity, total

Figure 1



Projected changes in temperature and precipitation for Spain, for the four SRES scenarios [26] and four General Circulation Models (GCM) of the TYN SC1.0 dataset [24].

precipitation, total hours of sunshine, and wind speed. Climate data are subsequently evaluated against a benchmark indicating its suitability for tourism based on light activities, such as walking. The scale of each of the indices ranges from −3 (extremely unfavorable) to 5 (optimal). The aggregated TCI ranges from −20 (extremely poor) to 100 (optimal). Following Mieczkowski [12], values lower than 40 indicate unfavorable conditions, scores between 60 and 80 indicate good conditions and TCI values in excess of 80 represent excellent conditions. Mieczkowski [12] provides full details on the conceptual and methodological aspects of the TCI.

The baseline TCI is calculated for the seven distinguished regions on the basis of 1961–1990 climate. Future TCI values for the HadCM3-A1 and CSIRO2-A1 climate change scenarios in 2060 are calculated on the basis of average climate for the period 2051–2080, extracted from the TYN SC1.0 dataset [24]. Because the wind speed and minimum humidity data were not available for the climate change scenarios, wind speed was assumed to be constant and mean humidity was used instead of minimum humidity.

In this paper, tourist flow is modeled by a new, basic model, built on the assumptions that tourism depends on (i) the intrinsic attractiveness of a region (based on landscape, nature, tourism facilities, cultural aspects, proximity to population centers, etc.) and (ii) the climate of the region. The model specification allows accounting for monthly changes in tourism numbers. Tourism flows are expressed as visitor nights spent by foreign visitors. The use of one indicator to capture all non-climate related variables is conform Hamilton *et al.* [6•]. However, in our paper, a log linear relation is used, as it is assumed that tourists choose their holiday destination on the basis of a joint consideration of climatic factors and intrinsic attractiveness. The equation reflects that some substitution between the two is possible, that is, a not so good climate can be partly compensated for by a high intrinsic attractiveness. The equation is presented below:

$$V_{r,m} = \lambda \cdot P \cdot A_r^{\alpha} \cdot C_{r,m}^{\beta} \quad (1)$$

V is the number of visitor nights spent in a region (r) in a specific month (m); P represents potential changes in tourist numbers as a function of increases or decreases in the population number of the countries of origin of the tourists; A is the relative attractiveness of a region for tourism independent of its climate; C is the monthly climate in a specific region, expressed as the TCI factor; λ is a scaling parameter; and α and β are coefficients.

The number of visitor nights (V) spent each month in each of the seven distinguished regions (five Spanish regions, north-western Europe, other Mediterranean) in the year 2004 is derived from statistics. FRONTUR [27] provides monthly visitor rates to each of the Spanish regions, and EU [28] presents monthly visitor rates to other European countries, which have been scaled up to the 2004 figures based on Schmidt [23]. FRONTUR [27] does not distinguish different origins of visitors in the statistics of monthly visitors (expressed as visitor nights spent), and for the paper it has been assumed that there is a *per rato* distribution of visitors from different countries over the different Spanish regions.

The factor P has been calculated on the basis of the SRES-A1 scenario, which includes countrywide projections of demographic changes up to 2100 (IPCC data distribution center; socioeconomic data; URL: http://sres.ciesin.columbia.edu/tgcia/). In order to calculate the impact of demographic changes (P), the growth in the population size of the seven countries each supplying more than 3% of the total visitor numbers to Spain has been considered, on a proportional basis. These countries are the UK, Germany, France, the Netherlands, Italy, Portugal and Belgium that together account for around 80% of the tourist arrivals in Spain [27]. On the basis of population growth in these countries, P would increase from 1.00 in 2004 to 1.07 in 2060 (representing a weighted average 7% growth in population numbers in countries of origin of visitors to Spain in the period 2004–2060). Demographic changes between age classes and different preferences for tourist destinations between age groups are not considered in this study.

The compound variable A is used to indicate the number of tourists visiting a region as a function of all aggregated characteristics of the region besides the region's climate. The variable A is used in the model in order to separate the influence of the attractiveness of a tourist destination's climate from other factors determining a visitor's choice for a specific destination. It represents therefore no specific, measurable physical, but it is retrieved on the basis of regression analysis of monthly visitor nights spent in the seven regions, based on the 2004 figures.

The coefficients α and β represent the preference of tourists for attractiveness versus climatic factors. The model is calibrated (i.e. λ, α and β are calculated) for the current monthly tourist flows to the seven distinguished regions. There is a high spread in the monthly TCI values, which facilitates analyzing the climate dependency of tourism flows. It is assumed that A, and the coefficients λ, α and β are constant over time. This presupposes that the preferences of tourists for cultural, natural and other sights do not change, and that there is no change in the relative attractiveness of areas because of different investments in tourism facilities. Furthermore, it is assumed that there is no change in preference for the monthly timing of the holiday. This latter assumption was required because time preference could not be separately modeled owing to data constraints.

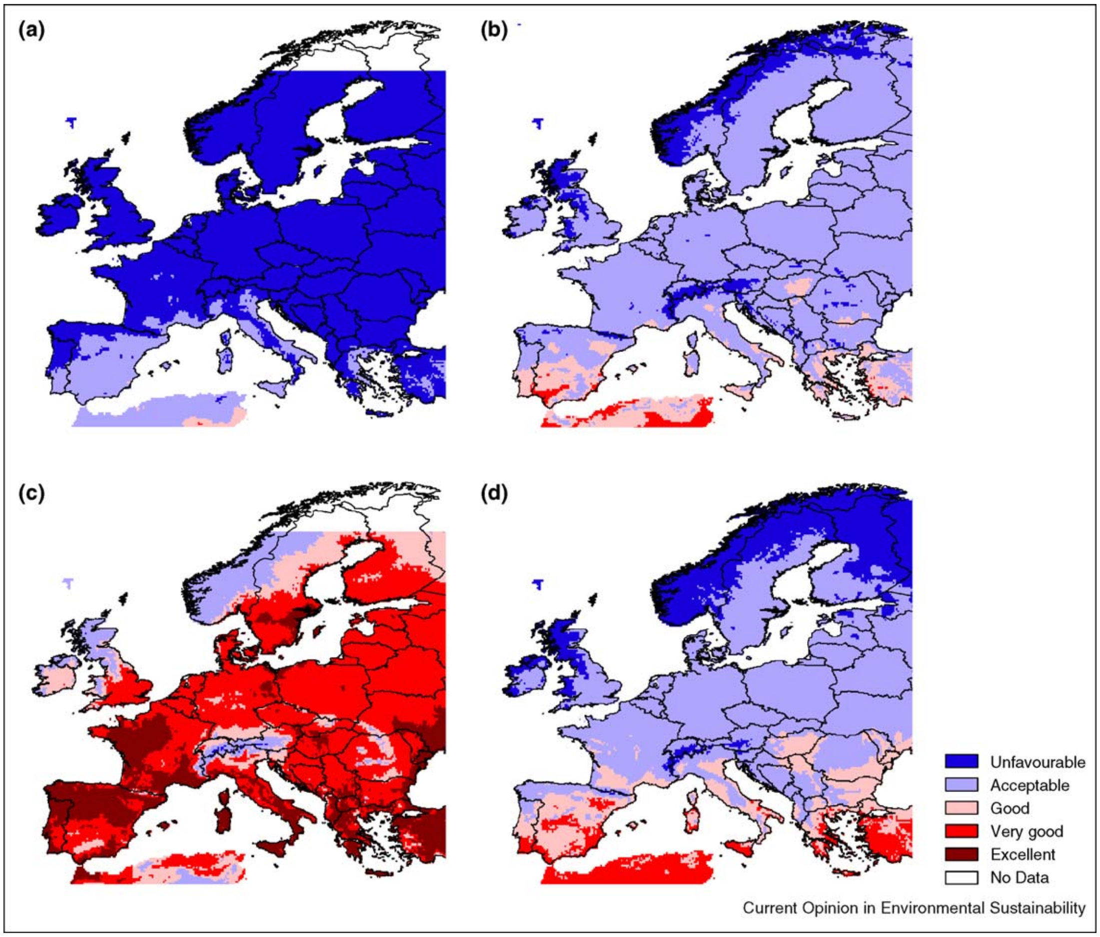
The details of the model and the specified parameters can be obtained from the authors.

Results and discussion

Maps of the TCI under baseline conditions, representing the current climatic conditions for tourism in Europe, are presented in Figure 2. Generally, summer TCI values are high throughout Europe, with the exception of Norway, the northern part of the UK and the Alps. During spring and autumn, high TCI values are only found around the Mediterranean, while in the rest of Europe values remain between 40 and 60 (acceptable) or below that score (unfavorable) in mountainous areas and high latitudes. Finally, winter is dominated by low TCI scores in most of Europe.

The projected winter TCI in 2060 differs little from the present situation (Figure 3). The Mediterranean has acceptable TCI values, while the rest of Europe still has a TCI that is rated as unfavorable for visitors. Spring and autumn depict a situation with very good and excellent conditions in most of the Mediterranean region, with big patches in France and eastern countries with good scores, and northern countries below the threshold of 60 (acceptable). In autumn, there is a tendency towards a good situation distributed homogenously in most of the continent, with fewer areas with better conditions than in the spring.

Figure 2



Maps for the Tourist Climate Index for the 1961–1990 baseline: **(a)** Winter (December–February); **(b)** Spring (March–May); **(c)** Summer (June–August) and **(d)** Autumn (September–November).

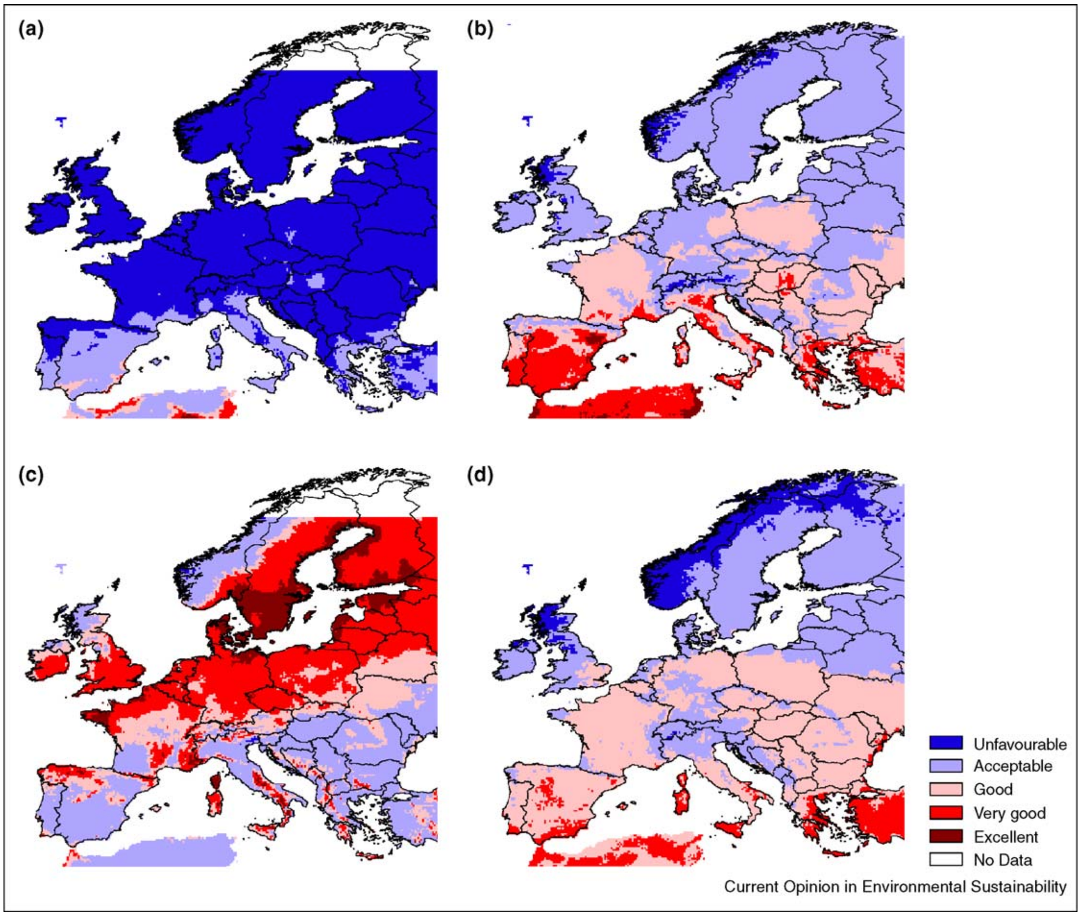
Summer, the most important tourist season, is suffering the most striking change. Conditions in almost the entire Mediterranean region change from the very good and excellent conditions (values above 70 and 80 respectively) to merely an acceptable situation, with scores below the threshold of 60. Conversely, the very good conditions are now located in the northern half of the continent, with excellent scores along the Atlantic coast and even the Baltic Sea. This tendency is consistent the environmental shifts discussed by Metzger *et al.* [29] and confirms the findings of previous research by Amelung and Viner [14].

The current TCI is calculated per month for each of the seven regions, based on calculations of weather characteristics for the period 1961–1990. It is assumed that these characteristics are also representative for 2004, the reference year of the study. For the regions 'North-western Europe' and 'Other Mediterranean', the monthly TCI values of the selected cities have been averaged.

Using the baseline TCI values and 2004 data on visitor nights spent, the model was calibrated for 2004 using a regression analysis. For the baseline year, the model parameters (A, λ, α, β) were significant at $P < 0.001$ ($n = 84$, $R^2 = 0.83$, $F = 411$). The consequences for the tourist flows to Spain in 2060, expressed as nights spent by foreign visitors, are presented for the two selected climate change models in Figure 4. Tourism to north-western Spain would increase during the summer, while the total number of international summer tourists to Spain would sharply decline. From these projected changes, it is clear that climate change will have important impacts on tourist flows in Europe.

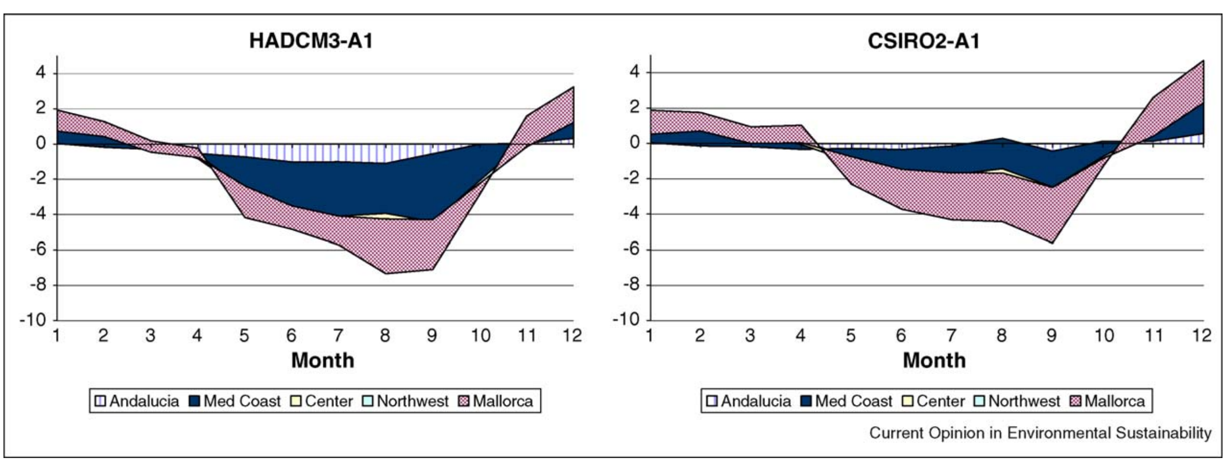
On the basis of the climate changes projected by HadCM3-A1, the total number of tourists visiting Spain is forecasted to decrease with 14% in 2060 compared with 2004. In other words, assuming no change in the preferences of tourists, the total number of tourists to Spain would drop by 14% in the coming 50 years as a

Figure 3



Maps for the Tourist Climate Index for the 2051–2080 time slice and the HadCM3-A1 scenario: **(a)** Winter (December–February); **(b)** Spring (March–May); **(c)** Summer (June–August) and **(d)** Autumn (September–November). HadCM3-A1fi.

Figure 4



Forecasted change in monthly tourist flows to Spain in 2060 (million visitor nights spent).

consequence of climate and demographic changes. In the summer period (June–August), the decline would be 26%, while the decrease in visitor nights spent during the rest of the year would be 6%. These figures account for a 7% demographic growth in the countries of origin of visitors to Spain.

With CSIRO2-A1 the projected changes would be lower: a reduction of 5% in total annual tourists visiting Spain. In summer the loss would 18%, in the remainder of the year there would be a 4% increase in visitor nights spent (also accounting for a 7% demographic growth). A main reason for reduced tourism to Spain under this scenario is that the climate of north-western Europe is becoming much more favorable for tourism, and the destinations in north-western Europe will be better able to compete with Spanish tourism destinations because of better weather conditions compared with the present situation (see also Figures 2 and 3).

Hence, our model projects a 5% (CSIRO2-A1) to 14% (HadCM3-A1) decrease in annual tourist flows. This reduction is consistent with previous assessments of climate change impacts on tourism in the Mediterranean region (e.g. [4•,14,22••]). The results are also, indirectly, supported by the findings of Hamilton *et al.* [6•], who project a decrease in the number of international tourist departures from the UK and Germany owing to climate change. Since both countries are key source countries of tourists visiting Spain, it can be assumed that such a trend would affect tourist flows to Spain. The case study therefore confirms the importance of considering a changing climate in both destination and source countries.

Current limitations and future challenges

The spatial resolution of climate change models is progressively increasing, which is greatly enhancing the possibilities of modeling impacts on tourism, as demonstrated also by our case study for Spain. The current preferences of tourists can be analyzed on the basis of present visiting patterns, which indicate tourists' current preferences for climate versus other factors that determine the attractiveness of an area. However, potential changes in tourist preferences are currently largely ignored in the literature. Such changes may occur as a function of the aging population of source countries for international tourism including most of Europe, and consequently an increasing aversion to (very) high temperatures. In addition, an aging population, or more flexible labor markets, may lead to increased flexibility regarding the timing of holidays.

Also there is a need to adjust the TCI index with regards to specific activities. The index was developed for tourism involving light activities (e.g. sightseeing), with an assumed 'optimal' temperature of around 20–27 °C. However, sightseeing, different sports and beach tourism may have different optimal temperature ranges. For instance, Moreno *et al.* [30] observed that the highest density of visitors was correlated with temperatures above 25 °C. Scott *et al.* [31] found that the ideal temperature for beach tourism differed between nationalities but was on average 26.8 °C. A further specification of the relation between beach tourism and climate is therefore required (see for example [10•,32]).

Besides changes in weather patterns, there are a range of other factors that could potentially cause large changes in tourist flows. For example, increasing fuel prices could make traveling more expensive. In addition, environmental issues, which may be related to climate change, may modify the attractiveness of an area for tourism. A general concern across the Mediterranean and in many other parts of the world is water availability, as water shortages may occur more frequently as a consequence of climate change. For example, water reservoirs are already under pressure in Mallorca [33] and it is therefore questionable if Mallorca would indeed be able to cope with an increase in the flow of tourists (as predicted in the case study model). And finally, sea level rise will affect beaches, although this impact may still be modest in most places in the coming 50 years. A more holistic approach is therefore required to assessing the full range of challenges facing the tourist sector in vulnerable regions.

The adaptation options of the tourist sector to climate change are country specific [22••]. For tourism, adaptation options include, for example, the development of other tourism activities that are less dependent on temperatures or less affected by water shortages, to adjust tourism facilities, and so on (see also [34,35••]). In Spain, potential adaptation strategies could include promoting off-season tourism and developing tourism facilities in north-western Spain, which will retain a favorable climate to tourism in the coming 50 years. Such strategies can be supported by vulnerability assessments, identifying key hazards for specific tourism activities and regions and potential adaptation options [36].

Finally, it is important to note that the outcomes of our study cannot be extrapolated to indicate the full economic costs of a decline in tourism for Spain. The analysis of economic impacts and adaptation options at the national level requires multi-sector, general equilibrium modeling, including simultaneous impacts on other sectors such as agriculture and changes in prices over time. A common challenge to such analyses is to feed the models with an adequate level of detail of the bio-physical impacts of climate change and to deal with spatial variations in impacts, which have been analyzed in the case study. Nevertheless, it is clear that climate change will have major economic implications for the tourism sector, and that Spain will be particularly affected, with potential reductions in tourism numbers of 5–14% in the coming 50 years.

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- • of special interest
- •• of outstanding interest

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The report analyzes the relationship between climate change and tourism, identifying the main impacts in regions and activities and issues of adaptation and mitigation. The report identifies as the main impacts on destinations: (i) direct effects through changes in precipitation patterns, extreme events and increasing temperatures, (ii) indirect consequences due to the environmental change originated by climate change such as loss of biodiversity, reduced landscape aesthetic and sea-level rise, (iii) repercussion of mitigation policies with negative impacts on tourism mobility and (iv) indirect societal effects on the economy and political stability of some nations.

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