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CHANGES IN THE CLIMATE COMFORT OF THE COAST OF SPAIN (1940-2022)

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ABSTRACT. The Spanish coastal regions register specific climatic conditions due to the combination of mild temperatures with little variation throughout the year, high relative humidity and the influence of maritime storms. In summer, the climatic comfort conditions are excessively hot, especially on the Mediterranean coast of Spain. Understanding these conditions and analysing the temporal evolution of recent decades, as well as regional differences, is fundamental for future summer tourism planning in the coming decades. This study analyses the principal 37 coastal tourist hubs of Spain grouped into 10 large regions (the Atlantic, Cantabrian, Mediterranean coasts, and the two archipelagos of the Balearic and Canary Islands). Daily data drawn from the ERA-5 (Copernicus) atmospheric reanalysis from 1940 to 2022 have been used (mean air temperature, mean relative humidity, and mean wind speed), with which the Climate Comfort Index has been calculated (CCI) by González (1998). The results show a significant reduction of the CCI in all the coastal areas analyzed, being more relevant in winter (-0.10 decade). The decrease in the index implies a decrease in cold thresholds and an expansion of comfort throughout the study area, especially in the central Mediterranean and Cantabrian Sea. For its part, in summer, the most important decreases (-0.07 and -0.08 / decade) show an increase in the most important climatic discomfort on the Cantabrian Coast – Euskal Kostaldea and on the Costa Brava-El Garraf, with a significant intensification and expansion temporary thermal sensation of heat. In other coastal sectors, in recent years, the climatic thresholds of heat and extreme heat have been reached for the first time.

Cambios en el confort climático del litoral de España (1940-2022)

RESUMEN. Las regiones costeras españolas registran condiciones climáticas específicas por la combinación de temperaturas suaves y poco contrastadas durante todo el año, humedad relativa elevada, e influencia de temporales marítimos. En verano, las condiciones de confort climático son de calor excesivo, especialmente en el litoral mediterráneo de España. Comprender estas condiciones y analizar la evolución temporal de las últimas décadas, así como las diferencias regionales, es clave para la futura planificación turística estival en las próximas décadas. Este estudio analiza los principales 37 ejes turísticos litorales de España agrupados en 10 grandes regiones costeras (litoral atlántico, cantábrico, mediterráneo, así como los dos archipiélagos de las Islas Baleares y Canarias). Se han utilizado datos diarios de reanálisis atmosférico ERA-5 (Copernicus) de 1940 a 2022 (temperatura media del aire, humedad relativa media del aire, y velocidad media del viento), con los que se ha calculado el índice Climate Comfort Index (CCI) de González (1998). Los resultados muestran una importante reducción del CCI en todos los ámbitos costeros analizados, siendo más relevantes en invierno (-0.10 década). El descenso del índice implica una disminución de umbrales fríos y una expansión del confort en la totalidad del área de estudio, especialmente en el Mediterráneo central y Cantábrico. Por su parte, en verano, los descensos más importantes (-0.07 y -0.08 / década) muestran un aumento del disconfort climático más importante en la Costa Cántabra – Euskal Kostaldea y en la Costa Brava – El Garraf, con una importante intensificación y expansión temporal de la sensación térmica de calor. En otros sectores litorales durante los últimos años se alcanzan por primera vez los umbrales climáticos de calor y mucho calor.

Key words: climatic comfort, coastline, tourism, reanalysis, ranks.

Palabras clave: confort climático, litoral, turismo, reanálisis, umbrales.

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1. Introduction

The analysis of thermal comfort (TC) has gained great scientific significance in recent years due to the close relationships existing between climate, health and certain economic activities related to the human enjoyment of the outdoors, such as tourism. TC is the condition of mind that expresses satisfaction with the thermal environment, as defined by the ASHRAE (1996) or Persons (2014). In recent years, many model indices have been designed that incorporate climate variables such as air temperature, relative humidity, wind speed and direction or solar radiation, which has given rise to climate comfort indices, such as Effective Temperature Comfort (ET) proposed by Missenard (1937); the Discomfort Index (DI) by Thom (1959), the Heat Index (Steadman, 1984), the Tourism Climatic Index (ICTI) by Mieczkowski (1985), the Comfort Index (IC) by González (1998), the Equivalent Temperature Index (Quayle and Steadman, 1998), the Universal Thermal Climate Index (UTCI) (Bröde *et al*. 2011), or more recently the Actual Sensation Vote (ASV) thermal comfort index proposed by Nikolopoulou and Steemers (2003).

The coastal regions are home to an increasing percentage of the global population, with approximately half of the planet's inhabitants (3.6 billion people) living within a radius of 200 km from the coast (Crossland, 2006). Furthermore, they continue to constitute spaces with a significant tourism impact, particularly in the summer season. Since its beginnings in the 1990s, the field of study of Tourism Climatology has evolved from addressing the climate-tourism bionomial to analysing the limiting factors for the practice of tourism today (Besancenot, 1991; Millán López, 2016; de Freitas, 2017; Tanana *et al*., 2021). The majority of studies on this topic identify it as being a priority in future ecological planning (Cetin and Sevik 2016a, 2016b).

Studies have been conducted that apply comfort indices to the tourism activity, due to its high degree of exposure to climate conditions and the high impact that it has on the GDP of the regions and destinations engaged in this economic activity. Hence, the effect that the current climate change process could have on the future evolution of the tourism activity, particularly the sun and beach model, is concerning. Therefore, in recent years, the comfort conditions in different parts of the planet with a clear tourism vocation or significant tourism potential have been analysed so as to be used in planning and decision-making at different scales.

According to Arabadzhyan *et al*., (2020), the priority given to the analysis of climate comfort in coastal areas is due to two reasons: the tourism activity is mainly based on the 3Ss (sea, sun and sand), possibly the largest tourism segment on a global level and second, due to the environmental fragility of the ecosystems, particularly on islands. For example, more frequent and severe heatwaves or the reduction in the availability of beaches due to the rising sea level influence the value of the recreational experience in the destination, affecting the demand and tourist expenditure. In this respect, different studies have confirmed the loss of thermal comfort recorded due to the considerable increase in “tropical nights” over the last few decades in different regions of the world, with a notable incidence in the coastal areas of the Mediterranean basin, related to the warming of the seawater (Olcina *et al*, 2019). The current context of change and global warming forebodes a greater frequency of hot days throughout the year, giving rise to increasingly severe summers in tropical and sub-tropical countries, leading to a loss of thermal comfort for visitors (de Freitas, 2003). This aspect could be particularly relevant in the city climate, where bioclimatic urbanism attempts to adapt to the new realities (Nikolopoulou, 2004).

In this respect, the impact of Climate Change (CC) on coastal tourism has been extensively analysed, but as it is a multidisciplinary topic, researchers from different fields propose their conceptual models for studying the vulnerability and adaptation of tourism to CC. According to Nilsson and Gössling, (2013), the changes occurring in the climate characteristics of the coastal spaces can give rise to the propagation of invasive marine species, with the resulting danger generated for tourists. To this we should add the future trend in the reduction of the size of the beaches due to the rising sea level and the greater frequency of extreme heat events. These aspects are some of the most important indirect environmental effects generated by climate change. So much so that the reduction in the area of the beach has a negative impact on the destination's image, leading to a decrease in arrivals and tourist revenue (Raybould *et al*., 2013).

The objective of this study is to analyse the evolution and distribution of climatic comfort on the Spanish coast. To do this, previous research on the topic conducted for the selected area of study has been analysed and based on the knowledge of the evidence of climate change, which is being recorded in the Spanish Mediterranean region, the following objectives have been established:

- To conduct a comparative analysis of the characteristics of climate comfort between the different coastal sectors of Spain, with the purpose of identifying regional differences and the changes registered over the last few decades.
- To study the temporal evolution of the Climate Comfort Index (CCI) and the changes experienced by the different climate comfort thresholds in recent decades (1940-2022).
- To identify changes in the seasonal distribution of the different climate comfort thresholds in the coastal regions analysed, with a view to establishing more favourable tourist seasons in the future.

2. Materials and methods

2.1. Study area

The area of study covers 7,905 km of Spain's coast, including the Iberian Peninsula and the Canary Islands and Balearic Islands (Fig. 1). A total of 37 coastal stretches corresponding to the most relevant Spanish coastal municipalities from a tourism point of view have been defined (tourist accommodation places), according to the *Atlas de contribution municipal del turismo en España* (Exceltur, 2023). The coastal stretches have been defined by proximity and geographical similarity (Table 1) and all of the official coastal municipalities of Spain are represented.

The 37 coastal tourist areas have been grouped into 10 regions or clusters, in order to simplify the results obtained. The regionalisation or clusterisation process had been conducted by way of a hierarchical clustering, following the Euclidean distance method, recommendable for this study as it uses homogeneous variables in similar units (Table 2). The regionalisation process determines two large Cantabrian regions (the most westerly of the Rías Gallegas – Costa Verde, and the most easterly of the Cantabrian Coast – Euskal Kostaldea). There are six large regions on the Mediterranean coast, from the northernmost part (Costa Brava - El Garraf) to the southernmost region (Costa del Sol - Tropical). The Costa Cálida in the Region of Murcia has been divided between the eastern part (next to the Costa Blanca) and the southern part (next to the coast of Almería). Then there is the archipelago of the Balearic Islands. Finally, on the Atlantic coast there are the regions of the south-west of the Iberian Peninsula (Costa de la Luz) and the Canary archipelago.

The data analysed for calculating the Climate Comfort Index (CCI) have been obtained through the atmospheric reanalysis of the Copernicus Project, formerly known as Global Monitoring for Environment and Security (GMES) programme of the European Union (EU) for establishing a European capacity for observing the Earth. The data have been downloaded from the ERA-5 reanalysis in the climate change service section. ERA-5 is the reanalysis of the fifth generation of the global meteorological model of the European Centre for Medium-Range Weather Forecasts (ECMWF) for global climate over the last eight decades. The data are available from 1940 to the present day. ERA5 provides hourly estimates of atmospheric variables with a horizontal resolution of 31 km and at 137 levels from the surface to 1 Pa (around 80 km) (Hersbach *et al.,* 2020).

Daily data have been downloaded corresponding to the average air temperature (ºC), the average relative air humidity (%), and average wind speed (m/s) from 01/01/1940 to 31/12/2022 through multidimensional files (NetCDF) for each of the 37 tourist areas.

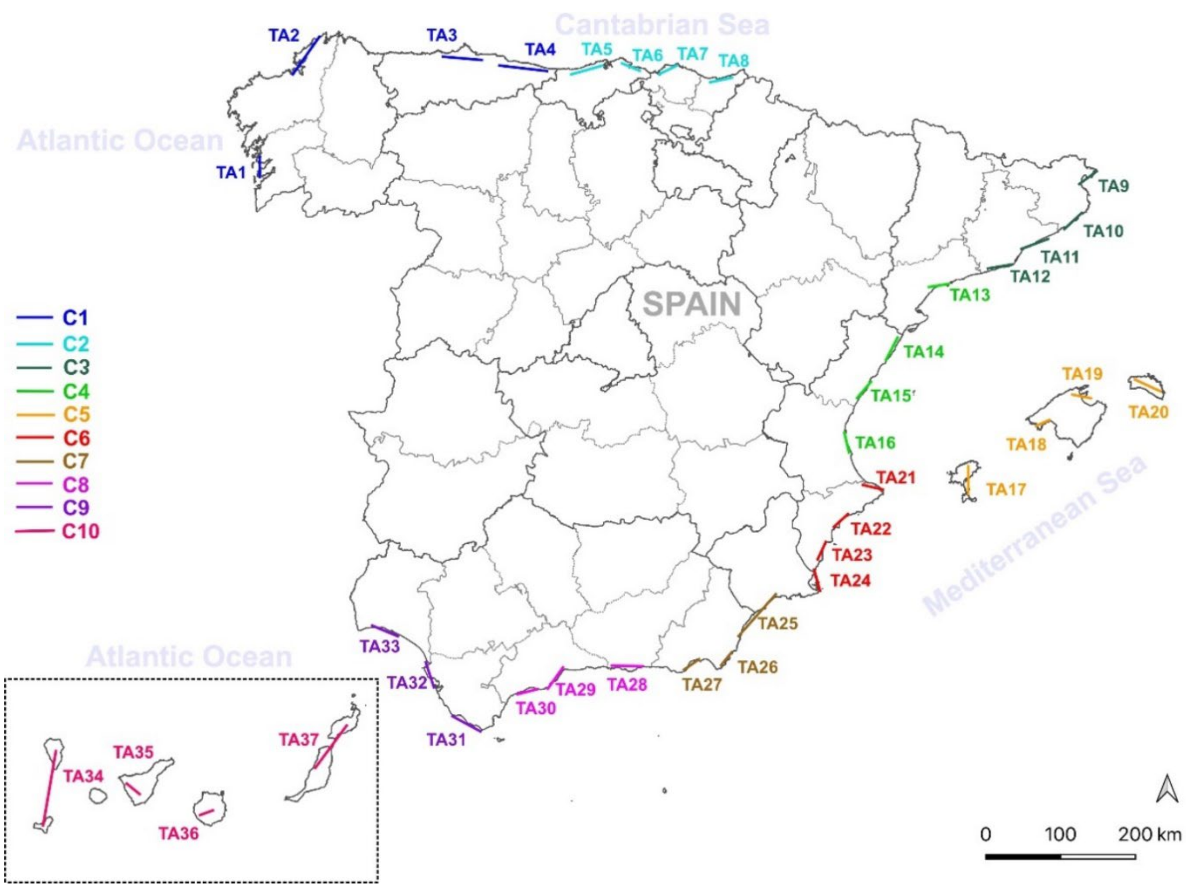

Figure 1. Coastal tourist areas (TA) grouped into clusters (characteristics in Tables 1 and 2)

Table 1. Principal coastal tourist areas in Spain analysed.

ID	NAME / MUNICIPALITIES	ID	NAME / MUNICIPALITIES
TA1	RIAS BAIXAS (Sansenxo, O Grove, Vigo)	TA20	BALEARIC I. – MENORCA (Ciutadella, Mahón)
TA2	RIAS ALTAS (A Coruña – Foz)	TA21	COSTA BLANCA N. (Denia, Jávea, Calpe)
TA3	COSTA VERDE W. (Cudillero, Gijón)	TA22	COSTA BLANCA C. (Benidorm, San Juan, Alicante)
TA4	COSTA VERDE E. (Ribadesella, Llanes, Villaviciosa)	TA23	COSTA BLANCA S. (Santa Pola, Torrevieja)
TA5	CANTABRIAN COAST W. (Santillana, Suances, Santander)	TA24	COSTA BLANCA S. – CÁLIDA E. (Orihuela, San Javier, Cartagena)
TA6	CANTABRIAN COAST E. (Noja, Laredo, Castro Urdiales)	TA25	COSTA CÁLIDA S. – EASTERN COAST OF ALMERIA N. (Mazarrón, Vera, Mojácar)
TA7	EUSKAL KOSTALDEA W. (Bilbao, Bermeo)	TA26	EASTERN COAST OF ALMERIA S. (San José, Las Negras)
TA8	EUSKAL KOSTALDEA E. (Mutriku, Zarautz, San Sebastián)	TA27	WESTERN COAST OF ALMERIA (Almería, Roquetas de Mar)
TA9	COSTA BRAVA N. (Roses, Cadaqués, Port de la Selva)	TA28	COSTA TROPICAL (Almuñécar, Motril, Nerja)
TA10	COSTA BRAVA C. (Platja D´Aro, Calonge)	TA29	COSTA DEL SOL E. (Málaga, Torremolinos, Fuengirola)
TA11	COSTA BRAVA S. (Tossa, Lloret de Mar, Blanes)	TA30	COSTA DEL SOL W. (Marbella, Estepona)
TA12	COSTA EL GARRAF (Barcelona, Sitges)	TA31	COSTA DE LA LUZ SE. (Tarifa, Barbate, Conil)
TA13	COSTA DORADA (Salou, Cambrils, Tarragona)	TA32	COSTA DE LA LUZ C. (Cádiz, Sanlúcar de Barrameda, Doñana).
TA14	COSTA AZAHAR N. (Vinaròs, Benicarló, Peñíscola)	TA33	COSTA DE LA LUZ NW. (Isla Cristina – Punta Umbría)
TA15	COSTA AZAHAR C. (Oropesa, Benicàssim, Castellón)	TA34	CANARY ISLANDS W. (Breña Baja, Llanos de Aridane – Valle Gran Rey)
TA16	COSTA AZAHAR S. (Valencia, Cullera, Gandía)	TA35	CANARY ISLANDS – TENERIFE (Adeje – Arona)
TA17	BALEARIC I. - IBIZA / FORMENTERA (Sant Josep de Sa Talaia - Sta. Eulalia del Río)	TA36	CANARY ISLANDS – GRAN CANARIAS (San Bartolomé de Tirajana – Mogán)
TA18	BALEARIC I. - MALLORCA W. (Calviá, Palma de Mallorca)	TA37	CANARY ISLANDS E. (Tías – Pájara)
TA19	BALEARIC I. - MALLORCA E. (Alcudia – Pollença)		

Table 2. Regionalisation of the different coastal tourist areas analysed.

Cluster	Region Name	ID (TA)
C1	Rías Gallegas – Costa Verde	T1, T2, T3, T4
C2	Cantabrian Coast – Euskal Kostaldea	T5, T6, T7, T8
C3	Costa Brava – Costa El Garraf	T9, TA10, TA11, TA12
C4	Costa Dorada – Costa Azahar	TA13, TA14, TA15, TA16
C5	Balearic Islands	TA17, TA18, TA19, TA20
C6	Costa Blanca – Costa Cálida (east)	TA21, TA22, TA23, TA24
C7	Coast of Almería – Costa Cálida (south)	TA25, TA26, TA27
C8	Costa Tropical – Costa del Sol	TA28, TA29, TA39
C9	Costa de la Luz	TA31, TA32, TA33
C10	Canary Islands	TA34, TA35, TA36, TA37

2.2. Climate Comfort Index (CCI)

This study analyses climate comfort through the use of the CCI. The indices described below have been subjected to a time trend analysis for each of the 37 coastal tourist areas, divided into ten different regions using a clustering process (Table 2).

The CCI proposed by González is adapted and adjusted from the Cooling Power of Leonardo Hill and Morikofer-Davos (IDEAM, 1998) with some modifications: first, a comfort index IC is obtained instead of a cooling power; second, the humidity parameter is included and third, the base values for each of the parameters are modified so that the results are more appropriate for our conditions, taking into account the change in temperature with altitude, as the relief in the country is an important factor (Table 3).

Table 3. Classification of thermal comfort according to climate comfort indices (CCIs).

Comfort Thermal Classification	CCI Ranks
Cold	13 -14
Cool-Cold	12 -13
Cool	11 -12
Cool-Comfort	10 -11
Comfort	8 -10
Comfort-Warm	7 -8
Warm	6 -7
Warm-Heat	5 -6
Heat	4 -5

The CCI is a function of the air temperature, relative humidity and wind speed measured at 10 m. In this case, the geographical coordinates of each weather station influence the results. Therefore, there are three variants of each of the formulas, depending on the altitude of the place: one for those with altitudes of under 1000 metres, another for those at altitudes of between 1000 and 2000 and a final one for those higher than 2000 metres.

All the mean ERA5 grid boxes centroids used in the analysis are located at an altitude of less than 1000 m, as they are coastal areas (Table 1).

$$CCI = (36.5 - TM)\ (0.05 + 0.04\sqrt{WS10} + HR250)$$

TM= Average daily temperature (%); WS10= Average daily wind speed (%); RH250= Average daily relative humidity (%).

The excessive heat (<4) and excessive cold (>14) thresholds have been omitted as they have not been recorded in any of the areas analysed (Table 3).

2.3. Trend Analysis

The time trend analysis was calculated using the Mann–Kendall test (MKT) (Mann, 1945; Kendall, 1975). In order to quantify the rate of temporal change, a trend line slope and Theil–Sen analysis (TSE) has been used (Theil, 1950; Sen, 1968). All trends were evaluated at a statistical significance of 0.05 (confidence level of 95%).

The MKT statistic S is that which has a mean of zero and a variance computed by Equation (3). It is calculated using Equations (1) and (2) and is asymptotically normal:

$$S = \sum k = 1n - 1\sum j = k + 1nsgn\ (xj - xk) \quad (1)$$

$$\mathrm{sgn}(xj - xk) = \{+1 \text{ if } (xj - xk) > 00 \text{ if } (xj - xk) = 0 - 1 \text{ if } (xj - xk) < 0\} \quad (2)$$

$$\mathrm{Var}(S) = [n(n - 1)(2n + 5) - \sum i = 1m\ ti(ti - 1)(2ti + 5)]18 \quad (3)$$

where S is the number of positive differences less the number of negative differences, n is the number of data points, m is the number of tied groups (a tied group is a set of sample data having the same value), and ti is the number of data points in the group. In cases where the sample size n > 10, the standard normal variable Z is computed by using Equation (4).

$$Z = \{S - 1\mathrm{Var}(S) \text{if } S > 00 \text{ if } S = 0S + 1\mathrm{Var}(S) \text{if } S < 0\} \quad (4)$$

Positive values of Z indicate positive trends, while negative values of Z show negative trends. When testing either increasing or decreasing monotonic trends at an α significance level, the null hypothesis was rejected for an absolute value of Z greater than $Z1-\alpha/2$, obtained from the standard normal cumulative distribution tables.

The TSE model for the trend magnitude is conducted by calculating the slopes of all possible combinations of data pairs (Equation 5).

$$\left(\begin{Bmatrix} n \\ V \\ 2 \end{Bmatrix}\right) = \frac{n\,(n-1)}{2} \quad (5)$$

The final slope is then defined as the median of all slopes (Equation (6)):

$$\beta 1 = median\,\{\tilde{}B\}, \tilde{}\mathrm{B} = \left\{\frac{\mathrm{bij}}{\mathrm{bij}}\right\} = \frac{yj - yi}{xj - xi}, xi \neq xj, 1 \leq i < j < n \quad (6)$$

Because the TSE computes the trend line's slope alone, the model intercept can be given by (Equation (7):

$$\beta 0 = \mathrm{Ymedian} - \hat{}\beta 1 \times \mathrm{Xmedian} \quad (7)$$

where Xmedian and Ymedian are the medians of the measurements and of the response variables, correspondingly.

3. Results

3.1. General characteristics of the CCI index

The Spanish coast displays a wide climatic diversity throughout the year, between the northern Atlantic and Cantabrian coasts (C1 and C2) with cool and cold climate thresholds during the winter season and comfortable summers and the Mediterranean coast from the Costa Brava of Gerona (C3) to the Costa de la Luz of Cádiz and Huelva (C9) with cool and comfortable winters and hot summers. With different dynamics due to their subtropical location, the Canary Islands (C10) exhibit lesser annual oscillations, with a comfortable end of winter and spring and a warm CCI threshold at the beginning of autumn (Fig. 2).

Over the last eight decades (1940-2022), significant changes have taken place in the annual evolution of the CCI in the different coastal regions analysed. On the Cantabrian Coast (C1 and C2), a highly significant change is recorded during the coldest period of the year, with cold thresholds from mid-December to the end of February (1941-1970 and 1951-1980) to cool-cold thresholds in the more recent periods of reference. Even during the month of February, the values are close to 12.0 (cool). One of the most remarkable changes has occurred during the first half of March, from values close to 13.0

(cool-cold) to records of average values of 11.3-11.2 (very close to comfort-cool). This is the moment in the year with the greatest reduction in the CCI. The months of December, January and February register the greatest reductions from -0.10 to -0.12 / decade, being statistically significant (Table 4). In general, the largest CCI decreases are concentrated between the second half of December and the first half of January. During the summer, despite the fall in the CCI the value recorded is one of the lowest in the year, with significant changes registered, particularly during the month of August, reaching the warm-comfort threshold in the Rías Gallegas and the Costa Verde (C1) for the first time during the last periods of reference.

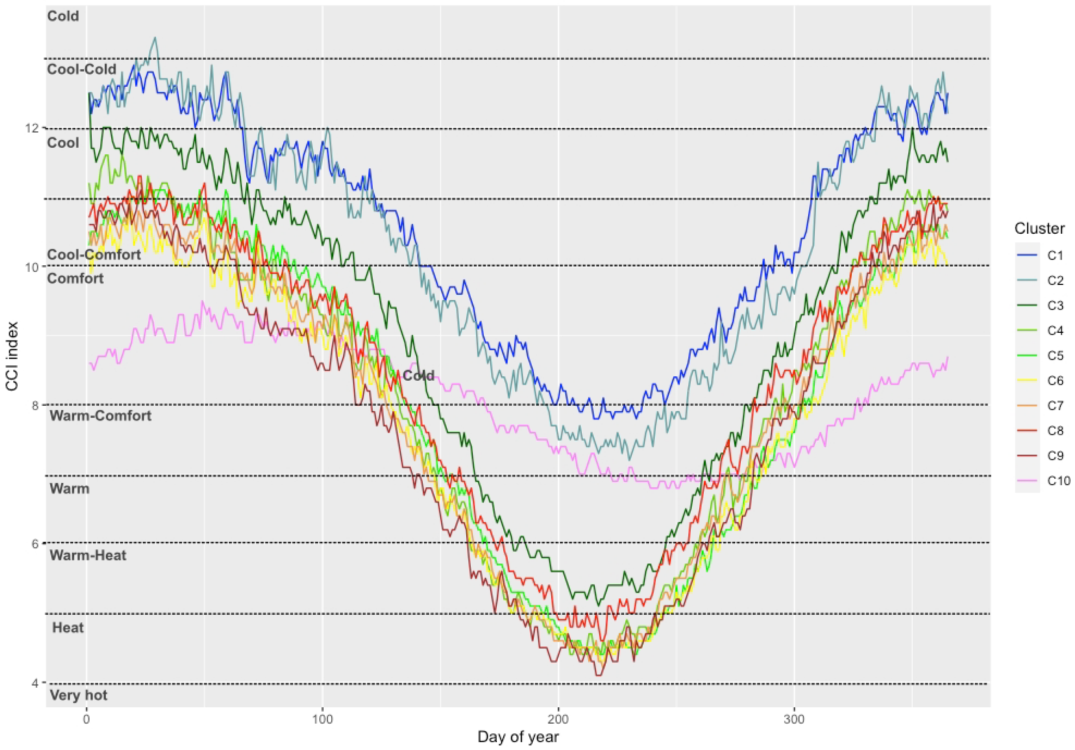

Figure 2. Annual average evolution of the CCI in the different regions of analysis (1991-2020).

Table 4. Monthly and seasonal trends in the CCI in the different regions of analysis (by decade). Values in bold are statistically significant (p value <0.01).

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	Spain
Jan	**-0.10**	**-0.11**	**-0.10**	**-0.17**	**-0.10**	**-0.14**	**-0.11**	**-0.09**	**-0.08**	**-0.05**	**-0.11**
Feb	**-0.11**	**-0.09**	**-0.10**	**-0.15**	**-0.08**	**-0.09**	**-0.09**	**-0.07**	**-0.07**	-0.02	-0.09
Mar	**-0.09**	-0.05	**-0.09**	**-0.14**	-0.05	-0.06	**-0.06**	**-0.08**	**-0.10**	0.00	-0.07
Apr	-0.06	-0.07	**-0.06**	**-0.08**	**-0.04**	**-0.05**	-0.04	-0.03	-0.01	-0.02	-0.05
May	**-0.09**	-0.07	-0.07	-0.08	-0.05	-0.05	**-0.07**	-0.07	-0.07	-0.03	-0.06
Jun	-0.05	**-0.06**	-0.08	-0.08	-0.07	-0.07	-0.06	-0.05	-0.03	-0.03	-0.06
Jul	-0.05	**-0.06**	-0.07	-0.05	**-0.06**	-0.05	**-0.04**	-0.02	-0.01	-0.02	-0.04
Aug	-0.06	**-0.08**	**-0.08**	**-0.07**	**-0.06**	**-0.06**	**-0.06**	-0.04	-0.02	-0.03	-0.06
Sept	**-0.06**	**-0.05**	**-0.05**	**-0.06**	**-0.05**	**-0.06**	**-0.04**	-0.02	-0.02	-0.03	-0.05
Oct	-0.07	**-0.10**	**-0.07**	**-0.12**	**-0.08**	**-0.10**	**-0.09**	**-0.07**	**-0.06**	-0.04	**-0.08**
Nov	**-0.06**	-0.05	**-0.06**	**-0.11**	-0.04	**-0.09**	**-0.09**	**-0.06**	**-0.05**	-0.04	**-0.06**
Dec	**-0.13**	**-0.14**	**-0.10**	**-0.13**	**-0.09**	**-0.11**	**-0.10**	**-0.08**	**-0.07**	**-0.04**	**-0.10**
Win	**-0.11**	**-0.12**	**-0.10**	**-0.15**	**-0.09**	**-0.11**	**-0.10**	**-0.08**	**-0.07**	-0.04	**-0.10**
Spr	**-0.08**	-0.06	**-0.07**	**-0.10**	-0.05	-0.05	-0.06	-0.06	-0.06	-0.02	-0.06
Sum	-0.05	**-0.07**	**-0.08**	-0.07	-0.07	-0.06	**-0.05**	-0.03	-0.02	-0.03	-0.05
Aut	-0.06	**-0.07**	**-0.06**	**-0.10**	-0.06	**-0.08**	**-0.07**	-0.05	-0.04	-0.04	**-0.06**
Year	-0.08	**-0.08**	**-0.08**	**-0.10**	**-0.06**	**-0.08**	**-0.07**	-0.06	-0.05	-0.03	-0.07

Again, the most significant changes in the CCI in the C3 and C4 regions (Costa Brava – El Garraf and Costa Dorada – Azahar) were recorded during the winter season, with the difference that they extend to the month of March. In this coldest period of the year, the CCI thresholds have shifted from being cool-cold to cool, even reaching values of 11 (cool-comfort) on the Costa Dorada-Azahar. The summer season records the principal changes during the month of August, with C3 (Dorada-El Garraf) close to the heat threshold. The same is the case for C4 (Costa Dorada – Azahar) with a very hot threshold during the final reference periods. This coastal area is where the greatest decreases in the CCI are recorded for the whole of the Spanish coastline (-0.17 / decade in January and 0.15 / decade in the winter as a whole) (Table 4).

The coastal area C5 (Balearic Islands) registers the greatest decreases in the CCI during the second half of December and the first half of January, with rates that are lower than those of the Cantabrian regions and the northern Mediterranean area. The data corresponding to the winter season shift from cool conditions during the first periods of reference (1941-1970 and 1951-1980) towards the comfort-cool threshold during the later years. This is where the greatest decreases (statistically significant) are recorded, with values of -0.10 / decade in January and -0.09 / decade in December (Table 4). In the summer period (JJA), the second half of August is particularly noteworthy. There is a change in the thresholds from warm-hot in the first decades of the study to the hot threshold during the second half of the time period analysed.

The coastal area of the south-east of the Iberian Peninsula (C6 and C7), comprising the Costa Blanca in the Region of Valencia, the Costa Cálida in the Region of Murcia and the Coast of Almeria also register the highest rates of decreases in the CCI during the winter season. This is particularly the case during the second half of December and the month of January. In the case of the Coast of Almería, the decrease is greater and lasts until the first half of March. One of the most notable cases is on the Costa Blanca-Cálida (east) where the cool conditions prevailing during the first periods of reference change to comfort conditions during the winter months in 1991-2020 (Fig. 3). This is where the greatest statistically significant decrease rates are recorded during the month of January (-0.14 / decade and -0.11 / decade in December). In the summer season, the second half of August in C6 and the first half of August in C7 with a statistically significant decrease of between -0.05 and -0.06 / decade stand out. In the last period of reference (1991-2020), the summer records are close to the very hot threshold (4) on the Almeria coast and the southern part of the Costa Cálida.

The southernmost coast of the Iberian Peninsula, the Mediterranean area of the Costa Tropical and the Costa del Sol (C8) and the Atlantic with the Costa de la Luz (C9) register the most significant changes during the winter and the first half of spring, specifically from the second half of December until the second half of March. In December, January and March statistically significant decreases are recorded of between -0.07 and -0.10 / decade (Table 4). In the case of the thresholds, the change is evident, with a shift from cool characteristics to comfort-cool characteristics (Fig. 3). Meanwhile, the lowest variations in all the coastal areas analysed are recorded in the summer season, with slight reductions of between -0.04 and -0.01 / decade. The thermal thresholds have not changed particularly in the last few decades and, despite a less significant decrease being recorded than in the rest of the Iberian Peninsula, in the last periods of reference (particularly 1991-2020) the hot threshold was reached in the Costa Tropical – Costa del Sol (C8). Furthermore, the Costa de la Luz (9) recorded the hottest summer thresholds and during the last period of reference values very close to the very hot threshold (4).

Finally, the Canary Islands (C10) experienced the greatest changes during the autumn (between the second half of October and the first half of November) and the central part of winter (between the second half of December and the first half of January). With regard to the change in the CCI index, January and December stand out (-0.04 and -0.05 / decade) as the only months with statistically significant reductions (Table 4). During the last periods of reference, the CCI values during the winter remained within the comfort threshold, although increasingly further away from the cool-comfort threshold. Meanwhile, during the summer season, there has also been an increase in temperatures over the last few decades increasing from a comfort-warm threshold to a hot threshold for the first time during the two last reference periods (1981-2010 and 1991-2020) (Fig. 3).

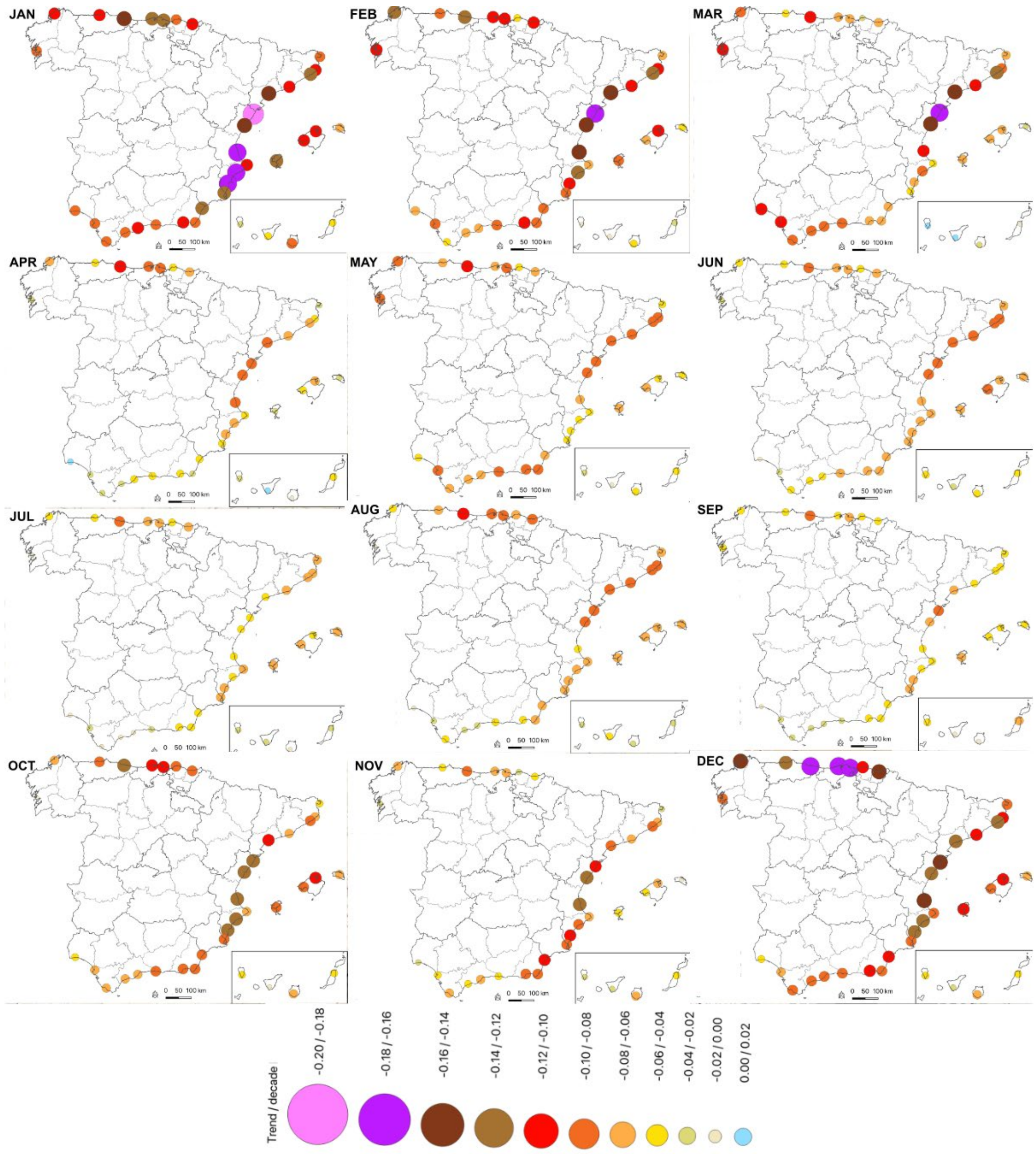

Figure 3. Space-time distribution of the CCI index trend for the different months of the year.

3.2. Seasonal changes in the CCI index (1940-2022)

Figure 4 shows the space-time evolution of the different thresholds of the CCI index, according to the different reference periods used. Combined with Table 5, we can observe the changes at the start, end and the total number of days per threshold. Therefore, Table 5 groups the different thresholds into three large blocks: warm, comfortable and cold conditions. Warm conditions have not been detected on the Cantabrian strip (C1 and C2) during the last few decades, but comfort-warm conditions have been recorded. The cold threshold disappears as from the reference period 1981-2010, with a reduction in the number of days of the cold group from 198 to 179 days in C1 (-29 days) and from 192 to 169 in C2 (- 23 days). Meanwhile, the comfort threshold increased in terms of the number of days from 167 to 186 (19 days) in C1 and from 173 to 196 in C2 (23 days).

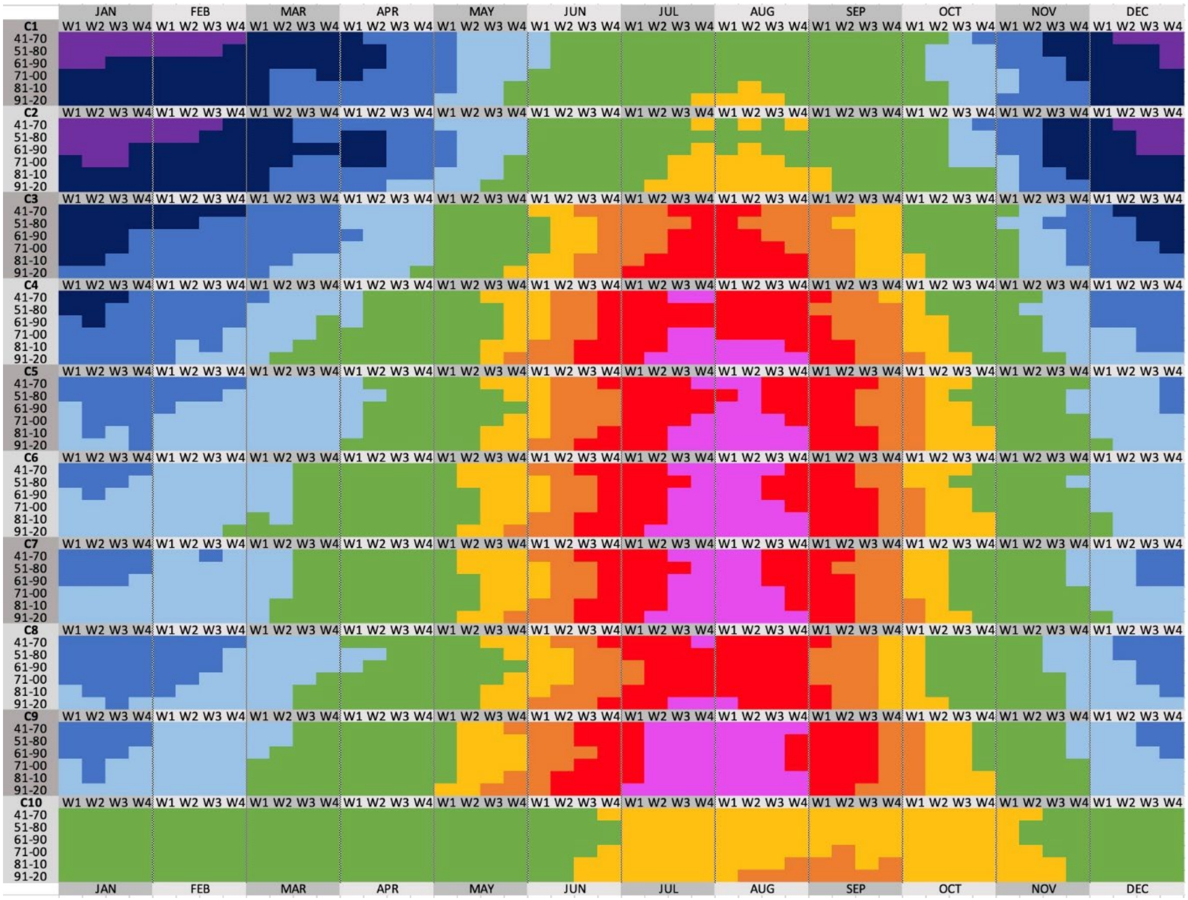

Figure 4. Weekly CCI thresholds during the year in the regions of study (according to periods of reference). Legend: Pink (heat), red (heat-warm), orange (warm), Pink (warm-comfort), green (comfort), light blue (cool-comfort), blue (cool), dark blue (cool-cold) and dark purple (cold).

Table 5. Changes in the number of days of the different climate threshold groups of the CCI for the regions of study and reference periods.

		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Warm Heat	41 -70	0	0	89	114	120	121	116	107	138	4
	51 -80	0	0	81	108	115	117	112	101	128	0
	61 -90	0	0	80	110	117	122	115	100	127	1
	71 -00	0	0	79	111	116	123	119	101	132	10
	81 -10	0	0	94	122	123	130	127	109	137	28
	91 -20	0	0	99	130	133	138	134	115	144	54
	Variation	**0**	**0**	**18**	**22**	**18**	**21**	**22**	**15**	**17**	**54**
Comfort	41 -70	169	176	144	151	179	220	195	177	187	361
	51 -80	167	173	150	168	192	230	209	188	194	365
	61 -90	172	182	151	170	206	229	219	201	205	364
	71 -00	175	186	156	190	220	239	237	217	218	355
	81 -10	183	195	155	180	220	235	237	222	222	337
	91 -20	186	196	166	198	222	227	230	237	219	311
	Variation	**19**	**23**	**22**	**47**	**43**	**7**	**35**	**60**	**32**	**-50**
Cool Cold	41 -70	196	189	132	100	66	24	54	81	40	0
	51 -80	198	192	134	89	58	18	44	76	43	0
	61 -90	193	183	134	85	42	14	31	64	33	0
	71 -00	190	179	130	64	29	3	9	47	15	0
	81 -10	182	170	116	63	22	0	1	34	6	0
	91 -20	179	169	100	37	10	0	1	13	2	0
	Variation	**-21**	**-33**	**-34**	**-63**	**-56**	**-24**	**-53**	**-68**	**-41**	**0**

On the Costa Brava – El Garraf (C3) a notable prolongation of the warm-heat threshold can be observed during the months of July and August. In the last reference period (1991-2020), this applies to the whole of both of these months, while in the reference period 1951-1980 it is recorded for the last week of July and the first week of August. The increase in the number of days of the heat grouping is considerable from 79 to 99 days (20 days). The cool-cold threshold disappears as from the reference period 1991-2020, with the number of cold days reducing from 134 to 100 (-34 days). Finally, an increase in the number of comfortable days can be observed, rising from 144 to 166 days (22 days) (Table 5).

The cold CCI thresholds of coastal region C4 (Costa Dorada – Costa Azahar) have decreased notably, with the elimination of the cold-cool characteristic in January as from the reference period 1970-2000 and with a very large decrease in the number of days, from 100 to 37 (-63 days). This decrease has been partly compensated by the comfort threshold with an increase from 151 to 198 days (47 days) and, on the other hand, by the increase from 108 to 130 days of the warm thresholds (22 days). The heat CCI threshold appears during the last reference period 1991-2020 throughout the last three weeks of July and the whole of the month of August (Fig. 4).

The Balearic Islands (C5) follows the same pattern as the rest of the area of study. There is a clear reduction in the cold CCI thresholds; in the last reference period the cool threshold was present only in the last week of January. The number of cold days reduced from 66 to 10 days (-56 days). Similarly to the rest of the regions, an increase in the comfortable days throughout the year may be observed, rising from 179 to 222 (43 days). Finally, during the last few decades, there has been an expansion of the warm thresholds, with an increase from 115 to 133 days (17 days). The heat CCI threshold appears during the last reference period 1991-2020, during the second half of July and the whole of the month of August (Fig. 4).

The cold thresholds have practically disappeared from the Mediterranean regions in the south-east of the peninsula (C6 and C7) represented by the Costa Blanca, the Costa Cálida and the Coast of Almería over the last few decades. Specifically, the cool CCI threshold has disappeared since the reference period 1971-2000 to the present day, from 24 days to 0 days in C6 (-24 days) and from 54 to 1 days in C7 (-53 days). The loss of the cold winter has been replaced with more comfortable conditions. There has been an increase from 195 to 230 days in C7 (35 days). On the other hand, in region C6, a greater change in the increase in the warm thresholds can be observed, with an evolution from 117 to 138 days (21 days). The change is also evident in C7, with an increase from 112 to 134 days over the last few decades (22 days). In both regions, the heat threshold appears during the last reference period 1991-2020, throughout the last three weeks of July and the whole of the month of August (Fig. 4).

The southern coast of Spain, represented by C8 and C9 (Costa Tropical, del Sol and Costa de La Luz) has experienced a drastic reduction in the cold thresholds during the winter, to the point where the decrease is particularly notable in C8 (from 81 to 13 days) and in C9 (from 40 to 2), with reductions of 68 and 38 days, respectively. There has also been a major time extension of the comfort threshold, with the period starting earlier from the third week of March and ending between the second and third week of November. In total, the increase in the number of days reached 60 days in C8 and 32 in C9. Finally, the warm conditions lasted longer during the last decades of the period of study, with an increase from 15 to 17 days, respectively. After several reference periods, the hot threshold appears in C9 during 1991-2020 from the third week of July to the first week of August (Fig. 4).

Finally, the Canary Islands (C10) have experienced the expansion of the warm-comfort threshold and the warm threshold appeared for the first time (reference period 1991-2020) between the second week of August and the whole month of September. The CCI comfort group experienced a notable decrease (-50 days) in detriment to the warm group (54 days).

A greater decrease in the CCI is recorded in the winter trimester (DJF) throughout the whole of Spain (-0.10 / decade). This is a significant reduction. Of the different areas analysed, the Costa Dorada – Azahar (C4) particularly stands out with the greatest recorded decrease (-0.15 / decade) (Fig. 5). In general, and with the exception of the Costa de la Luz (C9) and the Canary Islands (C10), the decreases have been homogeneous from the 1940s to the present day. In the latter two cases, there was a cooler period during the 1960s and 1970s. Furthermore, in recent years, the reduction of the CCI has accelerated in certain coastal sectors, particularly the Costa Dorada – Azahar (C4) and Costa Blanca – Cálida (C6). During the last winters of the time period, milder CCI values were registered, particularly in 2022. Therefore, there has been a clear increase in winter thermal comfort on the Spanish coast in recent years, except in the Rías Gallegas-Costa Verde (C1), where the CCI has not followed this trend over the last two decades.

No significant changes have been observed in the spring (MAM) during the last few decades, at least in the full-time trend from 1940 to the present day (-0.06 / decade). The decreases on the Costa Dorada – Azahar (C4), in the Rías Bajas of Galicia (C1) and the Costa Brava – El Garraf (C3) are notable, with statistically significant values between -0.10 and -0.07 / decade. On the other hand, the Canary Islands (C10) record the smallest decrease with -0.02 / decade. Figure 7 shows the evolution of the CCI in the different coastal regions, with the coolest values during the 1970s and 1980s particularly standing out (in the Mediterranean regions). After the decrease that occurred mainly in the 1990s and part of the 2000s, without trend can be observed in several coastal regions in recent years, such as the north Atlantic strip and Cantabria (C1 and C2), the Balearic Islands (C5) or the Costa Tropical-Sol (C8). There has even been a slight recovery (cooler springs) in the coastal areas of the south-east of the peninsula (C6 and C7) and the Costa de la Luz (C9).

Summer (JJA) is the season with the lowest decrease of the year in Spain as a whole (-0.05 / decade), mainly due to the fact that the CCI already establishes low values (heat thresholds). Even so, the decrease is evident in all of the regions in the study, but particularly in eastern Cantabria (C2) and the northernmost Mediterranean coast (C3) with statistically significant values between -0.07 and -0.08 / decade, respectively. The sector in the north-east of the peninsula is where the summers are becoming increasingly hotter. Meanwhile, the smallest decreases are recorded in the southern Mediterranean coast (Costa Tropical -Sol) and the south-west Atlantic coast (Costa de la Luz) with -0.02 and -0.03 / decade. In the same way, the Canary Islands register a decrease of -0.03 / decade. The areas between TA10 and TA15 (central and southern Costa Brava, El Garraf, Costa Dorada, and northern and central Costa Azahar) with a decrease of between -0.09 and -0.08 / decade).

Figure 6 shows the time evolution of the CCI during the summer season. We can observe that the 1970s was the least warm decade of the period of study (1940-2022). From then, there has been a constant decrease in all of the regions of study, but with spatial differences. In this respect, during the last years of the study there was an evident decrease in the CCI in the majority of the areas studied (from C3 to C8), that is, the Mediterranean coast of the peninsula from the Costa Brava in Gerona to the Costa del Sol in Málaga. Therefore, it should be pointed out that the summer of 2022 was the hottest since 1940 in C3, C4, C6, C7 and C8, that is, the Mediterranean coast on the peninsula, from the Costa Brava to the Costa del Sol. On the other hand, the east of Cantabria (C2) and the Canary Islands (C10) experienced a slight decrease. Meanwhile, the two Atlantic coastal regions displayed a dynamic that was different to the rest of the regions. The Costa de la Luz (C9) experienced very little changes during the last years of the study period and the Rías Gallegas and the Costa Verde in Asturias even experienced a slight increase in the CCI (less hot) in the last two decades.

Finally, in the analysis of the autumn (SON), there was a national decrease of -0.06 / decade (statistically significant) but more homogeneous than the rest of the seasons. With the exception of the Costa Dorada-Azahar (C4), which recorded a greater decrease of -0.10 / decade, the rest of the Mediterranean coast (C3 to C7) experienced reductions of between -0.06 and -0.08 / decade. In this regard, it is necessary to point out that the southern coast on the peninsula (C8 and C9) and the Canary Islands registered the smallest decreases (-0.04 to -0.05 / decade). Figure 8 shows the evolution of the CCI during the autumn season, which indicates that the coolest CCI rates were recorded during the 1970s. From then until the present day, there has been a homogeneous and generalised decrease in all of the regions of study, with the exception of the Canary Islands, which recorded a trend with a few changes during the last years. A coastal warming in the autumn season has been manifested in recent years, particularly in 2022. The lowest average values were recorded in C3, C5, C6, C7 and C8, that is, on the majority of the Mediterranean coast of the peninsula from the Costa Brava and the Costa del Sol. In many cases, the figures display a wide margin of difference, constituting, to date, the hottest autumn in the Mediterranean region since 1940.

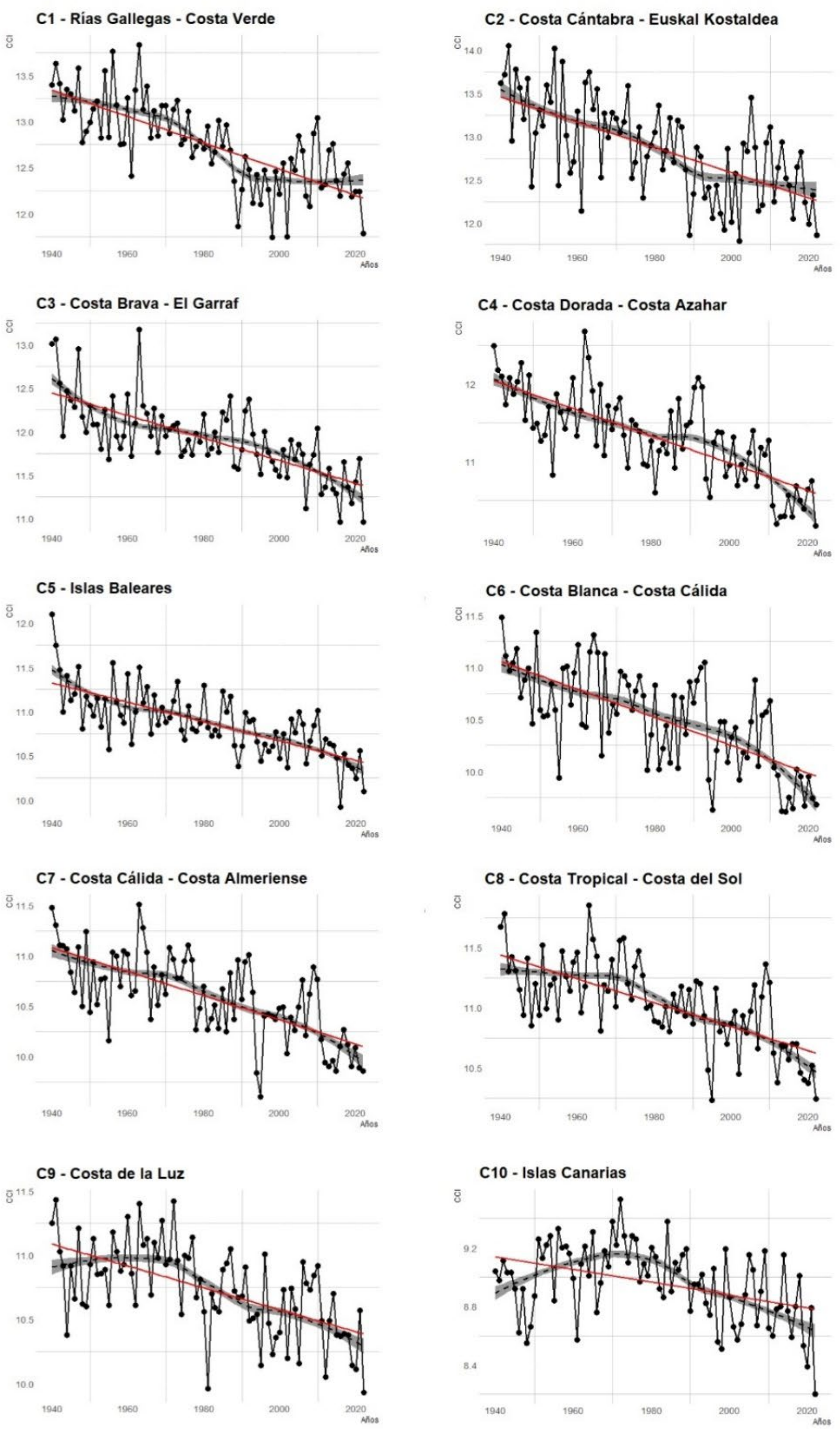

Figure 5. Time evolution of the CCI in the winter season (DJF) in the different regions (1940-2022).

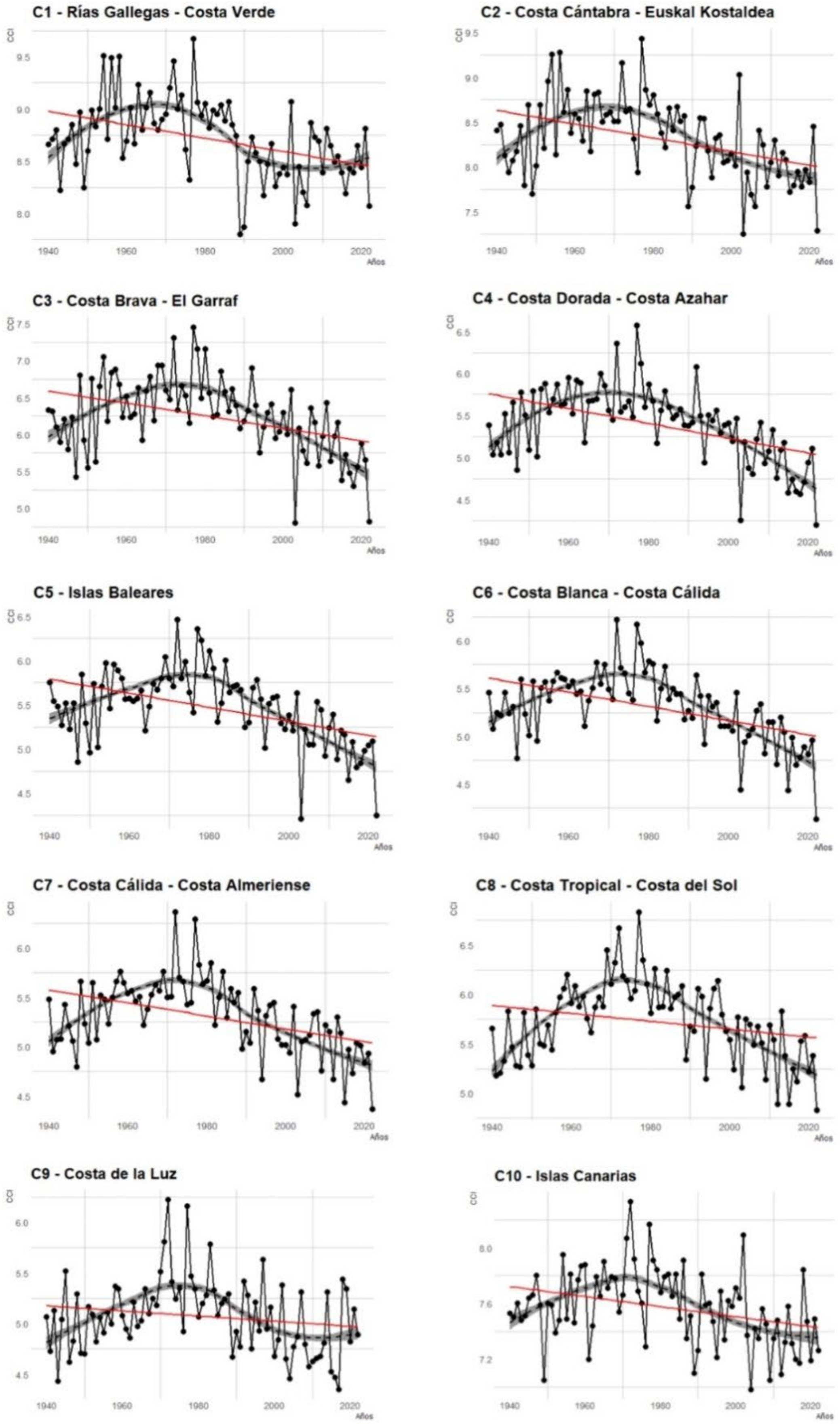

Figure 6. Time evolution of the CCI in the summer season (JJA) in the different regions (1940-2022)

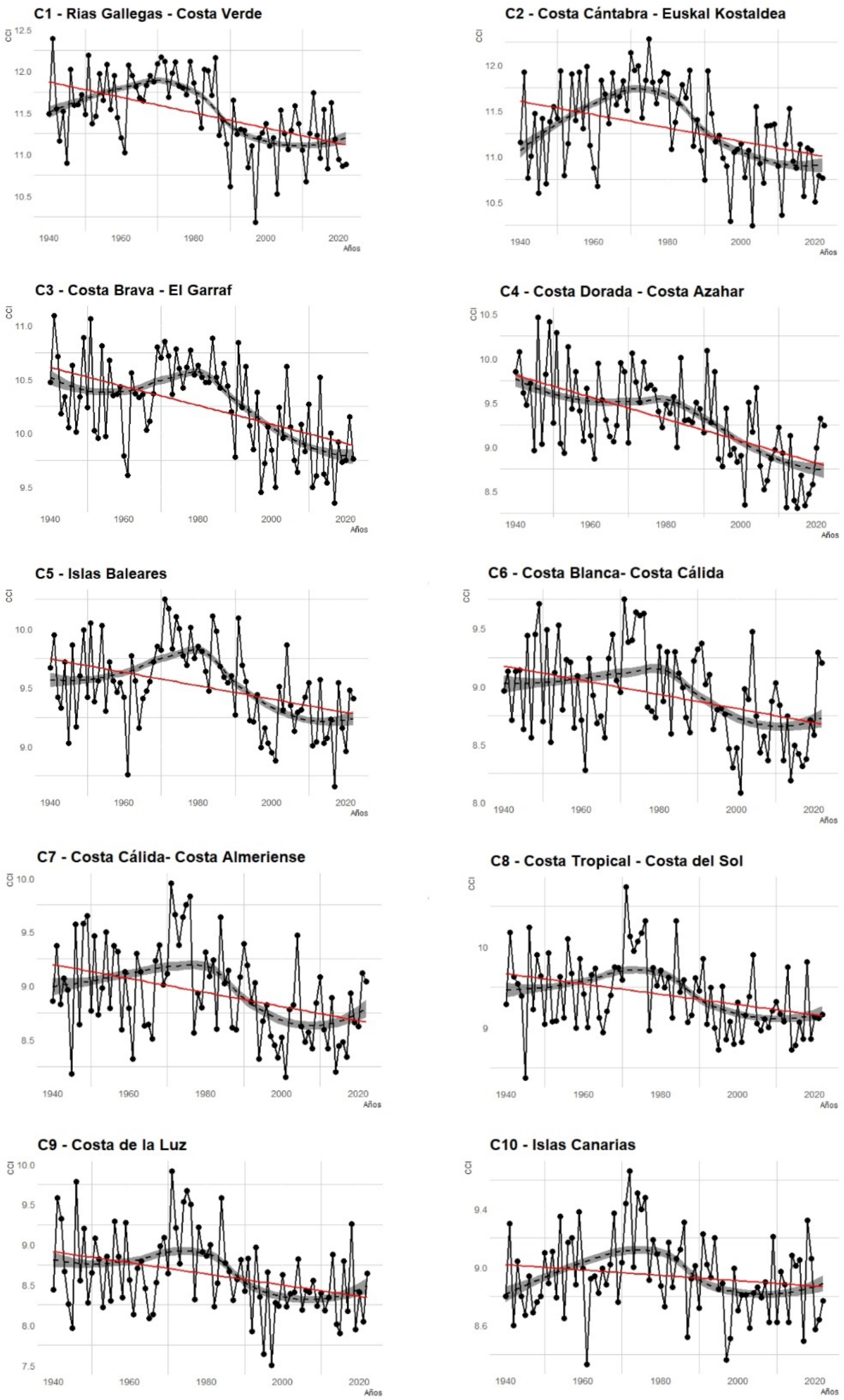

Figure 7. Time evolution of the CCI in the spring season (MAM) in the different regions (1940-2022).

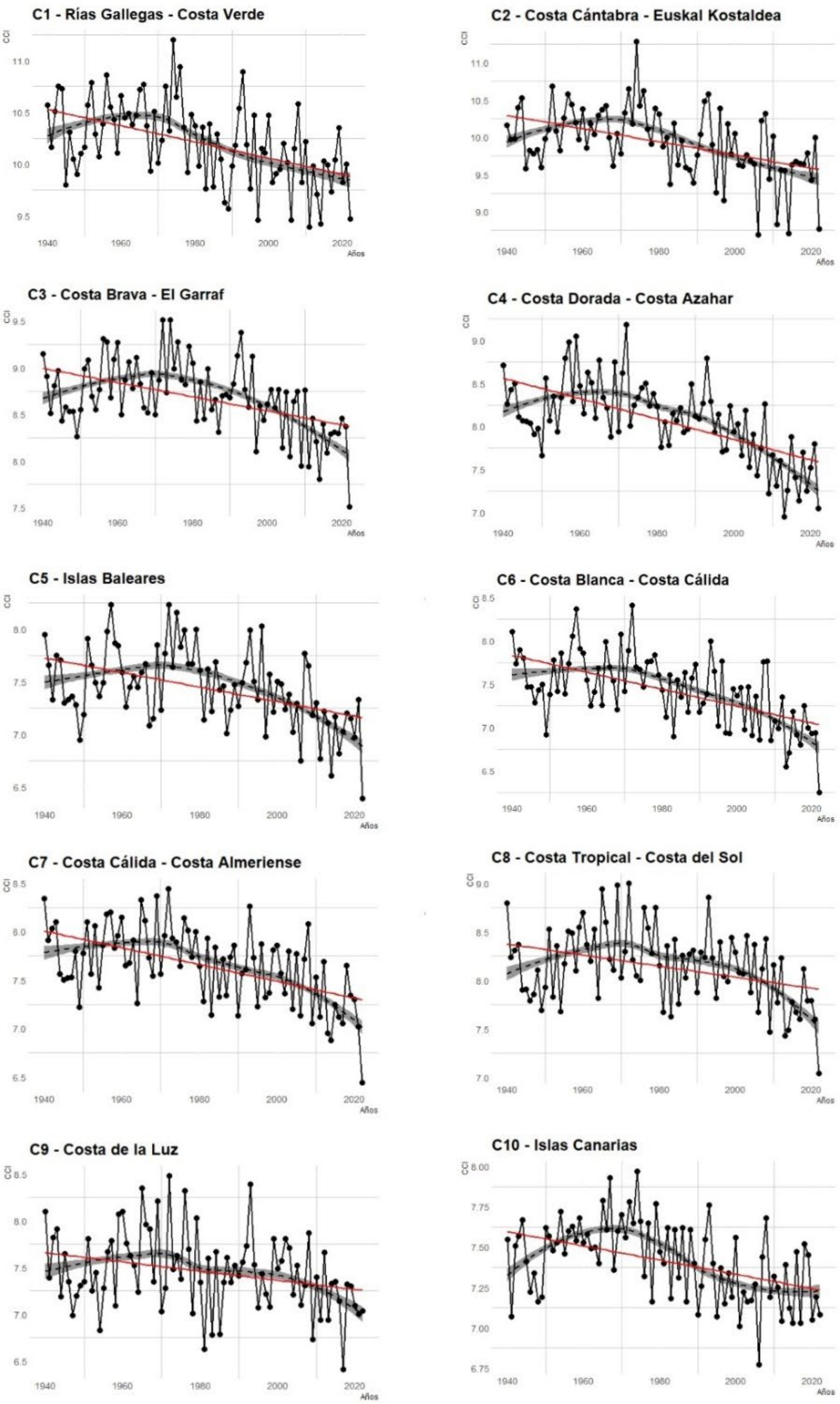

Figure 8. Time evolution of the CCI in the autumn season (SON) in the different regions (1940-2022).

4. Discussion

The Spanish coastline has been facing a new climate reality in recent years, particularly significant during the summer season with the increase in the duration and intensity of climate discomfort. The different coastal regions of Spain, particularly the Costa Blanca (Benidorm), the Costa Dorada (Salou), the coast of the Balearic Islands (Calviá), the Costa del Sol (Marbella) or the Canary Islands (Adeje), are regional leaders in sun and beach holidays in Europe, based on a Ford (mass) tourism model and characterised by high seasonality and environmental pressure. Therefore, analysing the current conditions and the evolution of the last few years is fundamental for evaluating the future tourism potential of the different coastal regions of Spain. According to Bafaluy et al., (2013), the climate conditions will continue to deteriorate during the peak period of tourist visits, while they will improve in spring and autumn. Thus, future efforts to understand tourists' destination decision-making in the context of climate change should consider climate change-induced cognition-affective aspects as part of knowledge-centered models connecting destination choice with perceived risks (Lin and Wang, 2023).

In the final years of the study period, the relationship between climate, tourism and water has been analysed and it has been found that there is a clear relationship between the increase in temperatures and the reduction in rainfall on the Mediterranean coast of the Iberian Peninsula, which has caused severe droughts with major economic losses (Martínez Ibarra, 2015). Moreover, beach tourism requires relatively high temperatures for it to be attractive to tourists, and relatively modest changes have been observed in the tourist flows in recent years. As concluded by March *et al.,* (2014), tourists do not seem to be so worried by climate change on the coast, but more so in winter tourist destinations (ski resorts).

It is likely that the Mediterranean will continue to constitute Europe's leading beach tourist destination in the summer for at least the next 50 years (Moreno and Amelung, 2009), although the extreme climate discomfort values, which have been increasingly recurrent in recent years, could modify the time distribution, with a greater occupancy in the months prior to and after the summer. According to Gómez-Martín (2006), in recent years, the beginning and the end of the summer are the best times for tourism. However, currently the visitor rates at these times are low considering how ideal the conditions are. The repercussions of climate change on the Spanish tourism sector will require an adaptation of the activity to the new calendars, either to create new tourism products or to take advantage of the new climate characteristics (Gómez-Martín, 2017). The studies also show that the loss of attractiveness of coastal tourist destinations can lead to changes in the flow and behaviour of tourists (Perry, 2005), generating a carry-over effect on other elements of the system.

According to the B1 scenario (CGCM2 model) developed by Flato and Boer (2001), the provinces in the south of Spain are those that would experience a greater reduction in the frequency of visits. The study by Bujosa and Rosselló (2013) finds that Málaga and Tarragona would be the provinces with the greatest loss of tourism (-5.4% and -5.1%, respectively), although other provinces with a high tourism weight, such as Almería or Barcelona would lose -3.6% and -3.1%, respectively. The greatest gains, on the other hand, would be seen in Gerona and Valencia (5.6 and 4.6%). The authors conclude that the coastal provinces that will lose most tourists are those located in the south of Spain (particularly Huelva, Cádiz, Málaga and Almería), while the coastal provinces of the north (A Coruña, Cantabria, Guipúzcoa and Girona) will experience a major increase in their probabilities to be chosen as destinations. At the same time, the impact on the eastern provinces of Spain (Murcia, Alicante, Valencia, Castellón, Tarragona and Barcelona) would be lesser but there would be a greater variability from one province to another.

Contrary to the flows and variations in tourists that will occur in the coming years, the data analysed in this study show that the Mediterranean coastal regions with a greater thermal discomfort are those in the north. This analysis reveals a clear gradient in the time trend of the CCI from the northern regions to the southernmost Mediterranean regions. From the summer decrease of -0.08 / decade of the Costa Brava to the -0.02 / decade of the Costa de la Luz.

The practice of mass sun and beach tourism cannot be understood without the conditions of sun and heat, and authors such as Besancenot (1985, 1989), Gómez-Martín (2005), Batista and Matos (2004), and De Freitas *et al.* (2008) coincide in giving greater importance to sunny and hot types of climate. Martínez Ibarra (2011) analysed the influence that thermal comfort, solar radiation, precipitation and wind speed have on the tourists who visit the beach on the east coast (Benidorm, Alicante), one with the greatest occupancy in Spain and with a lower deseasonalisation throughout the year. The results showed that the tourists most visited the beach with a wind speed of less than 8 m/s, with no rain and with thermal sensations or PET values (Physiological equivalent temperature) of between 35 and 41 (heat threshold). When a PET value of 41 (very hot) is reached or exceeded, the percentage of cases reduced considerably (25%).

According to *Hein et al.* (2009), the best conditions for practising sun and beach tourism (excellent) are found in the countries of the Europe Mediterranean Riviera, with large areas in Spain. According to the climate forecasts of the HadCM3-A1 (2051-2080) scenario, Spain would have favourable conditions on the Mediterranean coast and very good conditions on the Cantabrian coast. Excellent conditions would prevail on the French Brittany coast, the coasts of Germany and Denmark and the southern coast of the Baltic Sea. The conditions would be most favourable during the spring and autumn with good, very good and excellent categories. Finally, Jacob et al., (2018) conclude that between June and August, future negative impacts are forecast for the tourism activity in the south and east of Spain, with a potential reduction of between 2% and 8%, although this could be compensated by a probable increase in tourism on the northern coast of Spain. Furthermore, sea-level rise is a long-term, intractable problem during which costly, large-scale inundation could occur in many countries; hence, tourism development should take this matter into account because ecology and biodiversity are the fundamentals underpinning tourism performance (Yong, 2021).

5. Conclusions

The greatest CCI decreases throughout the year are recorded in the winter season (-0.11/decade) and are particularly relevant on the Costa Dorada - Azahar (0.14/decade). Here the reduction experienced by the northern part of the Costa Azahar (TA14) in the municipalities of Vinarós, Benicarló and Peñíscola during January (-0.20/decade) particularly stands out as it is the largest of the tourist areas analysed. This decrease has led to the change of cold conditions between 1941-1990 to cool-cold thresholds between 1971 and 2020 on the Atlantic coast of Galicia and Cantabria (C1 and C2). Currently, cool climate thresholds are registered in C3 and C4 (northern Mediterranean coast) and comfortable-cool on the rest of the Mediterranean coast. The number of days of cold climate thresholds has reduced considerably in recent decades, with decreases of up to 69 days on the Costa del Sol – Tropical (C8) or 63 days on the Costa Dorada – Azahar (C4). The trend of increasingly milder winters would be a very positive aspect for winter tourism, especially in Mediterranean coastal areas.

The changes experienced by the equinoctial seasons are also relevant, with reductions in the CCI of -0.06 in spring and -0.06 in autumn in the country as a whole. Particularly in the Mediterranean coastal sectors there has been a notable prolongation of the comfortable climate threshold, with an increase of up to 60 days on the Costa del Sol (C8) or 47 on the Costa Dorada – Azahar. For example, in the latter region, the comfort climate threshold has evolved from beginning in the second week of April in the time period 1941-1970 to beginning in the second week of March in that of 1991-2020. In other words, it starts one month earlier. This aspect is also tremendously positive for the tourist season outside of summer, with increasingly favourable weather conditions in the equinoctial months.

Summer is the season with the lowest decrease (-0.05), although it is statistically significant on the Cantabrian Coast – Euskal Kostaldea - C2 (-0.07), Costa Brava – El Garraf - C3 (-0.08) and Costa Cálida – Coast of Almería - C7 (-0.05). The greatest decreases (-0.09 to -0.10) are observed on the eastern part of the Costa Verde (TA4) in the municipalities of Ribadesella, Llanes or Villaviciosa). There is a clear gradient from a greater to lesser decrease from the Costa Brava – El Garraf (C3) to the Costa de la Luz (-0.02). As latitudes decrease along the peninsula Mediterranean coast until the Andalusian Atlantic coast, the CCI reduction becomes lower. Despite this, the changes experienced by the number of days with warm and heat climate thresholds is highly relevant, with increases of up to 54 days in the Canary Islands (C10). The increase in the number of hot days in the Canary Islands should be taken into account in future summer tourism planning for the coming years. The decrease in the CCI is mainly due to the increase in the average temperature in recent decades (0.02ºC / decade) as relative humidity and the average wind speed have hardly changed.

Finally, the analysis of the heat climate threshold shows a considerable expansion in terms of is duration through the year in the different coastal regions analysed (with the exception of the two northern coastal regions (C1 and C2) and the Canary Islands (C10)). In some coastal regions such as the Costa Dorada – Azahar (C4) the period has lengthened by 42.8 days, with the beginning of the heat threshold starting 12 days earlier (from 19 to 7 July) and the end date finishing 31 days later (from 2 August to 2 September). Without a doubt, the expansion of the warmest period of the year is one of the main conclusions of the analysis carried out, which should be taken into account for the coming years, especially with the increase in extreme thermal sensations of heat in the Mediterranean and the progressive comfort summer climate on the Galician and Cantabrian coasts.

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Annex

Time trend of the tourist areas (TA) analysed in the period 1940-2022. Values in bold are statistically significant (p value <0.01).

	ENE	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
TA1	**-0.08**	**-0.10**	**-0.11**	-0.03	**-0.09**	-0.03	0.00	-0.01	**-0.04**	-0.01	-0.03	**-0.09**
TA2	**-0.10**	**-0.13**	**-0.09**	**-0.07**	**-0.09**	**-0.05**	**-0.04**	**-0.05**	**-0.05**	**-0.07**	**-0.07**	**-0.14**
TA3	**-0.10**	**-0.09**	**-0.05**	**-0.05**	**-0.06**	**-0.05**	**-0.05**	**-0.06**	**-0.05**	**-0.09**	**-0.05**	**-0.12**
TA4	**-0.14**	**-0.13**	**-0.10**	**-0.11**	**-0.10**	-0.09	**-0.09**	**-0.10**	**-0.09**	**-0.12**	**-0.08**	**-0.17**
TA5	**-0.12**	**-0.11**	**-0.06**	**-0.08**	**-0.07**	**-0.06**	**-0.06**	**-0.08**	**-0.05**	**-0.11**	**-0.06**	**-0.16**
TA6	**-0.12**	**-0.11**	**-0.07**	**-0.08**	**-0.08**	**-0.07**	**-0.06**	**-0.09**	**-0.06**	**-0.11**	**-0.06**	**-0.16**
TA7	**-0.08**	**-0.05**	-0.03	-0.05	-0.05	-0.05	**-0.05**	**-0.07**	**-0.05**	**-0.09**	-0.03	**-0.11**
TA8	**-0.11**	**-0.10**	**-0.06**	-0.07	-0.07	**-0.07**	**-0.06**	**-0.08**	-0.05	**-0.09**	-0.05	**-0.14**
TA9	**-0.09**	**-0.06**	**-0.06**	**-0.03**	-0.05	-0.06	-0.06	-0.06	**-0.05**	**-0.05**	-0.03	**-0.09**
TA10	**-0.10**	**-0.10**	**-0.08**	**-0.05**	-0.08	-0.08	-0.07	**-0.08**	**-0.05**	**-0.07**	**-0.06**	**-0.10**
TA11	**-0.12**	**-0.13**	**-0.12**	**-0.07**	**-0.09**	-0.09	-0.07	**-0.09**	-0.05	**-0.09**	**-0.08**	**-0.12**
TA12	**-0.11**	**-0.10**	**-0.10**	**-0.07**	-0.08	**-0.09**	**-0.07**	**-0.08**	**-0.05**	**-0.06**	**-0.07**	**-0.10**
TA13	**-0.15**	**-0.14**	**-0.15**	**-0.08**	**-0.09**	**-0.09**	-0.05	**-0.08**	**-0.06**	**-0.11**	**-0.08**	**-0.13**
TA14	**-0.20**	**-0.16**	**-0.17**	**-0.08**	**-0.09**	**-0.09**	**-0.05**	**-0.08**	**-0.08**	**-0.12**	**-0.10**	**-0.14**
TA15	**-0.15**	**-0.14**	**-0.14**	**-0.09**	**-0.09**	**-0.09**	**-0.05**	**-0.09**	**-0.07**	**-0.12**	**-0.12**	**-0.12**
TA16	**-0.17**	**-0.15**	**-0.11**	**-0.08**	-0.06	-0.06	-0.04	-0.05	**-0.05**	**-0.12**	**-0.12**	**-0.14**
TA17	**-0.12**	**-0.09**	**-0.07**	-0.03	-0.06	-0.07	**-0.07**	**-0.07**	**-0.07**	**-0.09**	**-0.05**	**-0.10**
TA18	**-0.10**	**-0.07**	**-0.06**	**-0.04**	-0.06	**-0.08**	**-0.07**	**-0.07**	**-0.05**	**-0.08**	-0.04	**-0.08**
TA19	**-0.11**	**-0.10**	**-0.07**	**-0.06**	-0.05	-0.06	-0.05	-0.06	**-0.04**	**-0.10**	**-0.06**	**-0.11**
TA20	**-0.06**	**-0.05**	-0.02	**-0.03**	-0.05	**-0.07**	**-0.07**	**-0.06**	-0.04	**-0.06**	-0.01	**-0.07**
TA21	**-0.10**	**-0.07**	-0.05	-0.04	-0.04	-0.06	**-0.06**	**-0.06**	**-0.05**	**-0.07**	**-0.06**	**-0.08**
TA22	**-0.16**	**-0.12**	**-0.09**	**-0.06**	-0.05	-0.07	-0.04	-0.06	**-0.05**	**-0.12**	**-0.09**	**-0.13**
TA23	**-0.17**	**-0.11**	-0.06	**-0.06**	-0.05	-0.07	**-0.06**	**-0.07**	**-0.07**	**-0.12**	**-0.10**	**-0.12**
TA24	**-0.13**	**-0.08**	-0.04	-0.04	-0.05	**-0.06**	**-0.06**	**-0.07**	**-0.06**	**-0.08**	**-0.09**	**-0.09**
TA25	**-0.12**	**-0.08**	-0.06	-0.05	**-0.06**	-0.06	**-0.05**	**-0.06**	**-0.05**	**-0.09**	**-0.10**	**-0.10**
TA26	**-0.09**	**-0.09**	**-0.06**	-0.03	**-0.08**	-0.06	**-0.04**	**-0.06**	**-0.05**	**-0.09**	**-0.08**	**-0.09**
TA27	**-0.11**	**-0.11**	**-0.07**	-0.04	**-0.08**	-0.07	-0.04	-0.05	**-0.04**	**-0.09**	**-0.08**	**-0.10**
TA28	**-0.09**	**-0.08**	**-0.08**	-0.04	**-0.08**	-0.06	-0.02	-0.05	-0.02	**-0.08**	**-0.05**	**-0.08**
TA29	**-0.10**	**-0.07**	**-0.09**	**-0.04**	-0.06	-0.05	-0.01	-0.03	-0.02	**-0.07**	**-0.07**	**-0.09**
TA30	**-0.09**	**-0.06**	**-0.08**	-0.02	-0.06	-0.05	-0.01	-0.03	-0.02	**-0.07**	**-0.05**	**-0.08**
TA31	**-0.09**	**-0.05**	**-0.08**	-0.02	**-0.07**	-0.05	-0.01	**-0.04**	**-0.03**	**-0.06**	**-0.06**	**-0.08**
TA32	**-0.08**	**-0.08**	**-0.11**	-0.02	**-0.08**	-0.03	-0.02	-0.02	-0.03	**-0.07**	**-0.05**	**-0.07**
TA33	**-0.10**	**-0.07**	-0.05	-0.04	-0.04	-0.06	**-0.06**	**-0.06**	**-0.05**	**-0.07**	**-0.06**	**-0.08**
TA34	**-0.04**	-0.02	0.00	**-0.04**	**-0.05**	**-0.04**	-0.02	**-0.03**	**-0.06**	**-0.04**	**-0.05**	**-0.05**
TA35	**-0.08**	-0.04	-0.03	-0.01	**-0.04**	-0.04	-0.01	-0.02	-0.01	-0.06	**-0.07**	**-0.06**
TA36	**-0.04**	0.00	0.01	0.01	-0.01	-0.02	**-0.03**	**-0.04**	-0.01	-0.01	-0.02	-0.03
TA37	-0.03	-0.01	0.01	**-0.03**	-0.02	**-0.04**	**-0.02**	**-0.03**	**-0.05**	**-0.04**	**-0.03**	**-0.04**