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Present and future climate potentials for several outdoor tourism activities in Spain

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ABSTRACT

Spain is one of the leading tourist destinations worldwide, but also a climate change hot-spot. Weather conditions throughout the year have enabled the implementation of alternative outdoor leisure activities to beach-based tourism, helping to alleviate the strong seasonality. Climate is currently a positive resource but it could become a limiting factor for these activities in the future. Here, we assess the present and future conditions by adopting the second generation climate index for tourism (CIT) to quantify the climate potentials for cultural, golf, sailing, hiking, cycling and football activities. Present and future potentials are derived using observed and projected daily meteorological data from the ERA-5 reanalysis and the DMI-HIRHAM5 regional climate model (RCM) included in EURO-CORDEX project, respectively. A quantile–quantile adjustment is applied to the projected CIT data to correct biases at the local scale. Present climate potentials confirm the optimal conditions of the Spanish Mediterranean coast for practicing all the activities in spring and autumn, while in summer, ideal conditions only prevail for sailing. Projections show a general future increase of excellent climate potentials in winter and a general improvement of the weather assets in the northern half of the country during the shoulder seasons, except for cycling and football.

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Climate change; regional climate model; outdoor leisure activities; climate index for tourism; quantile–quantile adjustment; Spain

Introduction

Tourism is a well-known, climate-sensitive, socio-economic sector that entails a wide range of leisure activities worldwide (e.g. sun-sea-sand (3S), cultural, cycling, golf, ski, hiking or sailing). Source markets and tourists' characteristics (e.g. travel motivations and destinations choice), tourism operators (e.g. accommodations, infrastructure design and transport), and destinations are affected by climate variability and change (Scott & Lemieux, 2010). Climate plays a crucial role in determining the suitability of tourism destinations and seriously compromises the natural resources that define destination image and attract tourists (e.g. snow cover and wildlife; Scott et al., 2012). Tourists' thermal comfort is especially influenced by weather conditions. Therefore, climate change could deteriorate the optimal assets for the practice of outdoor activities in certain regions and seasons.

The tourist sector will also likely deteriorate due to the indirect climate change effects on water availability and quality, food costs, energy prices, sea level, beach erosion and fire frequencies (Scott & Lemieux, 2010; Gössling et al., 2012; Scott et al., 2012, 2019). Tourists' water use is

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especially relevant (Gössling et al., 2012; Hadjikakou et al., 2013; Becken, 2014) and the water demand is expected to grow with the increase in the number of tourists, hotels and tourism attractions (e.g. spas, pools and golf courses, Gössling & Peeters, 2015). The combination of increasing temperature and decreasing precipitation will accentuate changes in the water balance of a region. As a consequence, the economy of the countries that crucially depend on tourism might be severely affected (Giannakopoulos et al., 2009). Nevertheless, additional non-related climate aspects determine the frequency and satisfaction of tourist visits, such as socio-economic infrastructures, environmental resources, travel costs and time, political stability, activities and events, culinary attraction, novelty, socialisation, cultural heritage or standard of living in destination countries (Nikjoo & Ketabi, 2015; Kim et al., 2018; Martinez-Garcia et al., 2018; Sánchez-Sánchez et al., 2021). The vulnerability of the tourism sector to climate change has also been analysed using indicators that allow to include developing economies given their relative dependence on tourism (Scott et al., 2019). Six index dimensions integrate those indicators: tourism assets, tourism operation costs, tourism demand, host country deterrents, tourism sector adaptive capacity and host country adaptive capacity to climate change. The environmental assets are of particular interest because they considerably affect the recreation possibilities offered by a place.

The Mediterranean region is one of the hot spots to climate change impacts (Diffenbaugh & Giorgi, 2012; Paeth et al., 2017; Tuel & Eltahir, 2020; IPCC, 2021). In Spain, annual mean temperatures have notably increased with a higher magnitude than the global trend (between 0.1 and 0.2 °C per decade from 1961 to 2006; De Castro et al., 2005; Del Río et al., 2011). The analysis of the tendencies shows that temperatures have experienced increases by almost 2 °C since 1970. Moreover, climate change has brought a substantial redistribution of rainfall and other atmospheric variables (e.g. pressure, cloudiness and wind). For example, decreases in annual precipitation up to 70 mm have been reported in the Iberian Peninsula (Füssel & Jol, 2012), especially in the south of Spain and the Canary Islands. Recent studies using future regional climate model (RCM) projections under the RCP8.5 scenario point out an increase of daily mean surface temperature up to 5 °C in Spain by the late century (Garrido et al., 2020; Carvalho et al., 2021). Concerning rainfall, trends are not uniform across models, but they project a significant decrease in precipitation over Spain in spring and summer. In autumn and winter, accumulated precipitation is expected to slightly increase over some regions of the northwest and northeast, respectively, while a reduction is mostly projected in the southern areas (De Castro et al., 2005; Cardell et al., 2019; Ojeda et al., 2020).

Admittedly, Spain will have to face the challenges imposed by climate change through mitigation and adaptation strategies at local and regional scales for the tourist industry, which is the most important economic sector in terms of income revenues and workers employed. According to the UNWTO highlights (UNWTO, 2018), Spain became the world's second-largest destination in 2017 with 81.8 million international tourist arrivals and 68 $US billion tourist receipts. Moreover, it was the leading European country in foreign visitors' number of overnight stays. Climate change will likely degrade the present favourable conditions for outdoors tourist activities during the Mediterranean summer by 2050, while climatic conditions are expected to improve during spring and autumn (Moreno & Amelung, 2009; Rutty & Scott, 2010; Amengual et al., 2014; Kovats et al., 2014).

So far, the scientific literature has mainly focused on the analysis of climate change impacts in general features of sightseeing (Perch-Nielsen, 2010; Grillakis et al., 2016), beach-based (De Freitas et al., 2008; Hein et al., 2009; Amengual et al., 2014; Rutty & Scott et al., 2015), ski (Yu et al., 2009; Berghammer & Schmude, 2014; Yang et al., 2017; Demiroglu, Turp, et al., 2020) and urban/city tourisms (Scott et al; 2016; Öztürk & Göral, 2018), whereas studies of the climate potential for other relevant tourist activities are still scarce. The rise and consolidation of cultural, sailing, golf, cycling, hiking and to a lesser extent, football tourism in the Mediterranean countries makes necessary the assessment of their present and future climate potentials. Within this

Table 1. Summary of the main socio-economic aspects for each type of tourist activity in Spain.

Tourist activity	High season	Number of visitors per year	Spent money (M€/year)	Most visited region
Cultural	All	14.5 million	15.348	Catalunya, Illes Balears and València
Sailing	Summer	1.562 registrations	NA	Illes Balears, Catalunya and València
Golf	Spring/Autumn	1.6 million	4.640	Andalucía, Castilla y León and Catalunya
Hiking	Spring/Autumn	1/2 million	3.283	Pirineos and Serra de Tramuntana (Mallorca)
Cycling	Spring/Autumn	160,000[a]	2.258	Mallorca, Catalunya, València and Andalucía
Football	Winter	200 teams	NA	Málaga and Cádiz (Andalucía), Murcia and Alacant

[a]Data correspond only to the Mallorca Island.
NA: data not available

framework, we use the second generation Climate Index for Tourism (CIT; de Freitas et al., 2008), originally developed for beach-based tourism evaluation, and subsequently modified by Bafaluy et al. (2014) to rate the climate and weather resources for the six leisure activities of interest. First, the present climate potentials for these tourisms are derived by using daily series of meteorological variables from the fifth-generation European Atmospheric Reanalysis (ERA-5). Secondly, we analyse their possible future evolutions through the same daily meteorological data coming from the DMI-HIRHAM5 RCM, run under the RCP4.5 and RCP8.5 emission scenarios within the EURO-CORDEX initiative (Jacob et al., 2014).

We use the latest version of the Fiala Thermal Physiology and Comfort (FPC; Fiala et al., 2012) model to compute the thermal sensation through the Universal Thermal Comfort Index (UTCI; Błażejczyk et al., 2013). For each tourist activity, aesthetic, physical and thermal facets are combined in the respective weather typology matrix to derive the CIT. The idea is to identify the most suitable climate resources over Spain in the present and to qualitatively check whether they match the observed visitor's peak periods. This procedure serves as a safety test of the implemented methods depending on season and Spanish sub-region. Next, we assess the future changes in the climate potentials across seasons and areas. Prior to this, a statistical approach is applied to correct model biases rather than using the raw RCM outputs (Déqué, 2007). In particular, the quantile-quantile adjustment devised by Cardell et al. (2019) is implemented in order to correct uncertainties in the projected CIT cumulative distribution functions (CDFs) of each recreation activity.

Tourist activities

The 3S tourism represents the gross mass of international visitors coming to Spain during the summer season (35.8 million in 2018). However, weather conditions in combination with the environmental, social and cultural assets enable the development of several outdoor tourism activities, in addition to the well-known cultural and 3S tourism. The practice of leisure activities such as golf, cycling, nautical, hiking and football has become considerably popular during the last years (División de Estadística y Estudios [DEE], 2019; Table 1). They represent a good opportunity for economic development, employment and diversification in rural mountainous, coastal and inland environments in Spain (Lacosta, 2004; Clavé, 2004; Rivera, 2011). The growth and expansion of these activities are expected to gradually reduce the strong seasonality of the beach-based tourism (Barceló et al., 2010; Coll & Seguí, 2014). Nevertheless, climate change will unequally affect tourist activities as they require distinct weather conditions and show quite diverse physical demands (Bafaluy et al., 2014). Briefly, the main socio-economic characteristics of these examined leisure activities are:

Cultural

This kind of tourism is among the preferred activities of the international tourists visiting the country, being the Mediterranean coast the most popular destination (Artal-Tur et al., 2018). In 2019, foreign tourists travelling to Spain for cultural motivations were about 14.5 million (17.3% of international tourist arrivals) with an associated source of income of 15.348 M€ (Table 1; DEE, 2020). Although this tourism comprises a large number of activities, we only focus on these practiced outdoors. The preferred part of the year depends on the region, being spring and summer the most visited seasons in the Mediterranean coast.

Sailing

Spain has 292 marinas with nearly 131,000 moorings for vessels, 68% of which are located in the Mediterranean coast. Mainly in summertime, yacht routes are becoming an attractive nautical activity for tourists who often choice sailing boats to enjoy travelling around Mediterranean Spain. Only in 2019, pleasure boat rentals involved 1.562 new registrations of the total (6.080), after the historical growth of 60% in 2014 (ANEN, 2019). Night spent while sailing increasingly entails accommodation on a fixed site, which is an essential part of the marinas. On the other hand, there has been a recent growth of nautical activities in the north of the country, with 567 companies dedicated to the recreational boating activity in 2019.

Golf

This tourism accounts for more than 1.6 million annual trips to Spain, which is the favourite European destination for golf tourists. The annual expenditure of foreign tourists is estimated at 4.640 M€ (Santaló, 2020). The number of golf courses is around 437. Most golfers stay in hotels (45%) and apartments (17%), while 12% have second residences in Spain. Nowadays, a total of 283,000 houses belong to foreigners who practice this sport. The most demanded months are March, April and October.

Hiking

Spain is the second most mountainous European country after Switzerland and it has 13 protected National Parks, five of them in mountain destinations. Hiking routes are mainly located in highland inland or coastal regions (Gómez-Martín, 2019). There has been a significant growth in the number of kilometres of signposted paths, from 6000 km in the early 1990s to 80,000 km in the present. The international annual demand for hiking tourism is about half million people, being mainly concentrated in the Pirineos and Illes Balears (SGAPC, 2017; Table 1; Figure 1). The averaged direct expenditure in 2018 was of 3.283 M€ (DEE, 2019). Spring and autumn are the most preferred seasons (Martínez-Ibarra et al., 2019). That is, outside of the snow season and avoiding high summer temperatures.

Cycling

This tourism is one of the rising phenomenon within sports recreation in Spain, an activity that moved 2.258 M€ during 2019 (INE, 2020). The Illes Balears leads the number of cyclist visits, with an estimate of approximately 160,000 annual users only in Mallorca. A homogeneous distribution of practitioners is found along the different seasons of the year, although spring and autumn are the preferred seasons.

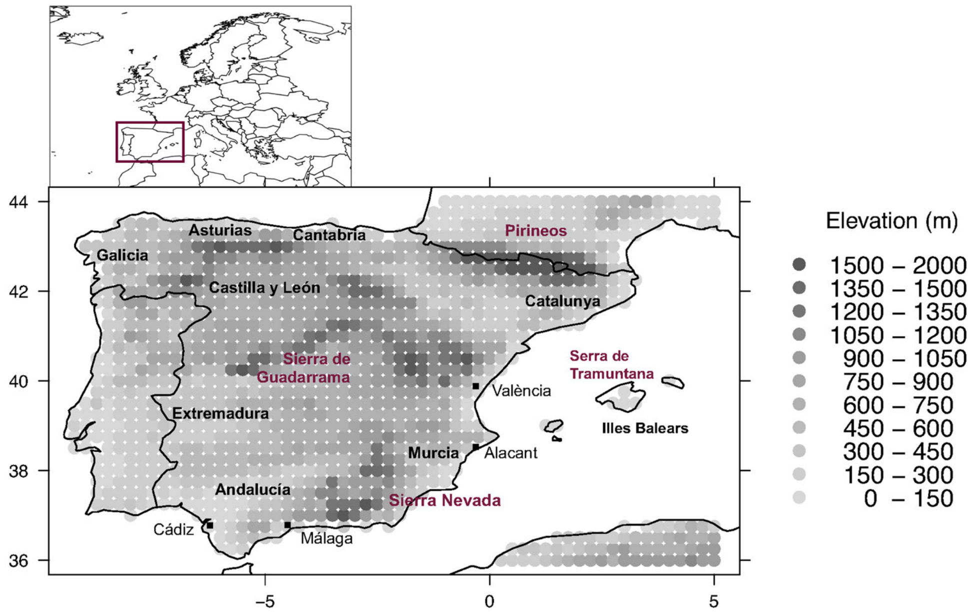

Figure 1. Geographical location of Spain, except Canary Islands, within the European domain (upper left) and geographical location of the principal tourist destinations (bottom). Also shown, in grenade colour, the names of the major topographic features.

Football

Although it is a tourist activity relatively unknown, its practice is notable within the Mediterranean region (Erdŏgdu & Tekeli Yazici, 2013). Semi- and professional football teams of north-western Europe and Asia travel to warmer countries during their winter break to continue training and playing outdoors. More than 200 professional football teams arrive every year to Spain during the winter season. Andalucía is the preferred destination, with the Costa del Sol as the most popular location for “warm-weather training” (Figure 1). Murcia and Alacant are also well-known regions within football tourism.

Database and methods

Climate indices for tourism

The demand and satisfaction of tourists rely, among other factors, on the climate conditions of the place. Leisure activities demand different optimal ranges associated with temperature and other meteorological variables. The assessment of climate change impacts on tourism requires suitable quantitative indicators. Some indices have been particularly designed to evaluate climate attractiveness for tourists. The Tourism Climate Index (TCI; Mieczkowski, 1985) and the subsequently Modified Climate Index for Tourism (MCIT; Yu et al., 2009) have been used to quantify the suitability for general tourism activities by merging seven climatic variables relevant to tourism into a single index. Afterwards, new generation indexes have been developed to analyse different forms of tourism, thus overcoming some limitations of the TCI and MCIT, such as the subjectivity of the rating scales, the weighting system of the climatic variables and the lack of overriding effects. The CIT (De Freitas et al., 2008) and the Holiday Climate Index (HCI; Scott et al., 2016) have been designed based on tourist climatic preferences to represent beach and urban destinations, respectively.

Originally, CIT was developed to rate the weather and climate resources for beach-based tourism along a favourable-to-unfavourable spectrum (De Freitas et al., 2008). From a meteorological perspective, CIT accounts for an optimal range of daily temperatures, precipitation and the effects of cloudiness, short- and long-wave radiation, wind speed, and relative humidity. Together with the temperature, it considers non-environmental aspects related to the activity level and clothing to derive a thermal sensation through a body-atmosphere energy balance. For CIT, the weather comfort perception crucially depends on the combination of three main facets: thermal (T), aesthetic (A) and physical (P; De Freitas et al., 2008).

The aesthetic and physical facets comprise the sky conditions and the influence of precipitation and wind, respectively. These variables are considered two suppressors of the tourist activity above certain thresholds. The thermal aspect requires an index with a physiological basis to describe the thermal effect on the human body of the meteorological and non-environmental variables. The value of this index is expressed as a thermal sensation by using the standard nine-point ASHARE scale that ranges from -4 to -4, with 0 indicating neutral thermal perception (Figure 3; Ansi & Ashrae, 2004). Finally, CIT combines the three facets in a weather typology matrix that ranks tourist comfort from very poor (i.e. CIT $=$ 1: unacceptable) to very good (i.e. CIT $=$ 7: optimal). The exceedance of a certain threshold exerts a dominant influence of a specific facet over the others and modifies the final rating. That is, the integrated effect of some weather conditions is not necessarily the mere addition of its aspects (Figure 2).

Under the assumption that prior foundations of CIT for beach tourism can be generalised to other kinds of outdoor leisure activities, Bafaluy et al. (2014) devised a modified set of weather topology matrices to rate the climate and weather resources for the following leisure activities: cultural, sailing, golf, hiking, cycling and football. Specifically, these authors interviewed local practitioners of each outdoor activity – including advanced amateurs – to estimate limiting weather thresholds for the aesthetic and physical aspects and the most suitable thermal conditions. In summary, they were asked to rate the tourist comfort from 1 (worst) to 7 (best) corresponding to each element of the typology matrices shown in Figure 2. These ratings and thresholds were qualitatively checked and refined based on monthly climatic data at well-known Mediterranean tourist destinations for each activity. Therefore, these generalised typology matrices adjust to different ranges of weather facets according to the specific requirements of each class of tourism.

Herein, the same weather typology matrices are used to assess climate potentials for all these activities across Spain, except that the state-of-the-art UTCI thermal index is considered to compute the thermal aspect of the typology matrices. Note that Bafaluy et al. (2014) used the Physiological Equivalent Thermal index (PET, Matzarakis et al., 2007) and analysed a single tourist destination: Bay of Palma (Mallorca, Spain).

Meteorological inputs

Observed atmospheric variables are obtained from the fifth generation ECMWF atmospheric reanalysis of the global climate (ERA-5; Hersbach & Dee, 2016). ERA-5 has a 30-km spatial resolution and 1-h temporal resolution, starting in 1 January 1950 (Hoffmann et al., 2019). In order to quantify present climate potentials, daily gridded data of 24-h accumulated precipitation and 2-m air temperature, 2-m relative humidity, total cloud cover and 10-m wind speed at 12 UTC are obtained for the 1981–2005 period (present, 25 years). Regarding future projections, we use the RCM simulations at 12-km spatial resolution included in the EURO-CORDEX project and run under the RCP4.5 and RCP8.5 future emission scenarios. This project accounts with more than 14 RCM simulations for the meteorological variables of interest (Jacob et al., 2014).

However, the use of all the available RCMs implies a too high computational cost when numerically deriving thermal sensation. Therefore, we have selected the RCM that better represents the present climate according to the Perking skill score measure (PSS; Perkins et al., 2007). The PSS measures the common area under the observed and simulated probability density functions (PDFs) of the different daily atmospheric variables. It provides a skill score equal to 1 when

(a)

Cultural

ASHRAE scale TSN [T]		Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (>5mm/d) [P]	Wind (≥10m/s) [P]
Extreme heat stress	(+4)	3	3	2	2
Very strong heat stress	(+3)	4	3	3	3
Strong heat stress	(+2)	6	5	4	4
Moderate heat stress	(+1)	7	6	4	4
Slight cold/No thermal stress	(0)	7	6	4	4
Moderate cold stress	(-1)	6	5	4	4
Strong cold stress	(-2)	5	4	3	3
Very strong cold stress	(-3)	4	4	2	2
Extreme cold stress	(-4)	3	2	1	1

(b)

Sailing

ASHRAE scale TSN [T]		Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (>20mm/d) [P]	Wind (<1.5 or ≥15m/s) [P]
Extreme heat stress	(+4)	5	4	3	1
Very strong heat stress	(+3)	6	5	3	2
Strong heat stress	(+2)	7	6	4	2
Moderate heat stress	(+1)	7	6	4	3
Slight cold/No thermal stress	(0)	6	5	4	2
Moderate cold stress	(-1)	5	4	2	2
Strong cold stress	(-2)	4	3	2	1
Very strong cold stress	(-3)	3	2	1	1
Extreme cold stress	(-4)	2	1	1	1

(c)

Golf

ASHRAE scale TSN [T]		Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (>10mm/d) [P]	Wind (≥4m/s) [P]
Extreme heat stress	(+4)	3	2	3	1
Very strong heat stress	(+3)	5	4	3	1
Strong heat stress	(+2)	6	5	4	2
Moderate heat stress	(+1)	7	6	4	2
Slight cold/No thermal stress	(0)	7	6	4	3
Moderate cold stress	(-1)	6	5	3	2
Strong cold stress	(-2)	5	4	3	2
Very strong cold stress	(-3)	4	3	2	1
Extreme cold stress	(-4)	3	2	1	1

(d)

Hiking

ASHRAE scale TSN [T]		Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (>5mm/d) [P]	Wind (≥10m/s) [P]
Extreme heat stress	(+4)	3	3	2	2
Very strong heat stress	(+3)	4	3	3	3
Strong heat stress	(+2)	6	5	4	4
Moderate heat stress	(+1)	7	6	4	4
Slight cold/No thermal stress	(0)	7	6	4	4
Moderate cold stress	(-1)	6	5	4	4
Strong cold stress	(-2)	5	4	3	3
Very strong cold stress	(-3)	4	4	2	2
Extreme cold stress	(-4)	3	2	1	1

(e)

Cycling

ASHRAE scale TSN [T]		Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (>10mm/d) [P]	Wind (≥8m/s) [P]
Extreme heat stress	(+4)	3	2	3	2
Very strong heat stress	(+3)	4	3	3	2
Strong heat stress	(+2)	6	5	4	2
Moderate heat stress	(+1)	7	7	4	3
Slight cold/No thermal stress	(0)	7	6	4	2
Moderate cold stress	(-1)	6	5	3	2
Strong cold stress	(-2)	5	4	3	1
Very strong cold stress	(-3)	4	3	2	1
Extreme cold stress	(-4)	3	2	1	1

(f)

Football

ASHRAE scale TSN [T]		Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (>10mm/d) [P]	Wind (≥8m/s) [P]
Extreme heat stress	(+4)	3	3	2	2
Very strong heat stress	(+3)	4	4	3	2
Strong heat stress	(+2)	6	6	4	3
Moderate heat stress	(+1)	7	7	5	4
Slight cold/No thermal stress	(0)	7	7	4	3
Moderate cold stress	(-1)	6	6	3	2
Strong cold stress	(-2)	5	5	2	1
Very strong cold stress	(-3)	4	4	1	1
Extreme cold stress	(-4)	3	3	1	1

(g)

CIT						
1	2	3	4	5	6	7
Unacceptable			Acceptable		Ideal	

Figure 2. Weather typology matrices for: (a) cultural, (b) sailing, (c) golf, (d) hiking, (e) cycling and (f) football tourist activities. [T], [A] and [P] refer to the thermal, aesthetic and physical facets, respectively. Also shown the CIT rating scale in (g).

the simulated and observed PDFs are identical and 0 when there is no overlap. Specifically, a comparison for a historical 25-year period of calibrated simulation data against observations was performed by Cardell et al. (2019). This analysis revealed the highest overlap for the DMI-HIRHAM5 simulations: PSS values ranged between 91.0 and 95.2%. Once this RCM is selected, we assess climate change impacts by late twenty-first century (2071–2095) under RCP4.5 and RCP8.5 scenarios. Note that the daily-simulated data of the atmospheric variables are bilinearly interpolated from the four nearest grid-points to the ERA-5 mesh covering the entire Iberian Peninsula (Figure 1; Akima, 1978, 1996).

Physiological model

Thermal sensations are computed through the UTCI by using the advanced multi-node dynamic FPC model version 5.4.2 of thermo-regulation and human comfort (Fiala et al., 2012). The FPC model is a mathematical framework of nested models that can predict human thermo-physiological and calorimetric responses to outdoor weather conditions. It presents two components that interact: the active and the passive systems. The former component simulates the thermoregulatory responses of the central nervous system. The latter system is a multi-segmental and multi-layer representation of the human body that simulates the dynamic transfer of heat and mass within the body and at its surface.

The UTCI represents the equivalent temperature of a reference environment causing the same physiological strain on the human body as obtained for a typical/average (unisex), slowly walking (2.3 met) person exposed for 2 h to the conditions of the actual environment (Błażejczyk et al., 2013). In the present work, this index is used to obtain the thermal facet of the weather conditions regarding tourist activities by converting it into the standard nine-point ASHRAE scale (Table 2 and Figure 2; Ansi & Ashrae, 2004). We derive a UTCI characteristic of morning-afternoon hours by using the following daily meteorological parameters as boundary conditions: 2-m air temperature, 10-m wind velocity, 2-m relative humidity, mean radiant temperature, mean incident direct and diffuse solar radiation and mean sun elevation angle. Different adaptive clothing and activity levels are selected depending on tourism (Table 3). For most activities, simulations consider a person wearing light clothing and the following physiological features: unisex, 1.70 m tall, 71.4 kg weight, a skin surface area of 1.83 m^2 and 22.6% fat content. Pre-exposure conditions start from a thermo-neutral physiological state of the body, a reclining (nude) human exposed to an environment of 30 °C. Next, the simulated person is exposed to the boundary conditions for 2 h according to the original definition of the UTCI. Finally, the daily thermal sensation is combined with the aesthetic and physical facets by using the weather typology matrices so as to derive the CIT for each tourist activity (Figure 2; Bafaluy et al., 2014).

Quantile–quantile (Q–Q) adjustment

The analysis of the future climate potentials for tourism requires reliable projections of climatic variables. However, RCM outputs still present important biases that need to be statistically corrected to obtain suitable results of the simulated climatic system (Štěpánek et al., 2016). Among correction methods, the application of Q–Q adjustment techniques to the simulated RCM improves the representation of the future climates – both mean regime and extremes – at the local scale (e.g. Boé et al., 2007; Déqué, 2007; Cardell et al., 2019, 2020). This is because the Q–Q technique identifies and amends the deviations between the control simulation and observed baseline CDFs and incorporates to the simulated future these same corrections.

In our specific case, the Q–Q adjustment procedure described in detail in Cardell et al. (2019) is applied between the 25-year present (control; 1981–2005) and future simulated (2071–2095) time-slices, yielding the calibrated future CDFs (see the schematic idea in Figure 3). Briefly, this method consists of a non-parametric function that, operating quantile by quantile, amends mean, variability and shape errors of the continuous CIT CDF for each type of tourism. The discrete CDFs of daily CITs are first transformed into continuous distributions using a stochastic transformation centred on each discrete value. The non-parametric function is expressed as the following relationship between the *i*th quantiles of the continuous CDFs (Figure 3): *pi* (projected or future calibrated), *oi* (control observed or baseline), sfi (raw future simulated) and sci (raw control simulated).

$$p_i = o_i + \alpha\bar{\Delta} + \beta_i(\Delta_i - \bar{\Delta})$$

The variation in the mean state $\bar{\Delta}$ is modulated by a scale factor α, while the change in variability and shape $(\Delta_i - \bar{\Delta})$ is calibrated by a form factor βi (see Cardell et al., 2019 for further

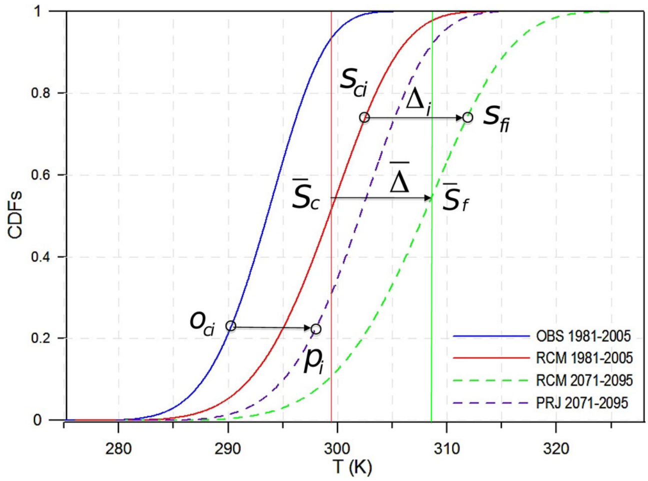

Figure 3. Graphical sketch of the Q–Q adjustment for the hypothetical example of a temperature variable. The CDFs of the mean temperatures are shown for the observed control (OBS 1981–2005), raw control (RCM 1981–2005), and future simulated (RCM 2071–2095) and calibrated or projected (PRJ 2071–2095) data. The statistical correction is illustrated between the 25-year past (1981–2005) and future (2071–2095) periods. Vertical lines denote mean values for raw control ($\bar{S}_c$) and future ($\bar{S}_f$) simulated periods.

Table 2. Thermal stress category as function of the UTCI equivalent temperature.

UTCI (°C) range	Stress category [ASHRAE]
Above +46	Extreme heat stress [+4]
+38 to +46	very strong heat stress [+3]
+32 to +38	Strong heat stress [+2]
+26 to +32	Moderate heat stress [+1]
+9 to +26	Slight cold/no thermal stress [0]
+9 to −13	Moderate cold stress [−1]
−13 to −27	Strong cold stress [−2]
−27 to −40	Very strong cold stress [−3]
Below −40	Extreme cold stress [−4]

Table 3. Thermal and physiological parameters used for setting-up the FPC model depending on each tourist activity.

	Cultural	Sailing	Golf	Hiking	Cycling	Football
Clothing insulation (clo)	0.5	0.3	0.4	0.3	0.3	0.3
Activity level (met)	2.0	2.5	2.5	3.0	4.0	5.0

Thermal insulation (in clo) and metabolic rates (in met) are assessed according to ASHRAE standards. (Note that 1Clo = 0.155 m^2K/W and 1met = 58.2 W/m^2).

details). Note that after the calibration, the continuous CIT CDFs are transformed back into discrete distributions.

Results and discussion

Present climate potentials

Prior to the assessment of the future climate potentials for the different outdoor tourism activities, we analyse the distribution of the present climate resources. The idea is to qualitatively check whether the spatial and temporal distributions of the present climate potentials match the available socio-economic information for each tourist activity, season and Spanish sub-region (Table 1). A seasonal exploration of the CIT distributions is carried out by studying the absolute frequencies of acceptable and ideal conditions. To this end, the following categories are used to simplify discussions: CIT $= 1-3$: unacceptable; CIT $= 4-5$: acceptable and; CIT $= 6-7$: ideal

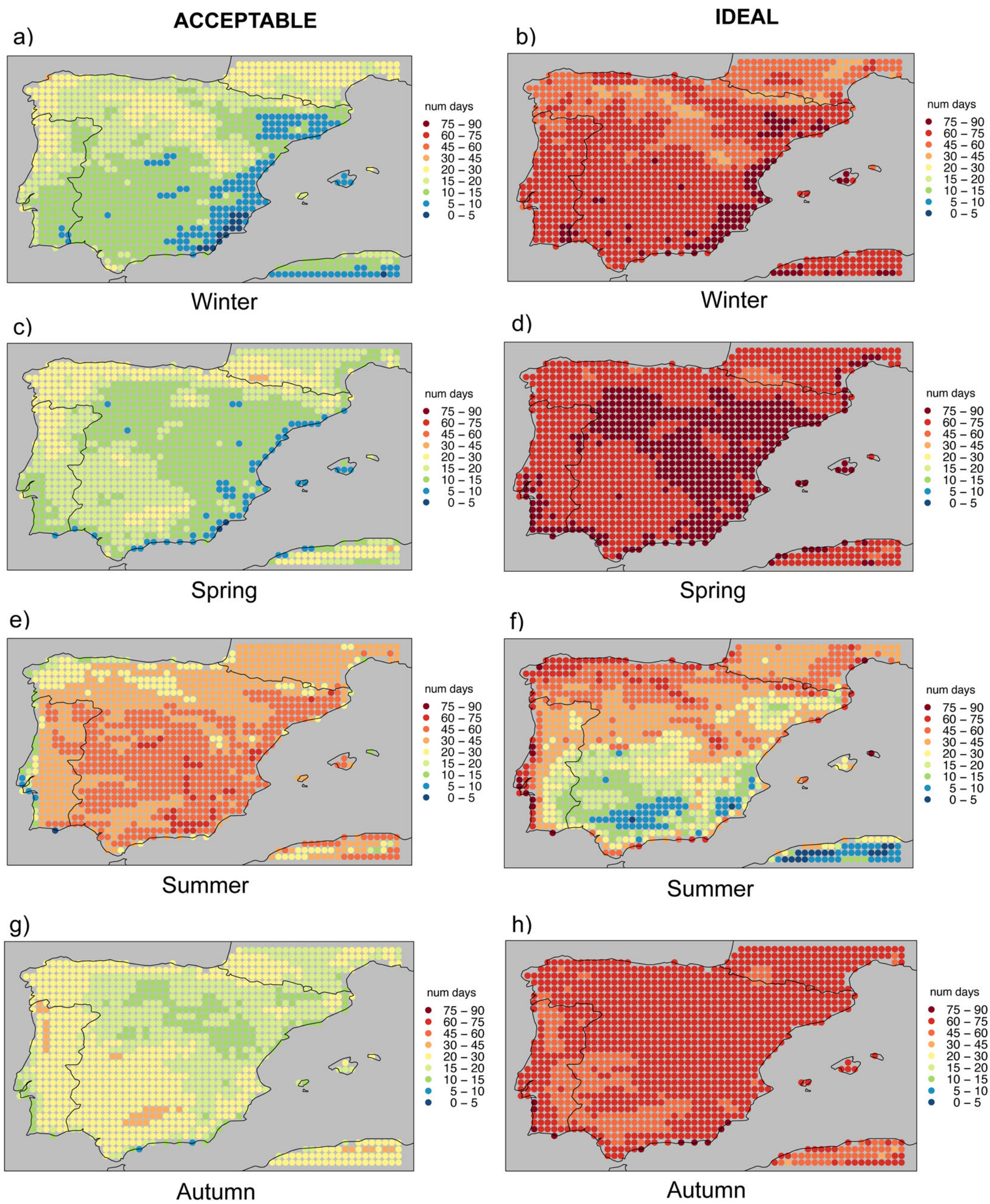

Figure 4. Mean seasonal frequencies of present (1981–2005): (a) winter acceptable, (b) winter ideal, (c) spring acceptable, (d) spring ideal, (e) summer acceptable, (f) summer ideal, (g) autumn acceptable and (h) autumn ideal conditions of the climate resource for cultural tourism in Spain. Absolute frequencies are expressed as number of days.

conditions, respectively (De Freitas et al., 2008; Figure 2(g)). Note that seasons are defined as: winter (DJF), spring (MAM), summer (JJA) and autumn (SON). Results are discussed for the high attendance period and shoulder seasons for each tourist activity (Table 1).

Cultural

In winter, excellent conditions prevail, as more than half of the seasonal days are rated as ideal (Figure 4(a,b)). Optimal climate conditions are over 75 days (d) in Mediterranean Spain. Central

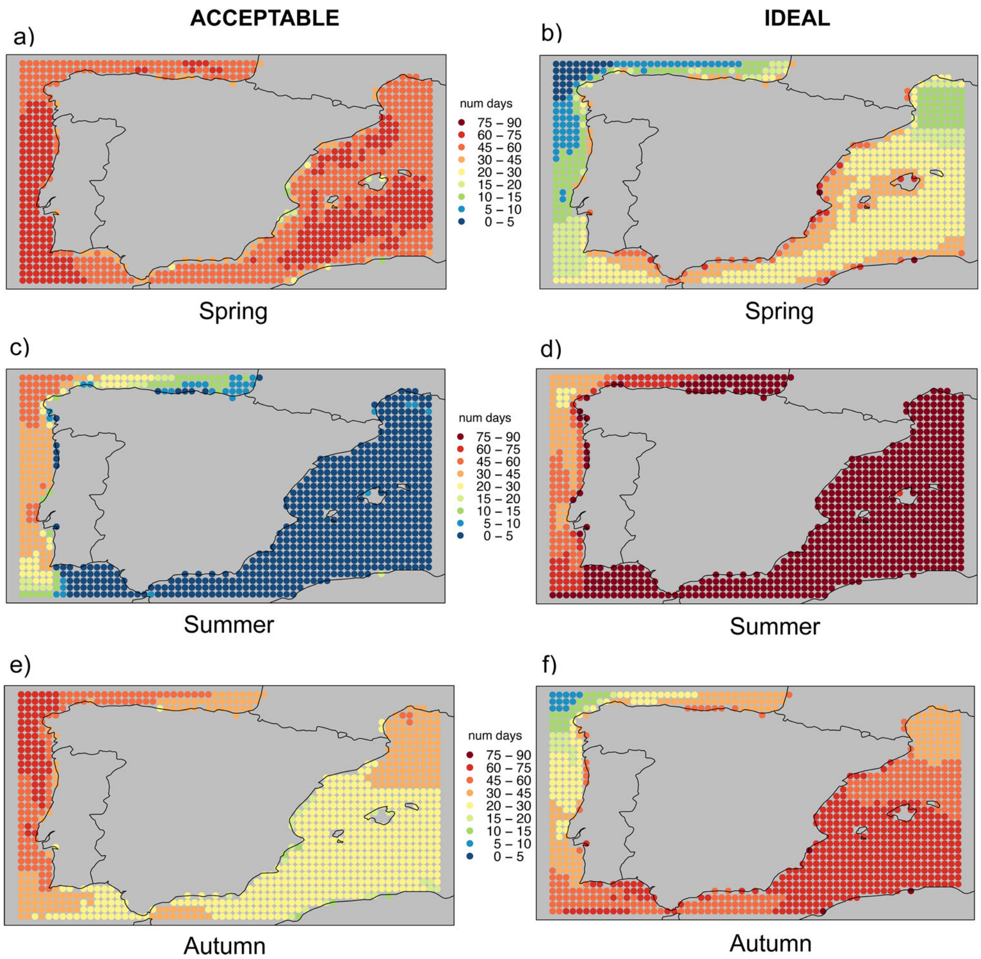

Figure 5. Mean seasonal frequencies of present (1981–2005): (a) spring acceptable, (b) spring ideal, (c) summer acceptable, (d) summer ideal, (e) autumn acceptable and (f) autumn ideal conditions of the climate resource for sailing tourism in Spain. Absolute frequencies are expressed as number of days.

regions present ideal conditions (above 60 d/season) in agreement with Tang (2013), where the inland city of Madrid is characterised by an excellent HCI-Urban rating. However, winter is the period of the year with the lowest number of tourists visiting Madrid (Millán López & Fernández García, 2018). According to the CIT rating, spring is the most optimal season for cultural practitioners (Figure 4(c,d)). This output agrees with the social and economic data recollected by the different governmental agencies (Table 1). The present spatial distribution of the climate potential for cultural tourism also matches with the most demanded geographical areas, in spite of not accounting for other non-climatic related but relevant factors (Figure 4(d)). Note that the excellent climate conditions dominate above 2 months in the Mediterranean coasts and many central regions during spring.

In summer, the distribution of the present climate resources for cultural activities is quite heterogeneous. Acceptable conditions prevail over most of Spain (Figure 4(e)). According to Tang (2013), central areas such as Madrid mostly present good conditions for practising cultural tourism. The northern regions exhibit higher frequencies in optimal than acceptable conditions, while southern areas show a clear degradation of the ideal conditions (Figure 4(f)). The summery northward shift of the high subtropical pressure belt results in high temperatures and persistent hot conditions, especially in the southeastern areas. According to the weather typology matrix,

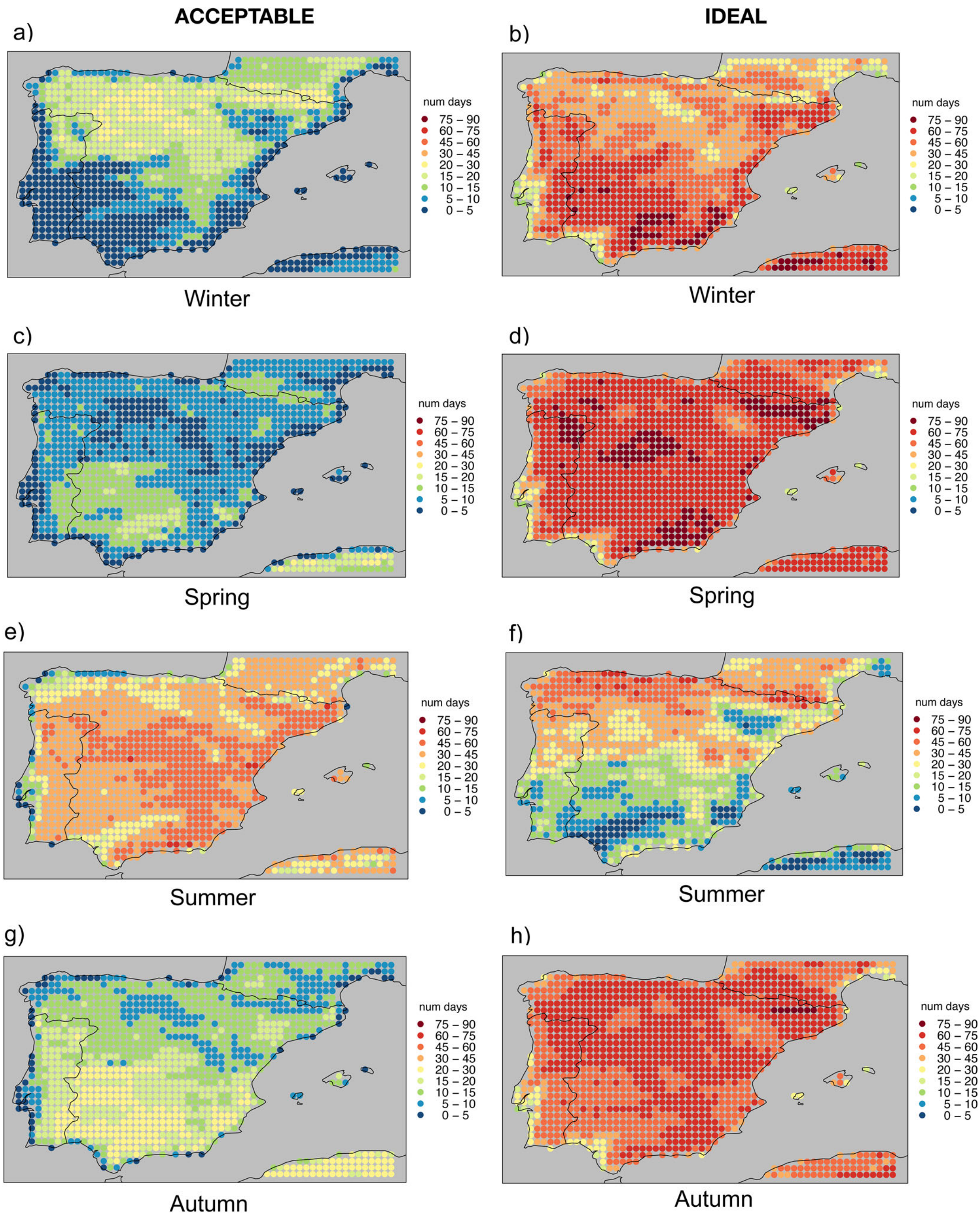

Figure 6. As in Figure 4, but for golf tourism.

the thermal aspect in these regions would be a definitive overriding factor when rating climate potential (Figure 2(a)). The predominantly acceptable conditions found along southeastern Spain contrast with the results of Demiroglu, Saygili-Araci, et al. (2020), who rated these areas with an ideal HCI-Urban index during the summer. Results in autumn show that excellent climate conditions dominate in most of Spain, with ideal absolute frequencies ranging between 45 and 60 d (Figures 4(g) and 4(h)). The distribution of the CIT in central regions indicates that spring and autumn are the most favourable seasons for the practice of cultural tourism, in line with previous findings by Millán López and Fernández García (2018) about cultural and city tourism in Madrid.

Sailing

According to CIT rating, sailing recreation is practiced under acceptable conditions for more than half of the days in the Mediterranean and Atlantic coasts during spring (Figure 5(a)). In contrast, the ideal absolute frequencies exhibit a very different distribution between both maritime regions. While excellent climatic conditions prevail in the Mediterranean and African coastlines, those are residual in the central and northern Atlantic coastlines (Figure 5(b)). The latter regions are often influenced by the passage of Atlantic cold fronts with associated strong winds. Wind velocities above 15 ms^{-1} override the remaining facets, resulting in a very poor tourist comfort (Figure 2(b)). As result, more than 20 d per season are rated as unacceptable in the northernmost areas (not shown).

Present climate potentials show excellent perceptions in summer ($>$ 75 d). Only the western shores present a balance between the acceptable and ideal conditions (30–60 d; Figure 5(c,d)). During this season, the prevalence of high pressures brings favourable conditions for sailing recreation (hot and dry weather, light-to-moderate winds and abundant sunshine). Sea breeze regimes are generated as result of the air temperature differences between the sea and inland of the Spanish Mediterranean region (Ramis & Romero, 1995; Azorín-Molina et al., 2011; Grau et al., 2021). These optimal conditions agree with the popularity and high demand for sailing in summer. Furthermore, the suitable tourist comfort obtained in the north of Spain would explain the recent growth in the number of companies dedicated to this sector.

The extension of the high-demand season to autumn would be possible for the central part of the Spanish Mediterranean region in the present, since ideal absolute conditions prevail (Figure 5(e,f)). Particularly, the Balearic Islands feature very optimal conditions ($>$60 d), thus agreeing with the results obtained by Coll and Seguí (2014) about the climate potential of nautical activities in the Mallorca island. However, these do not exceed half of the days on the northern Mediterranean coastlines. The contrast of the Azores anticyclone and low-pressure systems moving towards north-east Europe can generate intense north-western winds along the Rhone Valley that can affect negatively sailing tourism in the Gulf of Lion (Font, 2000). Finally, the Atlantic coastlines feature acceptable conditions over half of the days.

Golf

In winter, ideal absolute frequencies for golf recreation are predominant in the south-eastern and Mediterranean Spanish regions (above 60 d; Figure 6(a,b)). These areas are characterised by mild-winters, abundant sunshine and irregular precipitation. In the central and northern areas, almost half of the days are excellent while 15–30 d per season exhibit acceptable conditions. A very poor tourist comfort is found in the north (not shown). Colder temperatures, abundant cloud cover and frequent rainfall affect northern Spain as a consequence of the frequent and strong influence of extra-tropical weather systems. Excellent climatic conditions prevail across the country in spring. (Figure 6(c,d)). Thus, CIT ratings agree with the observed high demand for golf tourism during the months of March and April (Table 1). Mild temperatures and sunshine at noon are associated with the seasonal shift of the high-pressure systems northwards, fostering the practice of golf. The presence of a large number of golf courses in eastern Andalucía, Castilla y León and Catalunya is fully justified as excellent climatic conditions are over 75 d per season.

In summer, a transition from optimal to acceptable absolute frequencies occurs. While acceptable conditions for playing golf dominate in the central and eastern areas of Spain, optimal conditions prevail in the northern regions (Figure 6(e,f)). In contrast, ideal absolute frequencies are residual in the southernmost regions: Too high maximum temperatures negatively affect the comfort of golfers, resulting in a thermal sensation of extreme heat stress (Figure 2(c)). For instance, the monthly average maximum temperatures in summer on the island of Mallorca exceeds 25 °C, which is the maximum optimal threshold for the practice of golf according to the results stated in Coll and Seguí (2014). On the other hand, autumn is the second most suitable season for playing golf, according to the high number of ideal days across the country. The

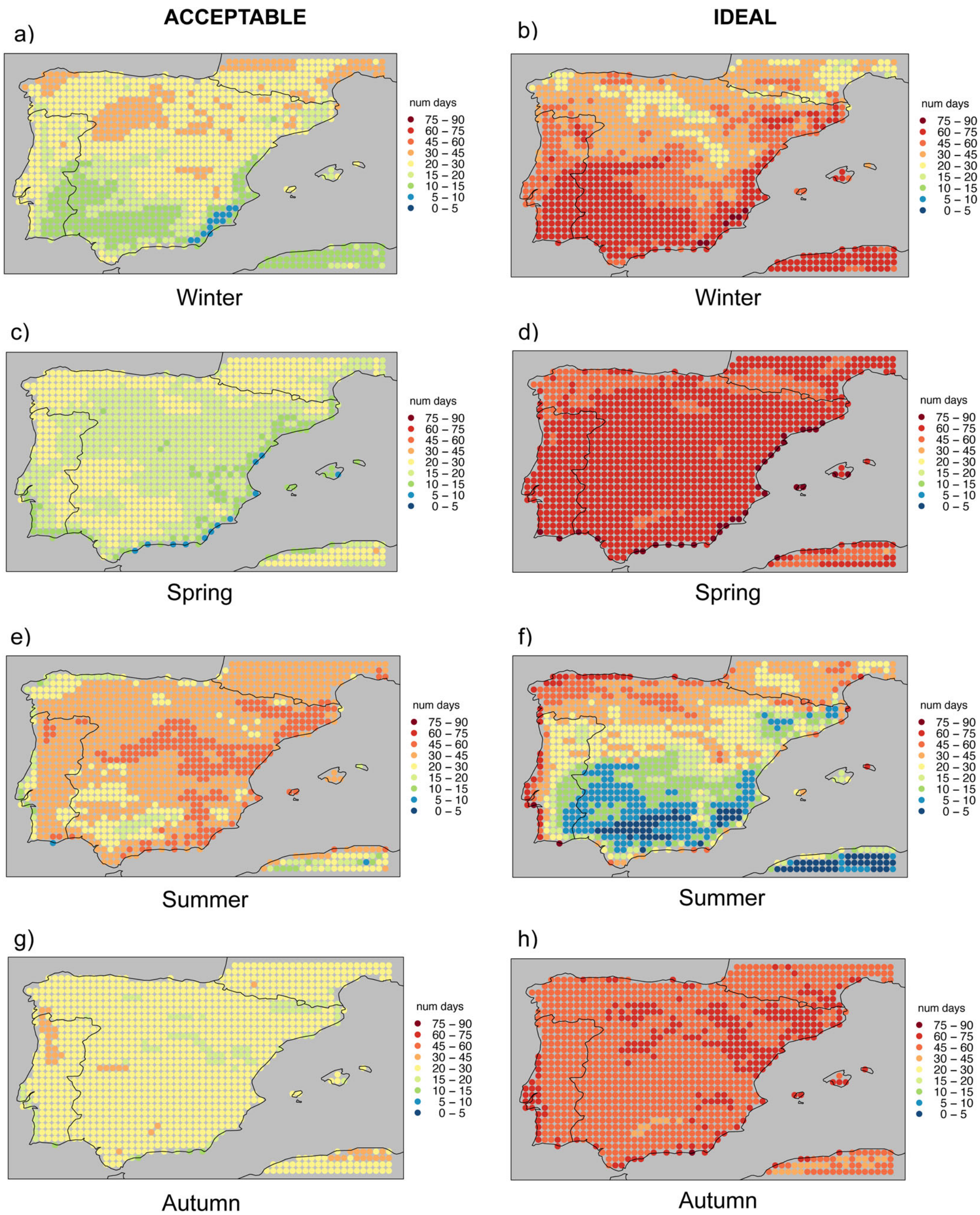

Figure 7. As in Figure 4, but for hiking tourism.

spatial distribution of the absolute frequencies is quite similar to that of spring, but the excellent climatic conditions are lower, resulting in a higher proportion of acceptable days throughout the country (Figure 6(g,h)).

Hiking

Optimal climatic conditions prevail in the southern and eastern parts of Spain during winter, ranging from 45 to 75 d per season (Figure 7(a,b)). The Spanish Mediterranean region is less influenced by the

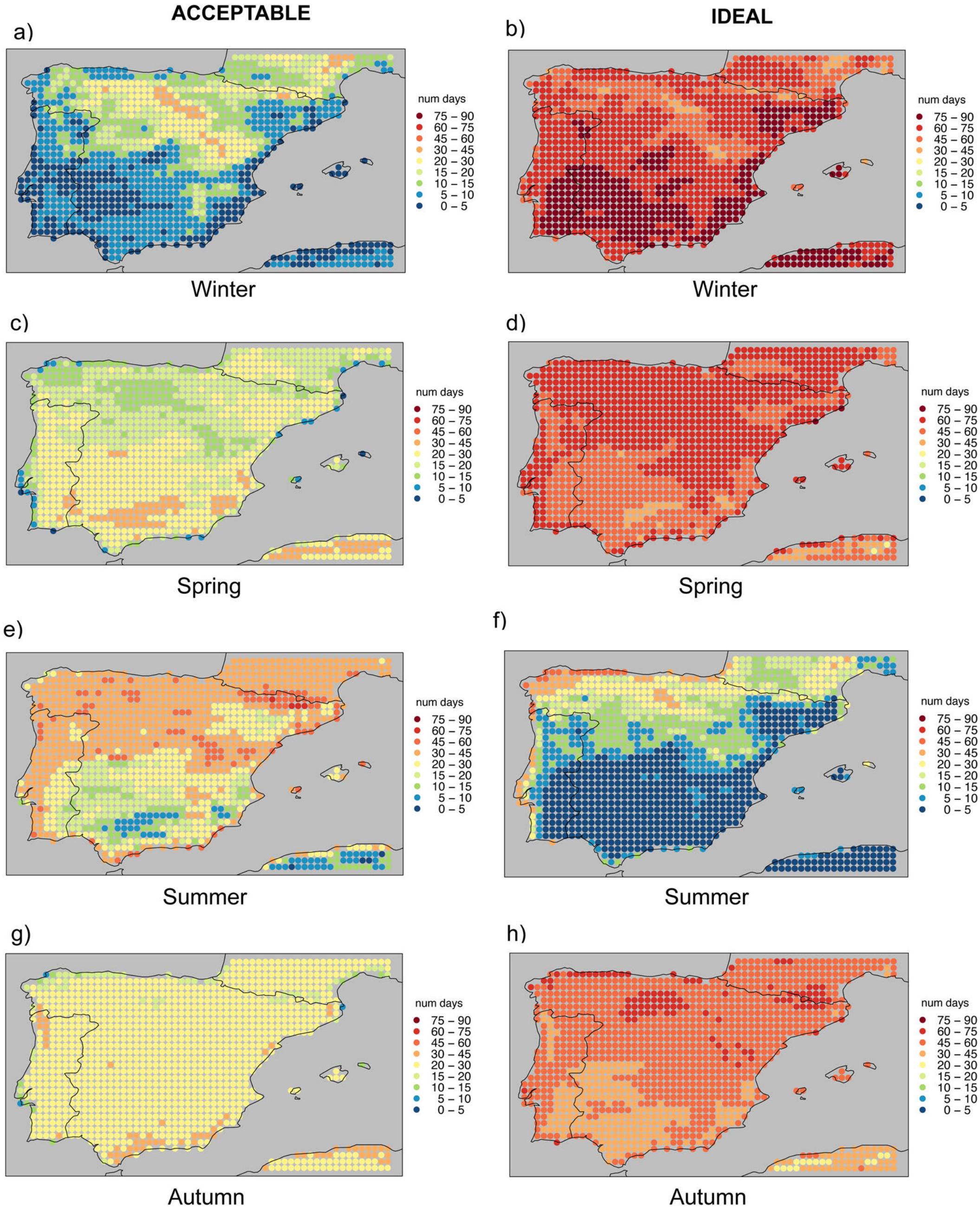

Figure 8. As in Figure 4, but for cycling tourism.

passage of Atlantic low-pressure systems, as being sheltered by its complex topography (Romero et al., 1998; Romero, Ramis, et al., 1999; Romero, Sumner, et al., 1999). Despite this passage, there is a balance between the number of acceptable and unacceptable days in the central and northern regions (10–45 d). In spring, acceptable conditions are residual and barely achieve 1 month (Figure 7(c)). Tourist comfort is excellent over the country, especially in the Spanish Mediterranean region during spring (between 60 and 90 ideal days; Figure 7(d)). This result confirms that CIT also performs well and matches the peak demand of the hiking tourist activity in terms of the present climatic potential as a relevant factor for promoting this type of outdoor sport (Table 1). In fact, spring is the

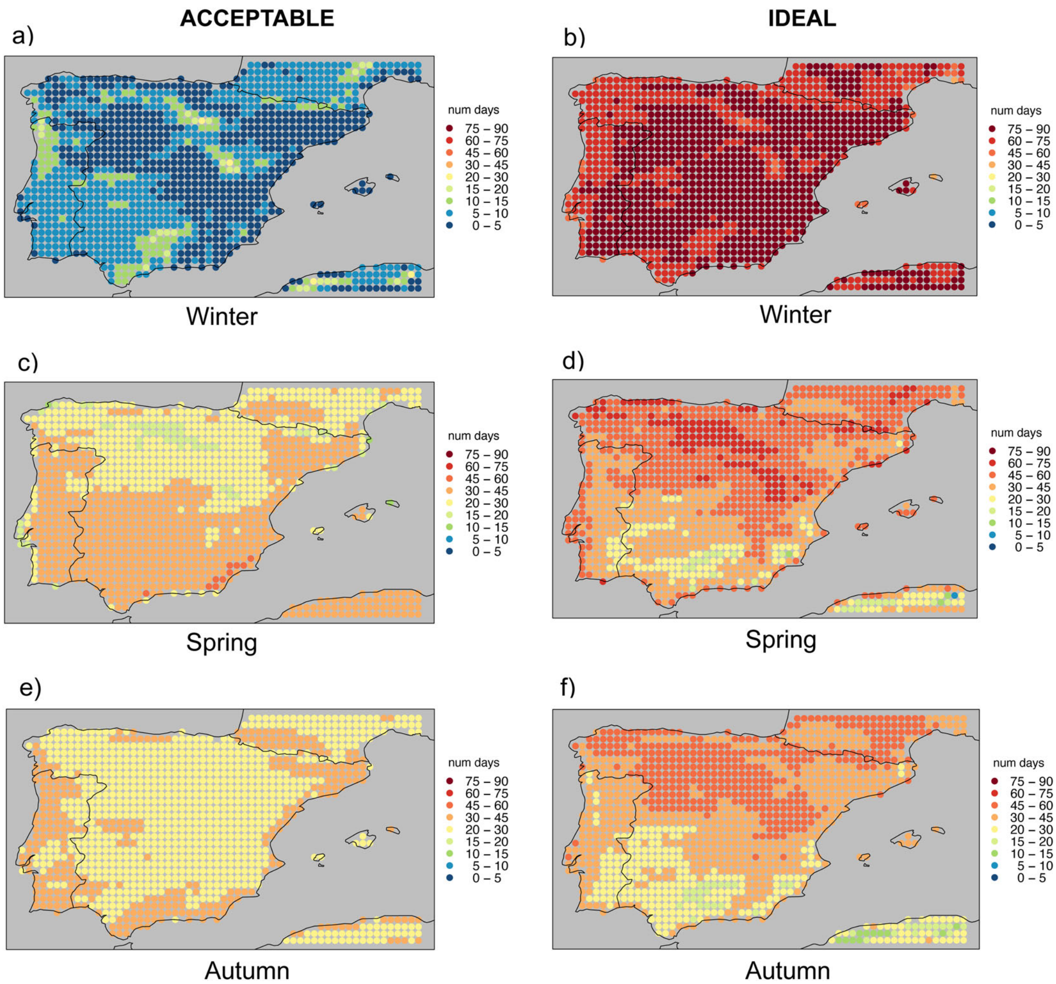

Figure 9. Mean seasonal frequencies of present (1981–2005): (a) winter acceptable, (b) winter ideal, (c) spring acceptable, (d) spring ideal, (e) autumn acceptable and (f) autumn ideal conditions of the climate resource for football tourism in Spain. Absolute frequencies are expressed as number of days.

best season for practising hiking in Spain followed by autumn, according to the climate-tourism preferences recollected by Martínez-Ibarra et al. (2019).

Tourist comfort in summer is mostly acceptable in central and east Spain (between 45 and 60 d per season; Figure 7(e)), while unacceptable conditions prevail in interior lowlands of Andalucía (not shown). In contrast, optimal conditions predominate along the northern coast (more than 30 d; Figure 7(f)), gradually reducing southwards, with barely 5 ideal days per season over Andalucía.

In autumn, acceptable frequencies are higher and more spatially uniform than in spring (20–30 d per season; Figure 7(g)). The spatial distribution of absolute frequencies shows that the areas with the highest number of ideal days are also the most popular mountain destinations for tourists (e.g. Pirineos, Sierras de Guadarrama and Nevada, with 60–75 d per season; Figure 7(h); Gómez-Martín, 2019).

Cycling

Nowadays, this type of tourism has a rather homogeneous distribution of practitioners along the different seasons, being spring and autumn the most preferred (Table 1). The assessment of present climate resources indicates the prevalence of excellent conditions during the coldest season over these Spanish regions that lead to the number of tourist visits (Figure 8(b)). That is, more than 75 d per winter are classified as optimal in the southern and Mediterranean zones. It seems that the high activity level associated with this type of tourism results in a suitable thermal comfort, in spite of winter having the lowest temperatures of the year. Coll and Seguí (2014) also pointed out that favourable months for cycling extend from January to May and from October to December, while summer months are unfavourable in Mallorca because of the extremely high monthly average maximum temperatures above 25 °C.

In spring, ideal climatic conditions predominate in central and northern Spain (Figure 8(c,d)). However, the amount of optimal days in the most visited regions is not as high as in winter. The northward displacement of the high-pressure system brings higher temperatures over southern Spain. As the thermal facet is computed using the temperature at noon – which is relatively high in these regions with a seasonal average of maximum temperatures of about 20 °C –, it results in a slight degradation of this aspect. Since summer brings still higher maximum temperatures, unacceptable conditions prevail in the southern half of the territory and also in northeastern Spain (not shown), while ideal conditions are very limited and restricted to the northernmost coastal fringe (Figure 8(f)).

Climatic assets in autumn offer a good tourist comfort for cycling as well. While the acceptable frequencies are spatially uniform across the country, ranging up to a month, the ideal conditions prevail, especially in the northern regions with around 60 days per season (Figure 8(g,h)). The seasonal CIT distributions do not agree with the peak demand for cycling in Spain: the excellent climate conditions predominate in winter, but tourist attendance is quite residual. A plausible explanation would be the strong influence of the non-climatic related factors in winter such as holidays, air connections, or support of public policies.

Football

Climate potential for this kind of tourism is especially relevant between January and March, in agreement with the arrival of semi- and professional football teams. According to CIT, excellent climatic conditions prevail over the Iberian Peninsula and the Balearics in winter ($>$ 75 d; Figure 9(b)). Some zones of south and eastern Mediterranean Spain are the most consolidated regions in terms of the number of visitors for practicing outdoors this "warm-weather" training. Other Spanish regions also present ideal perceptions for football tourism, but they are currently underexploited. As football is another highly demanding level activity, its practice results in a range of optimal thermal sensations, despite being practiced during the coldest months of the year over these regions.

The spatial distribution of the absolute frequencies is quite similar in spring and autumn, but the former season presents a higher number of ideal days in the northern part of the country (Figure 9(d,f)). This activity can be practiced under optimal conditions for half of the days in the most popular locations during spring. However, the optimal tourist comfort suffers a degradation in autumn. According to the social and economic data (Table 1), the level of this tourist activity is quite residual over the south-eastern Spanish areas during these seasons. Obviously, semi and professional teams are not visiting these regions during the shoulder seasons because they are out of the winter break.

Future changes in climate potential

After calibrating the projected CIT data, we explore the future climate potential for the different tourist activities. For the sake of brevity, we will focus the discussion and graphical displays on the expected changes during the late twenty-first century under the RCP4.5 emission scenario.

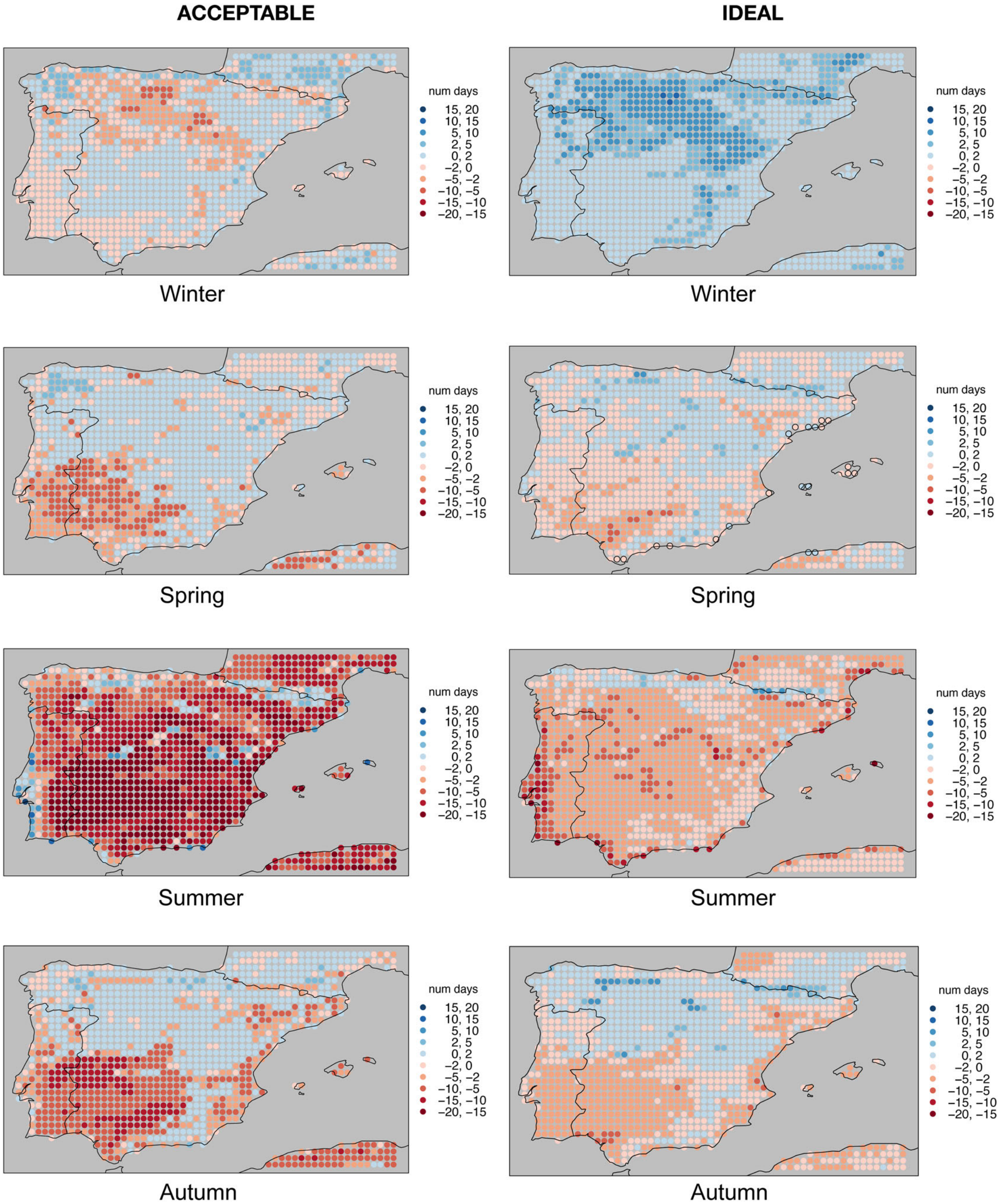

Figure 10. Seasonal mean absolute changes of: (a) winter acceptable, (b) winter ideal, (c) spring acceptable, (d) spring ideal, (e) summer acceptable, (f) summer ideal, (g) autumn acceptable and (h) autumn ideal conditions of the climate resource for cultural tourism in Spain by the late twenty-first century (2071–2095). Absolute changes are expressed as number of days. Black circles denote absolute changes <-14 d between the present and future inter-annual standard deviations.

However, additional comments are also included regarding the RCP8.5 scenario. Note that if all emission reduction pledges within the Paris Agreement were achieved, the RCP4.5 scenario would be the most likely emission pathway in the forthcoming decades (Dubash, 2021; Höhne et al., 2021; Kuramochi et al., 2021; Sognnaes et al., 2021). Furthermore, the 2071–2095 period provides long-term opportunities to the tourism sector to implement strategies before the challenges imposed by climate change.

In the following, absolute changes between the present and future CIT frequencies are discussed for the high attendance period and shoulder seasons. Summer climate potentials for the very physically demanding hiking and cycling tourisms are not discussed for being generally unacceptable in most of the territory already in the present climate. The pattern of changes for each tourist activity is very much alike under the RCP8.5 scenario but systematically more pronounced (maps not shown). Significant changes in the inter-annual CIT variability are also represented in the corresponding maps as black circles (namely, absolute changes between the present and future inter-annual standard deviations < -14 days). In this respect, we mainly find areas with future reduced inter-annual variability. Increases in variability are limited to a few spots and never exceed 3–5 d (not shown). The decline in the inter-annual standard deviations in the future is not only due to the stabilisation of GHG concentrations in the RCP4.5 from the mid century, but also to the comparison with an observed present that is increasingly accumulating excess radiative forcing. The projected decline in variability is interesting because it would favour the implementation of mitigation, adaptation or development strategies with enhanced reliability over time. That is, these strategies would be less vulnerable to the largely unpredictable irregularities in seasonal conditions from year to year.

Cultural

Projections indicate that optimal climate conditions could notably increase in winter, especially in the central and north-western regions, as a consequence of a transition from acceptable to excellent perceptions (Figure 10(b)). This growth could be as high as 15 d (a month in RCP8.5; not shown), being modest in the rest of the country. Scott et al. (2016) reported an increase in the number of future ideal conditions for HCI-Urban tourism in Barcelona (Catalunya). On the other hand, general degradation of the climate potential for cultural tourism can be expected in the south-western and Mediterranean regions during spring. In the former region, both acceptable and ideal absolute frequencies will decrease up to 10 d, while the latter areas may exhibit smaller losses (Figure 10(c,d)). Nevertheless, spring will remain the most suitable season for carrying out cultural activities. In particular, this finding complements and agrees with those presented by Tang (2013) and Bafaluy et al. (2014) when exploring projections for this kind of tourism in Barcelona and Mallorca, respectively. A considerable reduction in the future inter-annual variability is expected over these regions (Figure 10(d)).

Results in summer project general and significant losses in the climate asset for cultural activities. Overall decreases in the range of 10–20 d (1–2 months in RCP8.5) are expected for acceptable and ideal conditions (Figure 10(e,f)). Some areas of northern Spain would experience small increases (up to 5 d), while positive changes are projected only in scattered areas of the north-east and north-centre under RCP8.5. Perch-Nielsen et al. (2010) and Grillakis et al. (2016) have already pointed out a future decrease in the climate suitability for sightseeing tourism in summer over Spain. In contrast, Tang (2013) points out that some Mediterranean destinations, such as Barcelona would still remain at least suitable for urban tourism according to the HCI-urban rating. Again, the autumnal spatial redistribution of the absolute frequencies is quite similar to that projected in spring. However, larger decreases in suitable conditions are expected in south-western and Spanish Mediterranean regions (Figure 10(h)).

Sailing

The strong seasonality of this tourism could be gradually reduced by the late century. In spring, projections exhibit a significant increase in the optimal climate conditions -up to 10 days-, but mainly at the expense of acceptable tourist comfort (Figure 11(a,b)). On the other hand, notable

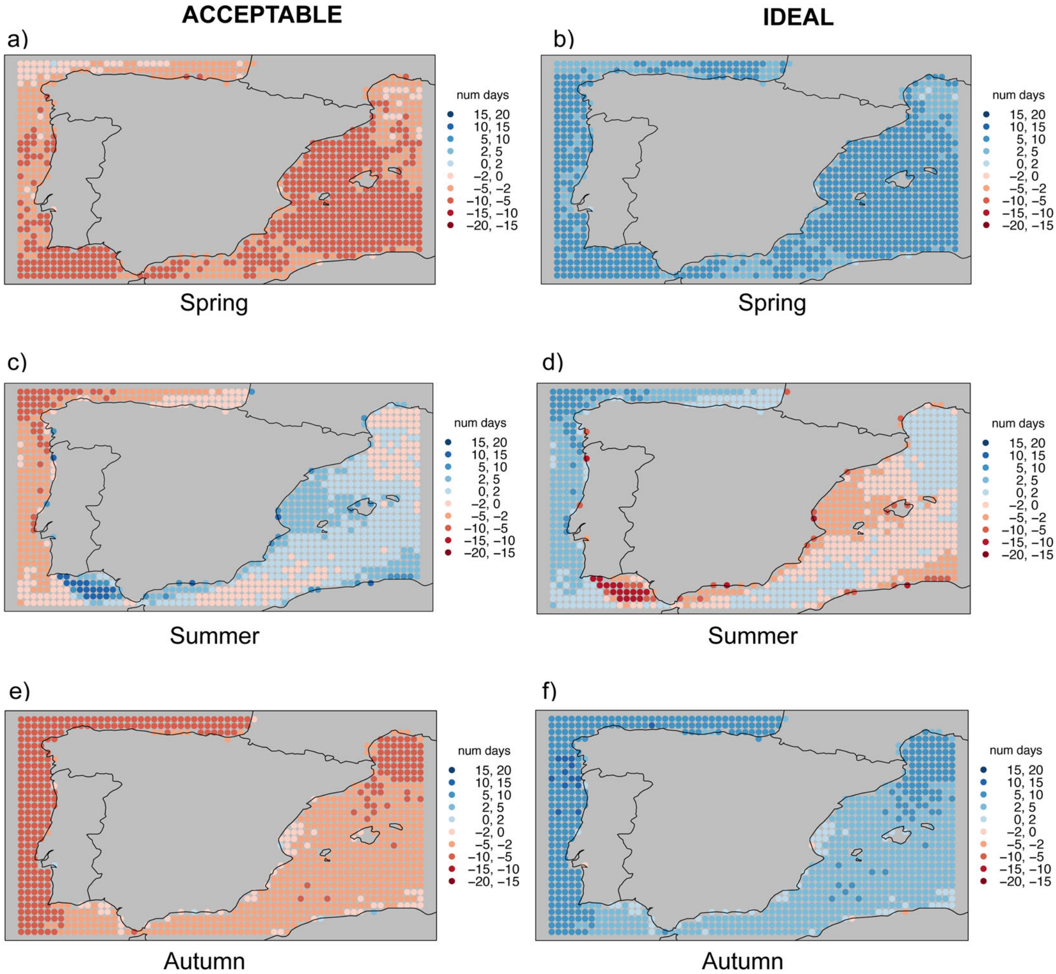

Figure 11. Seasonal mean absolute changes of: (a) spring acceptable, (b) spring ideal, (c) summer acceptable, (d) summer ideal, (e) autumn acceptable and (f) autumn ideal conditions of the climate resource for sailing tourism in Spain by the late twenty-first century (2071–2095). Absolute changes are expressed as number of days. Black circles denote absolute changes <-14 d between the present and future inter-annual standard deviations.

differences are expected in the present spatial distribution of the acceptable and ideal absolute frequencies between the Atlantic and Mediterranean coasts in summer (Figure 11(c,d)). A small degradation in climate potential is projected over the most popular Spanish Mediterranean locations for sailing (i.e. Illes Balears, Catalunya and València), due to the transition from excellent to acceptable climate perceptions. The projected increase of temperatures during the current peak demand may slightly deteriorate the climatic conditions for navigating over this region. In contrast, the north-western Atlantic coastlines will experience an increase in optimal days of up to 10 d per season (20 d under RCP8.5, not shown) due to the shift from the acceptable conditions. This result could favour the future growth and development of companies dedicated to sailing recreation in these areas.

It seems that the extension of the high-demand period to autumn may be possible by the late twenty-first century. Projections show a general spatial transition of the absolute frequencies from acceptable to optimal conditions (Figure 11(e,f)). In addition, the future increase of the excellent conditions would be remarkable over the Atlantic coastlines (up to 10 d). Alongside summer, autumn is projected to become an ideal season for sailing in Spain.

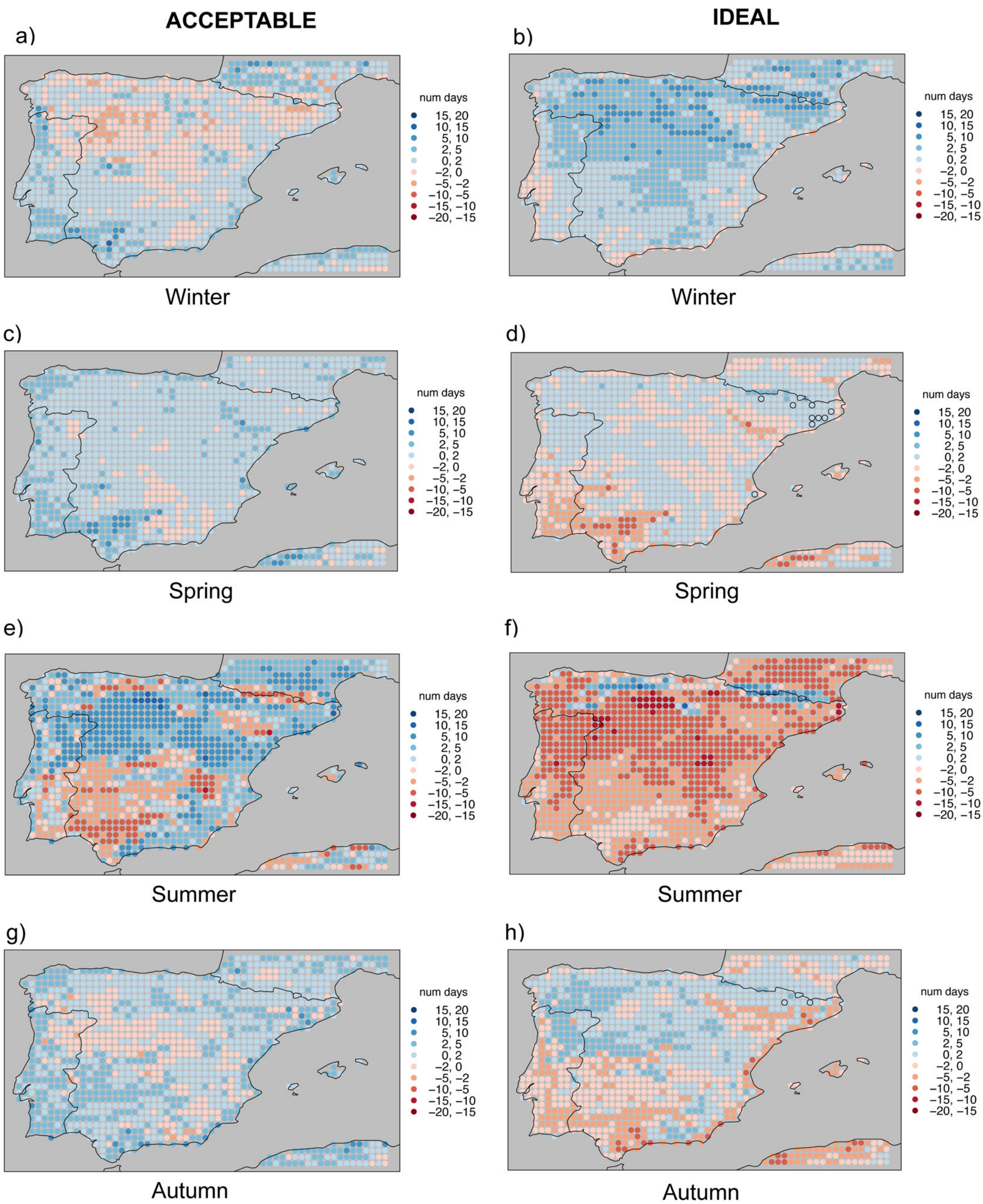

Figure 12. As in Figure 10, but for golf tourism.

Golf

In winter, positive changes for the optimal perceptions are projected to be noticeable from central to northern Spain due to the transition from the acceptable conditions (up to 10 d per season; Figure 12(b)). Even so, spring might remain the most suitable season for golf tourism, with more than 75 ideal days in the most popular destinations. Only western Andalucía would suffer a net degradation in this optimal weather asset, becoming acceptable (Figure 12(d)). This transition is also projected, but to a lesser degree, over some scattered areas of the Spanish Mediterranean region. Regarding the standard deviation across years, results show a future

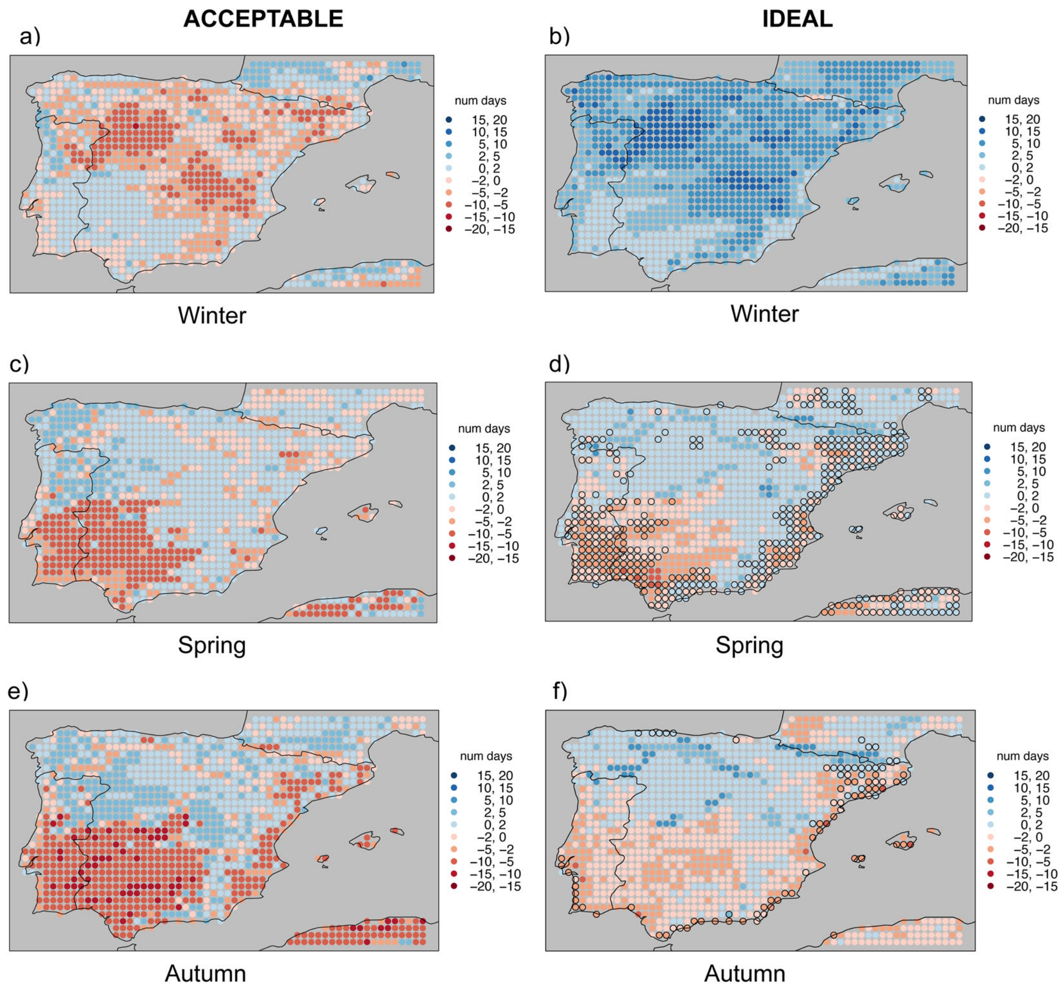

Figure 13. Seasonal mean absolute changes of: (a) winter acceptable, (b) winter ideal, (c) spring acceptable, (d) spring ideal, (e) autumn acceptable and (f) autumn ideal conditions of the climate resource for hiking tourism in Spain by the late twenty-first century (2071–2095). Absolute changes are expressed as number of days. Black circles denote absolute changes <− 14 d between the present and future inter-annual standard deviations.

decrease of up to 14 ideal days in Catalunya and isolated areas of the northern and Mediterranean coasts with respect to the present.

Climate change impacts could negatively affect the summery weather resources for golf recreation. In central and eastern Spain, the acceptable conditions are expected to notably increase at the expense of the ideal climatic conditions (Figure 12(e,f)). In addition, a general degradation of this climate potential is projected in western Andalucía by the end of the century. The projected growth in the daily maximum temperatures leads to stronger heat stress, resulting in a redistribution from ideal to acceptable, or even, unacceptable days. Only some scattered regions of the north may experience a shift from acceptable to ideal frequencies.

In autumn, the practice of golf under excellent conditions may deteriorate along the Mediterranean coastlines (Figure 12(h)). In these regions, projections exhibit decreases of up to 10 ideal days (up to 20 d under RCP8.5), mainly benefiting its practice under acceptable conditions. No significant degradations in the climate potential are expected in the remaining areas of the country.

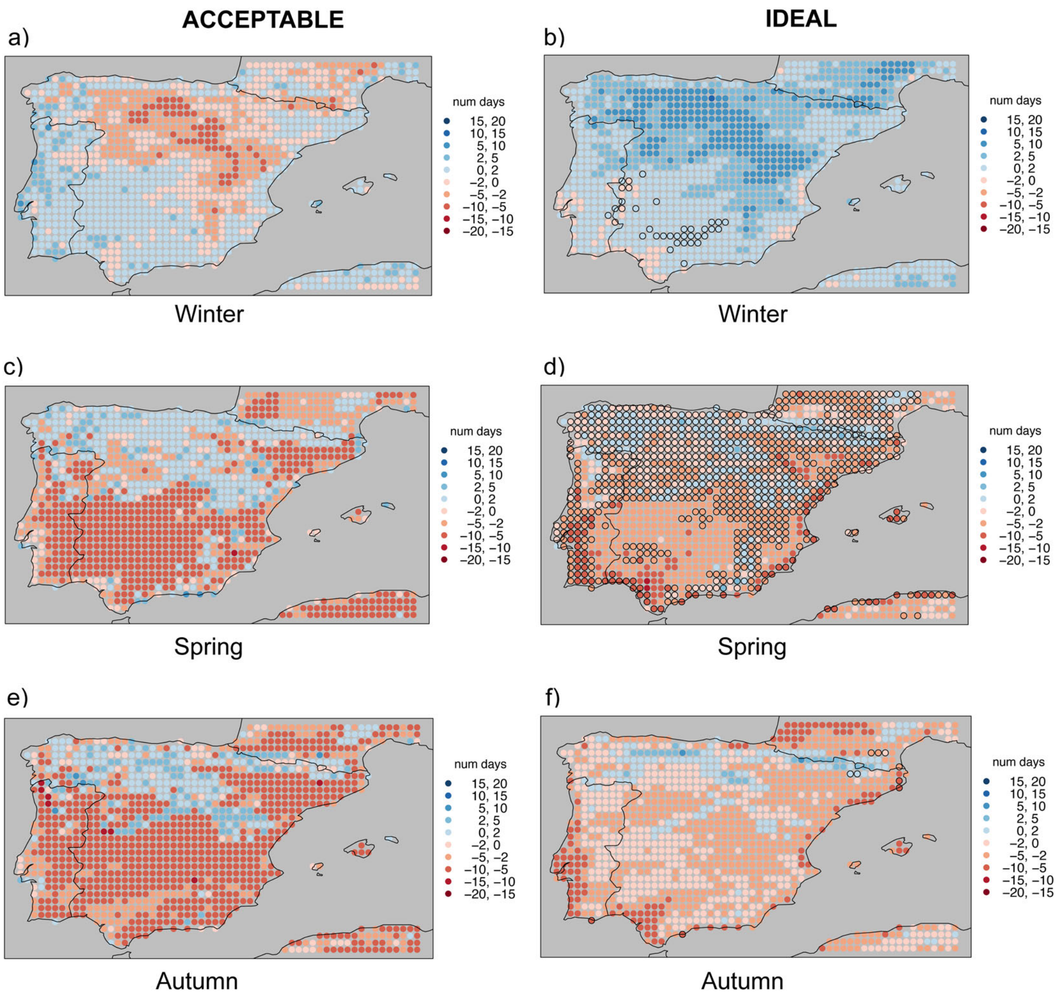

Figure 14. As in Figure 13, but for cycling tourism.

Hiking

The assessment of the future climate potential exhibits a considerable redistribution of the suitable towards optimal perceptions in winter. This pattern of change is especially relevant in popular mountain destinations from central and northern Spain (up to 15 d; Figure 13(b)). In spring, an overall degradation of this climate weather resource is projected over the south-western and Mediterranean regions, while a general enhancement is expected in the rest (Figure 13(c,d)). Losses in climate potential for hiking may be especially large in the latter areas owing to the increase of the temperatures, while the future inter-annual variability might be lower than present by 14 d.

Similar impacts are projected in autumn: a redistribution from acceptable and ideal conditions to unacceptable over the most popular regions, while improving in central and north Spain. In the end, southwestern and Mediterranean Spain could suffer a net degradation of the present climate asset up to 15 d (Figure 13(e)). Again, losses would be especially important in the south-western part of the country. Conversely, an increase in the excellent and acceptable frequencies can be expected over the most visited mountain locations of the north, resulting in a net profit in this climate potential (Figure 13(f)). These areas could experience increases up to 10 d per season in the optimal conditions (about 20 d under RCP8.5), resulting in a distinctive impact of climatic change in terms of latitude. The promotion of hiking in winter could be evaluated beyond spring and autumn in terms of improving the funding and betting on an institutional and business framework adapted to the new climatic needs (e.g. a good network of trails, a supply of hotel deals, quality accommodation, and good information and transportation services).

Cycling

The practice of cycling under excellent climatic conditions might be favoured during the coldest season by the end of the century: Most areas from central to northern Spain will experience positive changes in the optimal absolute frequencies (up to 10; Figure 14(b)). These increases would be at the expense of the acceptable conditions for central Spain, while a net gain is projected in the rest of the country. According to projections, winter could become the most suitable period for this type of tourism. In spring, climate change would negatively impact these regions that are currently receiving the highest number of visits. Losses in the climate asset are projected to be important in the southern and Mediterranean areas while decreasing the optimal inter-annual variability (Figure 14(c,d)).

In autumn, future climate potentials also exhibit an overall degradation of this weather asset. As in spring, a latitudinal spatial redistribution in the acceptable absolute frequencies could be expected, with positive changes in the north and negative signals in the rest of Spain (Figure 14(e)). Decreases in excellent conditions could achieve 10 d per season over the southern and Mediterranean coasts (approximately 20 d in RCP8.5, not shown), resulting in a clear net loss (Figure 14(f)).

Football

Winter may remain the most suitable season for training and playing football outdoors in the south and Mediterranean Spain, but with a clear degradation of the optimal climate potential. That is, acceptable conditions are expected to increase at the expense of excellent perceptions (Figure 15(a,b)). On the other hand, a general enhancement of the optimal and acceptable conditions is projected in the rest of the country due to a latitudinal spatial transition. In fact, the excellent conditions are expected to clearly predominate from central to north Spain.

The shoulder seasons show a general degradation of the climate weather resource for football (Figure 15(c–f)). The ideal absolute frequencies are projected to decline up to 15 d per season (a month in RCP8.5), excepting some scattered areas in the north (Figure 15(d,f)). Concurrently, the acceptable conditions would also decrease to the same extent, experiencing a net degradation in southern Spain, while the central and northern Atlantic coastal regions will experience a transition towards the acceptable conditions. In the latter areas, football could be played under suitable climatic conditions for up to 1 month per season (50 d in RCP8.5).

Final remarks

The Spanish socioeconomic activities strongly rely on the income revenues and jobs of the tourist sector. Undoubtedly, Spain has suitable climatic conditions, environmental resources and cultural heritage for different kinds of tourism, resulting in a clear competitive advantage. Besides beach-based tourism, the conjunction of these assets has enabled the rise and consolidation of alternative outdoor leisure activities, such as cultural, sailing, golf, hiking, cycling or football. Nowadays, these activities are widely implemented and practiced across the country, helping to alleviate the strong seasonality of the predominant beach-based tourism. For instance, there has been a rapid growth in the number of active companies dedicated to leisure and sport outdoor activities that are still improving their competitiveness compared to the rest of the tourism

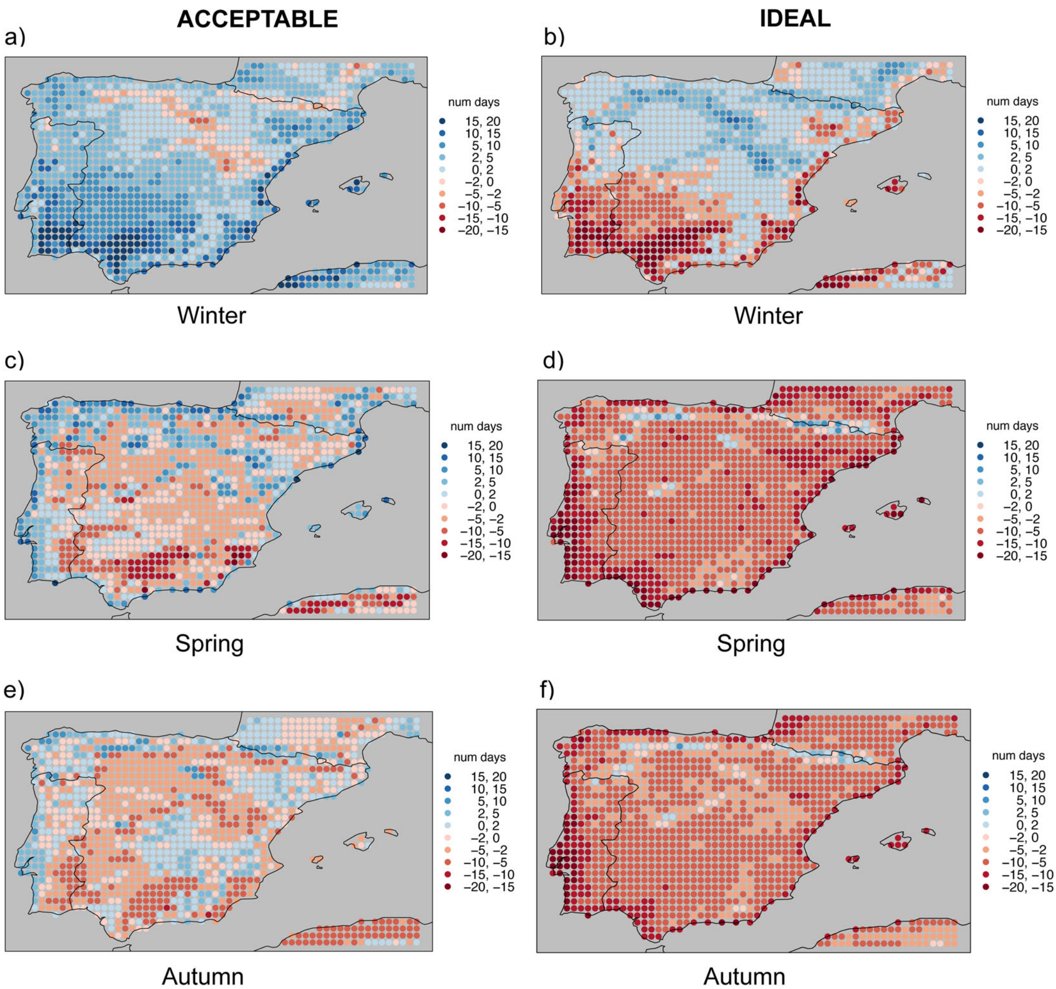

Figure 15. As in Figure 13, but for football tourism.

supply (Deloitte Advisory, 2014: Rivera Mateos, 2015; Molina Navarro et al., 2017; Molina Navarro et al., 2020).

However, the challenges imposed by climate change over these relatively novel leisure activities deserve special attention. This work has focused on this issue by implementing the methods derived in Bafaluy et al. (2014). Recall that the weather typology matrices for each leisure activity were adjusted based on the particular experience of a limited number of practitioners. Bafaluy et al. (2014) advised that the present CITs should be considered as a grounding step towards more empirically-based definitions built on in-situ observations and systematic surveys among wide and diverse sample groups. Nevertheless, outcomes point out that the present spatial and temporal distributions of the CITs are in good agreement with the available macroeconomic information about the number of visitors coming to Spain depending on each tourist activity, season and sub-region. This fact is a reliability check that increases our confidence in the obtained results and confirms the suitability of the first-guess weather topology matrices for the question at hand. Results on present climate resources confirm previous findings, namely that the Spanish Mediterranean coast features ideal conditions for practicing all the considered activities in spring and autumn, whereas in summer excellent conditions only prevail for sailing recreation.

Regarding future changes in climate potentials, some tourism operators work with a time horizon of few years for activities such as investing in hotel and travel offers and use of infrastructure. However, policymakers and key stakeholders also depend on longer-term perspectives for the proper design of new infrastructures, moving towards deseasonalisation or exploring new markets and destinations. In this work, we calculated projections with the late century in mind, but it should be noted that the results for the RCP4.5 scenario would also reflect the climate potentials for some earlier periods of interest since GHG concentrations in such scenario stabilise from mid-century (Meinshausen et al., 2011).

Projections point out a general increase of the excellent climate potentials for central and north Spain, while likely declining in south-western regions during the high seasons. This northward shift in the climatic assets would impact sailing tourism in most of the Spanish Mediterranean coastal regions during the present high-attendance period. Accordingly, companies dedicated to the latter sector should explore the expansion of this activity to autumn, as it is projected to become an ideal season. However, cultural and golf tourism could be practiced under optimal conditions in spring, since this season will likely remain as the most suitable in spite of the projected degradation of the excellent climate potentials in south-western and coastal Mediterranean regions. On the other hand, future changes in climate resources could enhance the practice of some outdoor activities in seasons that are sub-optimal in the present. Local and regional governments and stakeholders will have to face the promotion of cycling and hiking activities in winter, by improving direct (e.g. maintenance and path creation and security and access) and indirect (e.g. hotel and travel offer and gastronomy) investments.

Present and future winter climate potentials for football show ideal ratings over regions that are currently under-exploited, such as the centre and north of Spain. The football sector could encourage this activity by building or taking advantage of training camps, investing in hotels for semi- and professional teams and by organising tournaments. In addition, the projected redistribution of climate potentials by the late twenty-first century could benefit regions not suitable for some outdoor activities in the present. A clear example would be the northern Spanish coasts for sailing recreation during spring. It would be interesting to promote the practice of the latter activity outside the summer season by driving the business framework along the northwestern Atlantic coast.

In summary, the information provided herein can be useful for the implementation of new strategies and management practices to face challenges imposed by expected mid and long-term variations in tourism climate potentials. Ultimately, the progressive adaptation of all these outdoor leisure activities could seasonally adjust the entire Spanish tourist industry to the new climate.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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