



Universitat
de les Illes Balears



Assessment of the future climate potential for tourism over Spain using a combination of downscaling approaches and quantitative impact models

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1. Motivations

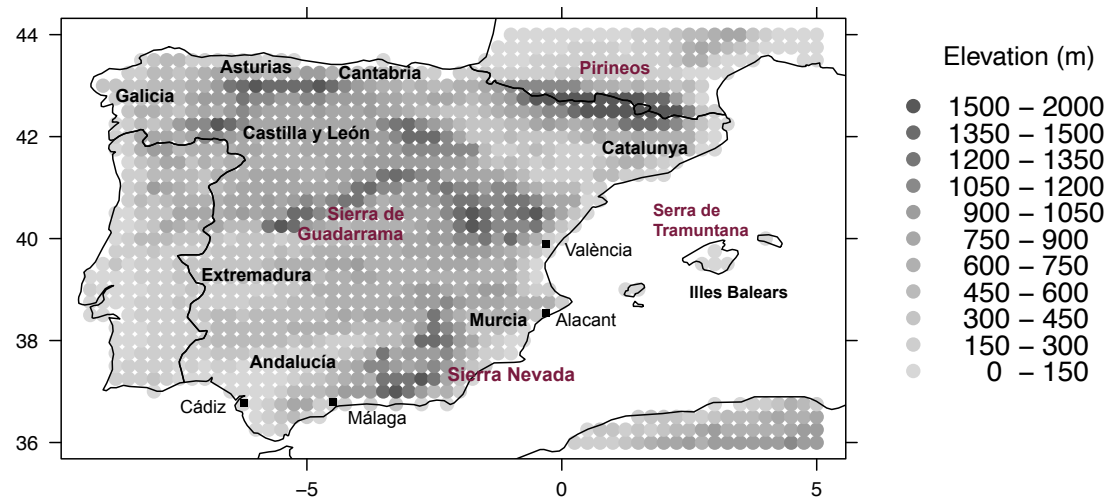
- **The Mediterranean region** is among the preferred worldwide tourist destinations and it is a highly sensitive area to climate change impacts (Stocker et al., 2013).
- According to the UNWTO (2018), **Spain** occupied the **2nd place** in the ranking of **international tourism destinations** with **81.8 million arrivals** and **68\$ US billion receipts** only in 2017.

*The weather conditions and environmental assets of Spain enable the development of **several types of tourism**, in addition to the 3S tourism (sun, sea and sand)*



1. Motivations

Climate change will unequally affect tourist activities as they require different weather conditions and show quite diverse physical demand (Bafaluy et al., 2013).



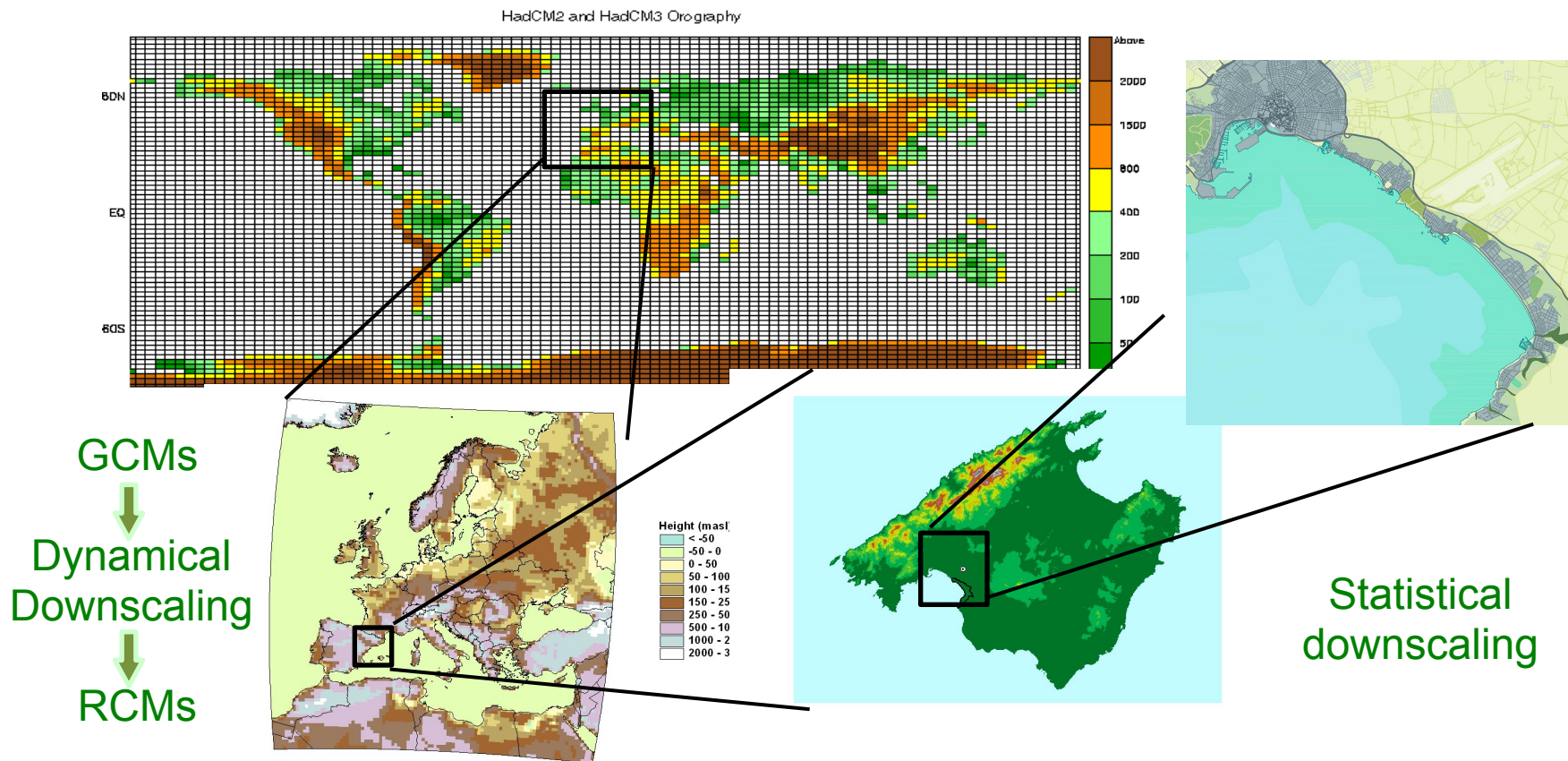
Tourist activity	High season	Number of visitors per year	Spent money (M€/year)	Most visited region
Cultural	All	14,5 million	15.348	Catalunya, Illes Balears and València
Sailing	Summer	1.562 registrations	NA	Illes Balears, Catalunya and València
Golf	Spring	1.6 million	4.640	Andalucía, Castilla y León and Catalunya
Hiking	Spring and autumn	1/2 million	3.283	Pirineos and Serra de Tramuntana (Mallorca)
Cycling	Spring and autumn	160.000*	2.258	Mallorca, Catalunya València and Andalucía
Football	Winter	200 teams	NA	Málaga and Cádiz (Andalucía), Murcia and Alacant

Table 1: Available information about the main socio-economic aspects related to each kind of tourist activity in Spain. *Data correspond only to the Mallorca Island. NA stands for data not available.

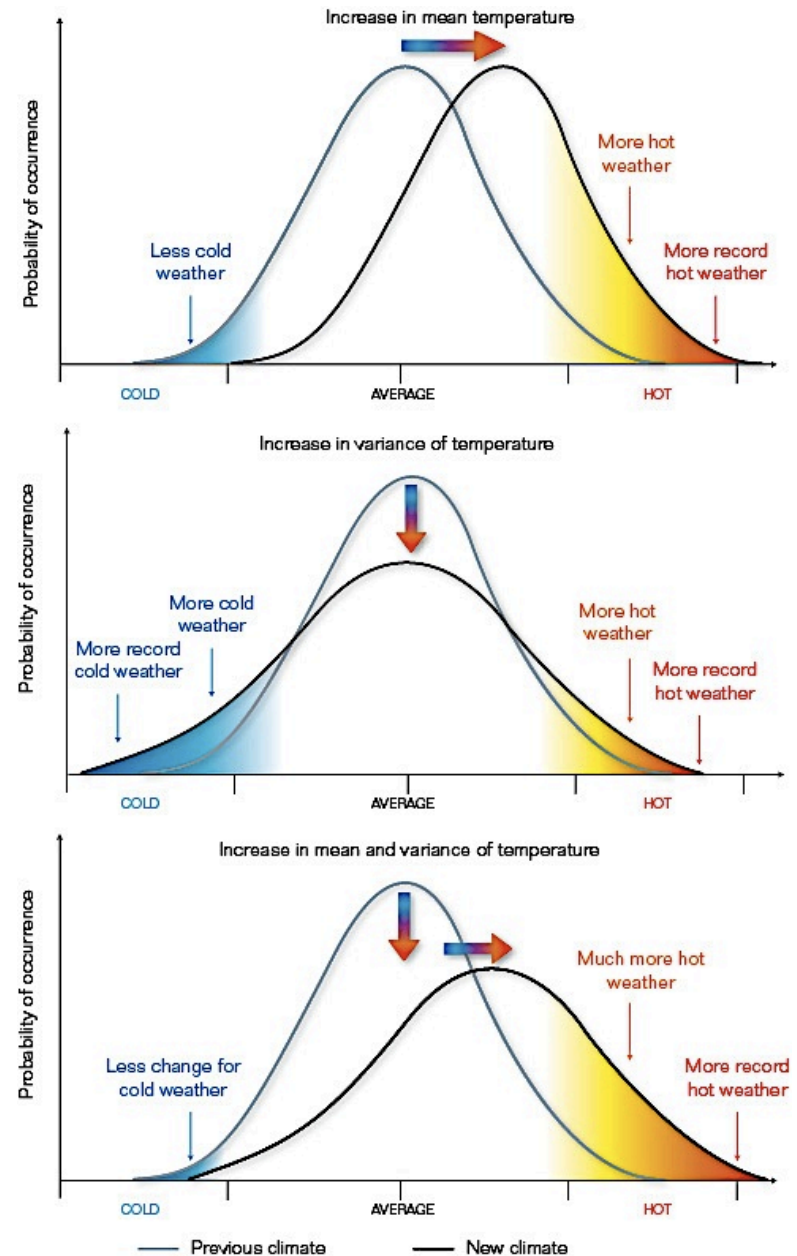
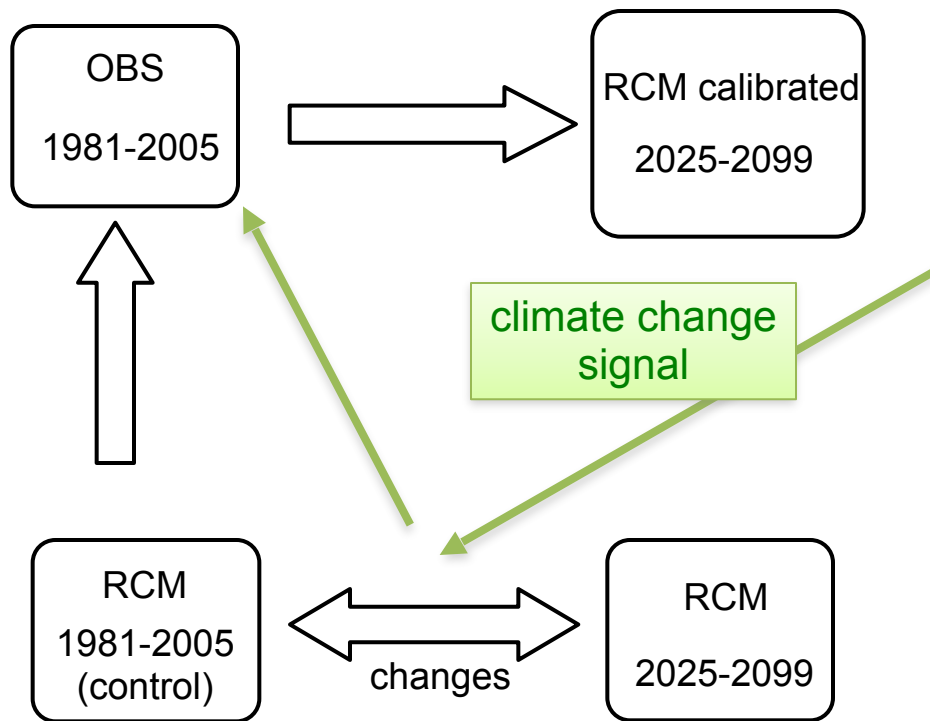
Tools for exploring climate change impacts

GCMs → RCMs

- **Regional scales:** Dynamical downscaling. Regional Climate Model (RCMs).
- **Local scales:** Statistical downscaling and model calibration from RCMs.



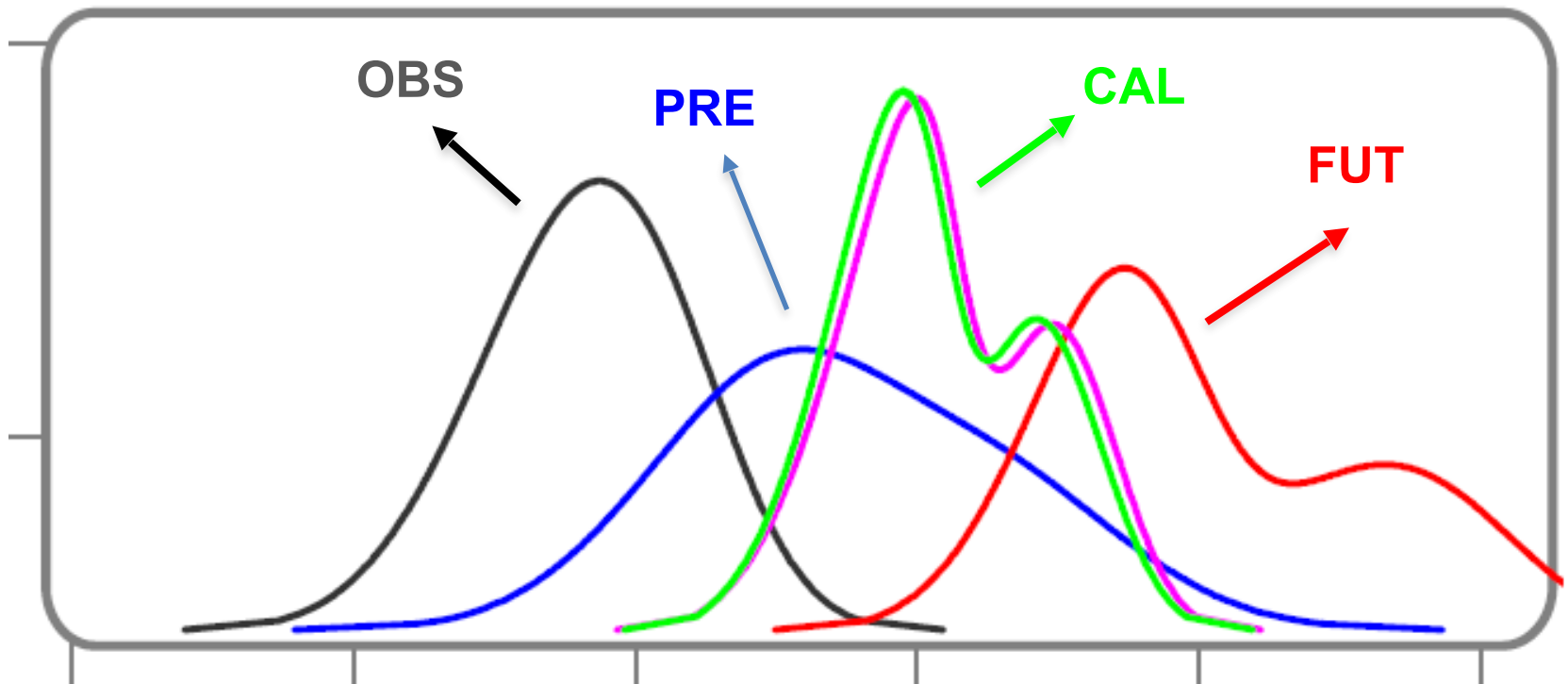
Statistical downscaling of RCM outputs



Quantile-Quantile adjustment

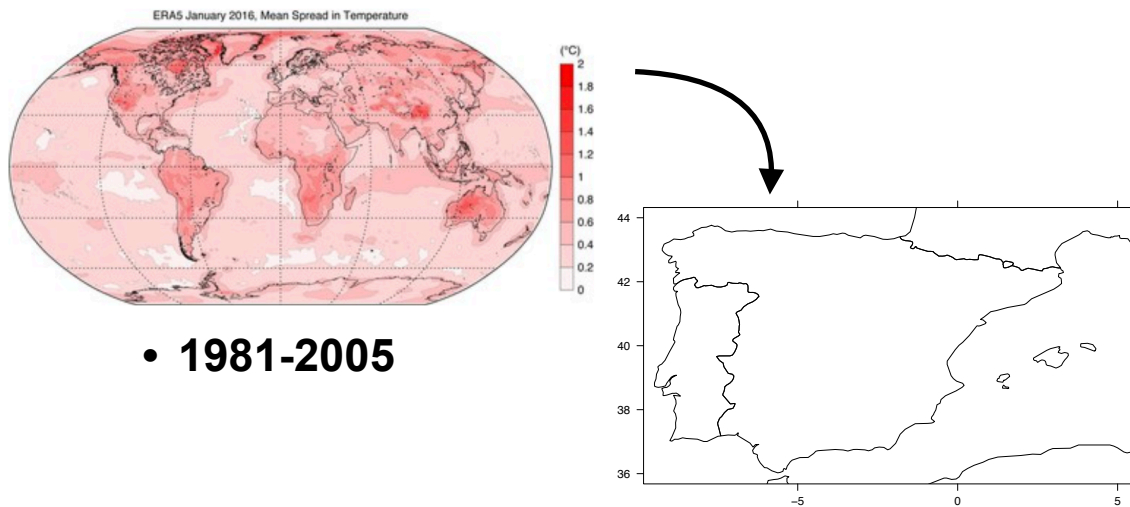
(Cardell et al. 2019)

$$p_i = o_i + g\bar{\Delta} + f\Delta'_i,$$

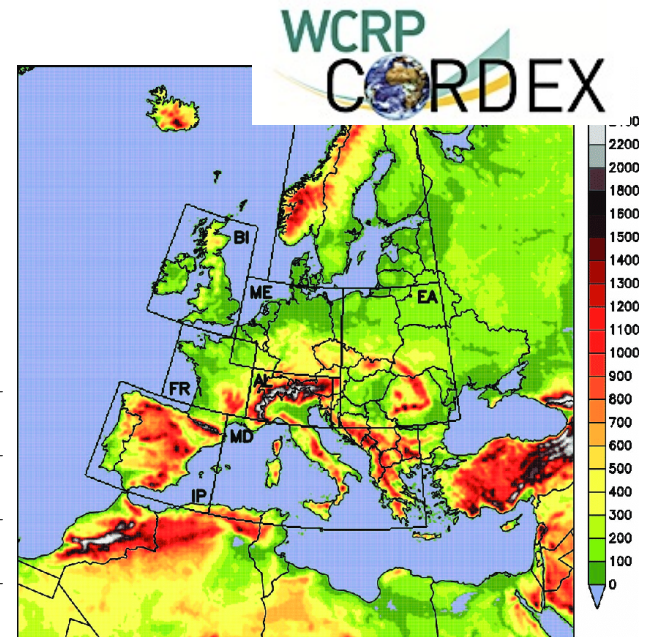


2. Database and methodology

ERA5 (31 km)



EURO-CORDEX (12,5 km)



Future regional scenarios **rcp8.5**

Daily series of **surface**:

1. Maximum temperature
2. Total precipitation
3. Mean wind speed
4. Mean fraction of cloud cover
5. Mean relative humidity

Changes in calibrated CDFs between a 25-year past (i.e. control/observed; 1981-2005) and successive 25-year RCM time-slices (2021-2045; 2046-2070; **2071-2095**).

Driving GCM

RCM

Institute

EC-EARTH

HIRHAM5

DMI

2. Database and methodology

- Weather typology matrices for the different kinds of tourism and Climate Index for Tourism (CIT) rating scale

(a) Cycling		ASHRAE scale TSN [T]	Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (≥10mm/d) [P]	Wind (≥8m/s) [P]
Cycling	Very hot (+4)	3	2	3	2	2
	Hot (+3)	4	3	3	2	2
	Warm (+2)	6	5	4	2	2
	Slightly warm (+1)	7	7	4	3	2
	Indifferent (0)	7	6	4	2	2
	Slightly cool (-1)	6	5	3	2	2
	Cool (-2)	5	4	3	1	1
	Cold (-3)	4	3	2	1	1
	Very cold (-4)	3	2	1	1	1
(b) Cultural		ASHRAE scale TSN [T]	Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (≥5mm/d) [P]	Wind (≥10m/s) [P]
Cultural	Very hot (+4)	3	3	2	2	2
	Hot (+3)	4	3	3	3	3
	Warm (+2)	6	5	4	4	4
	Slightly warm (+1)	7	6	4	4	4
	Indifferent (0)	7	6	4	4	4
	Slightly cool (-1)	6	5	4	4	4
	Cool (-2)	5	4	3	3	3
	Cold (-3)	4	4	2	2	2
	Very cold (-4)	3	2	1	1	1
(c) Football		ASHRAE scale TSN [T]	Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (≥10mm/d) [P]	Wind (≥8m/s) [P]
Football	Very hot (+4)	3	3	2	2	2
	Hot (+3)	4	4	3	2	2
	Warm (+2)	6	6	4	3	2
	Slightly warm (+1)	7	7	5	4	3
	Indifferent (0)	7	7	4	3	3
	Slightly cool (-1)	6	6	3	2	2
	Cool (-2)	5	5	2	1	1
	Cold (-3)	4	4	1	1	1
	Very cold (-4)	3	3	1	1	1
(d) Golf		ASHRAE scale TSN [T]	Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (≥10mm/d) [P]	Wind (≥4m/s) [P]
Golf	Very hot (+4)	3	2	3	1	1
	Hot (+3)	5	4	3	1	1
	Warm (+2)	6	5	4	2	2
	Slightly warm (+1)	7	6	4	2	2
	Indifferent (0)	7	6	4	3	3
	Slightly cool (-1)	6	5	3	2	2
	Cool (-2)	5	4	3	2	2
	Cold (-3)	4	3	2	1	1
	Very cold (-4)	3	2	1	1	1
(e) Hiking		ASHRAE scale TSN [T]	Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (≥5mm/d) [P]	Wind (≥10m/s) [P]
Hiking	Very hot (+4)	3	3	2	2	2
	Hot (+3)	4	3	3	3	3
	Warm (+2)	6	5	4	4	4
	Slightly warm (+1)	7	6	4	4	4
	Indifferent (0)	7	6	4	4	4
	Slightly cool (-1)	6	5	4	4	4
	Cool (-2)	5	4	3	3	3
	Cold (-3)	4	4	2	2	2
	Very cold (-4)	3	2	1	1	1
(f) Sailing		ASHRAE scale TSN [T]	Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (≥20mm/d) [P]	Wind (≤1.5 or ≥15m/s) [P]
Sailing	Very hot (+4)	5	4	3	1	1
	Hot (+3)	6	5	3	2	2
	Warm (+2)	7	6	4	2	2
	Slightly warm (+1)	7	6	4	3	3
	Indifferent (0)	6	5	4	2	2
	Slightly cool (-1)	5	4	2	2	2
	Cool (-2)	4	3	2	1	1
	Cold (-3)	3	2	1	1	1
	Very cold (-4)	2	1	1	1	1

CIT						
1	2	3	4	5	6	7
Unacceptable			Acceptable		Ideal	

De Freitas et al., (2008)

Bafaluy et al., (2013)

- Universal Thermal Climate Index (UTCI)

UTCI (°C) range	Stress Category
above +46	extreme heat stress
+38 to +46	very strong heat stress
+32 to +38	strong heat stress
+26 to +32	moderate heat stress
+9 to +26	no thermal stress
+9 to 0	slight to moderate cold stress
0 to -13	strong cold stress
-13 to -27	strong cold stress
-27 to -40	very strong cold stress
below -40	extreme cold stress

The UTCI (in degree Celsius) is defined as the air temperature (T_a) of the reference condition causing the same human body response as actual conditions.

Sailing	ASHRAE scale TSN [T]	Cloud (<45%) [A]	Cloud (≥45%) [A]	Rain (≥20mm/d) [P]	Wind (≤1.5 or ≥15m/s) [P]
	Very hot (+4)	5	4	3	1
	Hot (+3)	6	5	3	2
	Warm (+2)	7	6	4	2
	Slightly warm (+1)	7	6	4	3
	Indifferent (0)	6	5	4	2
	Slightly cool (-1)	5	4	2	2
	Cool (-2)	4	3	2	1
	Cold (-3)	3	2	1	1
	Very cold (-4)	2	1	1	1

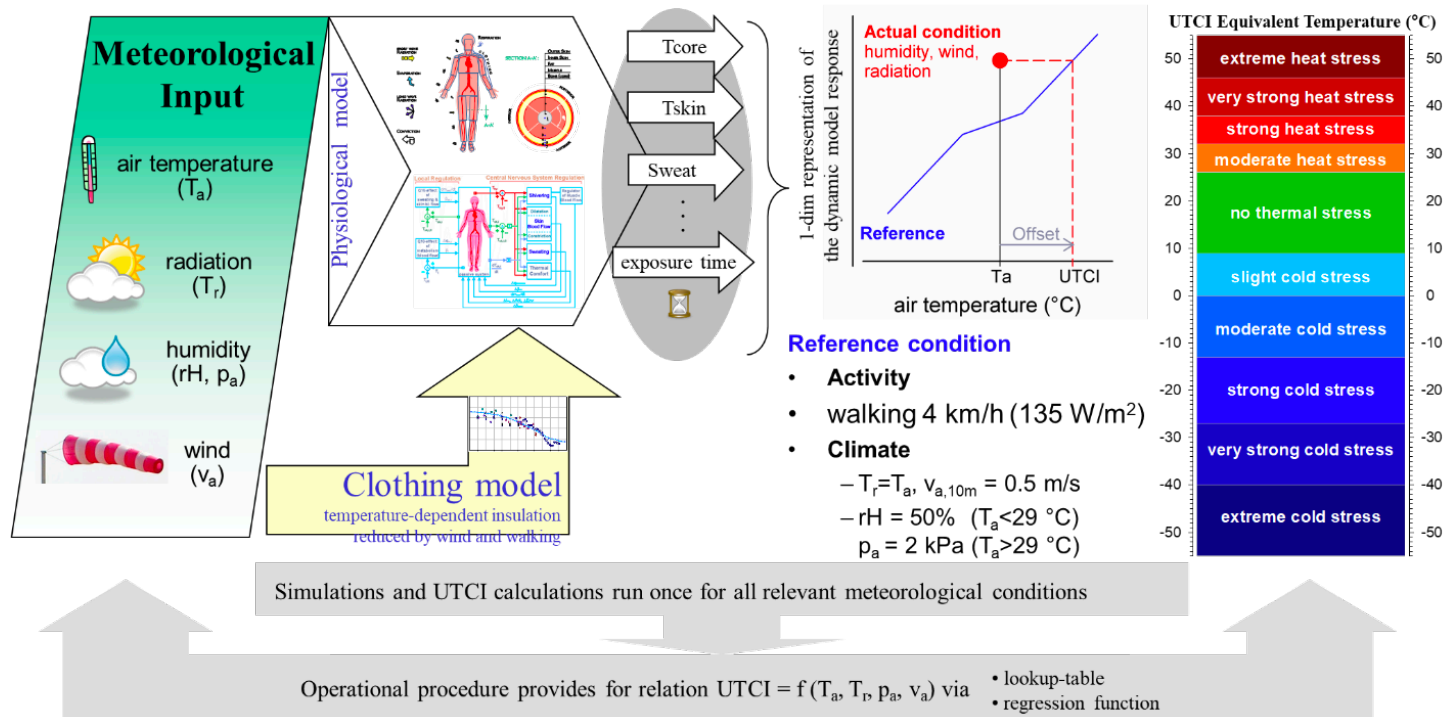
2. Database and methodology

Quantitative analysis of thermal system performance, human comfort and physiological response in:



- Architecture
- Automotive/aerospace industries
- Clothing research
- Medical engineering
- Biometeorology

- **UTCI-FIALA Model** was created and adapted for UTCI purposes to predict human thermophysiological and calorimetric responses to **outdoor weather conditions** using readily available meteorological data (Fiala et al., 2012)



- **RayMan Pro** A tool for Applied Climatology. Modelling of Mean Radiant Temperature and Thermal Indices

- **UTCI-FIALA Model**

Initial conditions. Thermo-neutral physiological conditions. A steady state exposure of a reclining (nude) person to an environment of 30°C, still air, no thermoregulation.

Simulated person. An average (35 years old, unisex) person weighting 71.4 kg, 169.7 cm tall, with a skin surface area of 1.83 m², and body fat content of 22.6% (16.17 kg in total), and an average body density of 1.05 g/cm³.

Air exposure boundary conditions

- **Mean radiant temperature**
- **Sun elevation**
- **Direct and diffuse solar radiation**
- Maximum temperature
- Mean relative humidity
- Mean wind speed

- **Time exposure (120 min, 25 time steps of 5 min)**
- Clothing
- Activity level (met)

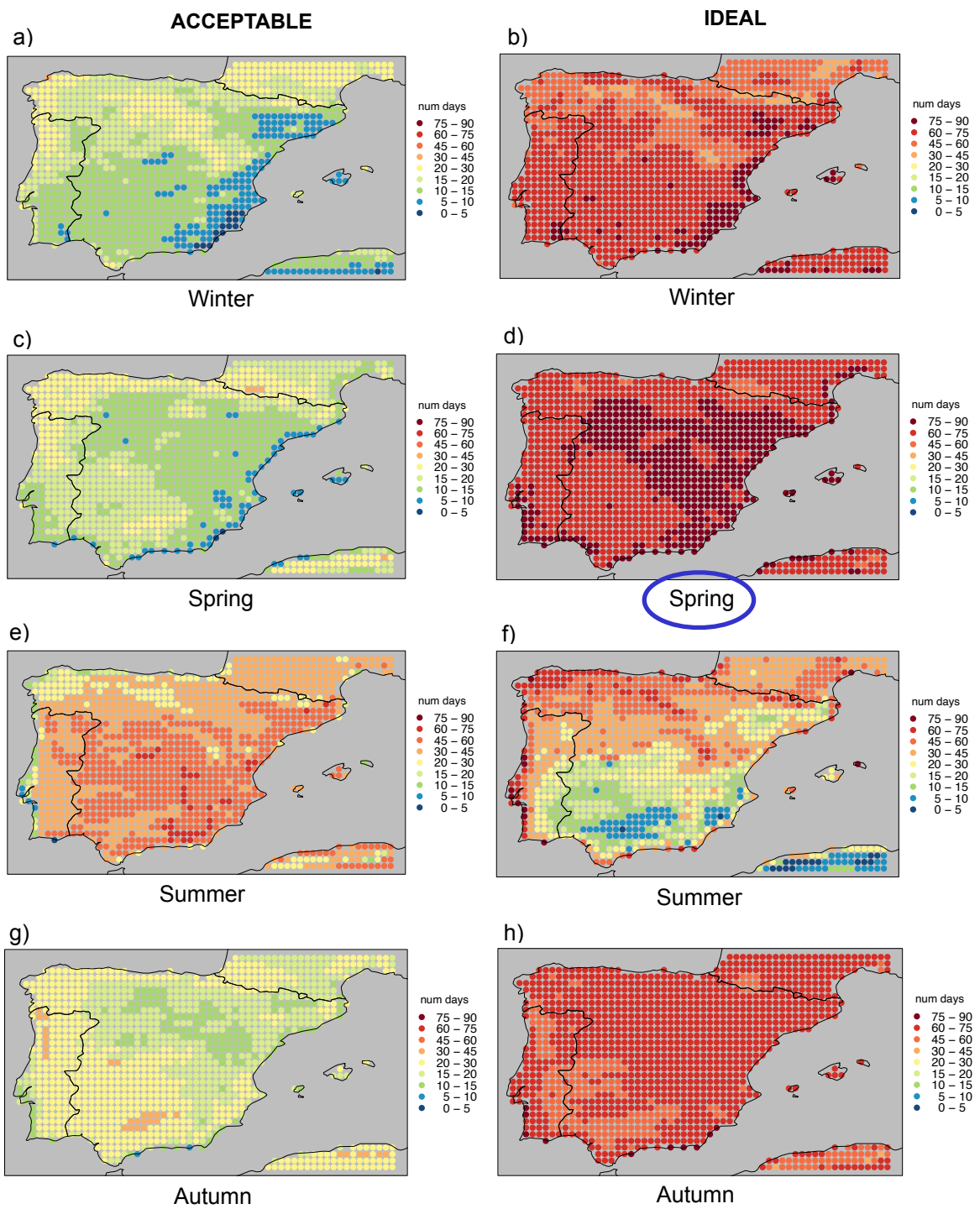
	CULTURAL	SAILING	GOLF	HIKING	CYCLING	FOOTBALL
Activity level (met)	2.0	2.5	2.5	3.0	4.0	5.0
Clothing insulation	0.5	0.3	0.4	0.3	0.3	0.3

3. Results

CULTURAL

Present climate potential

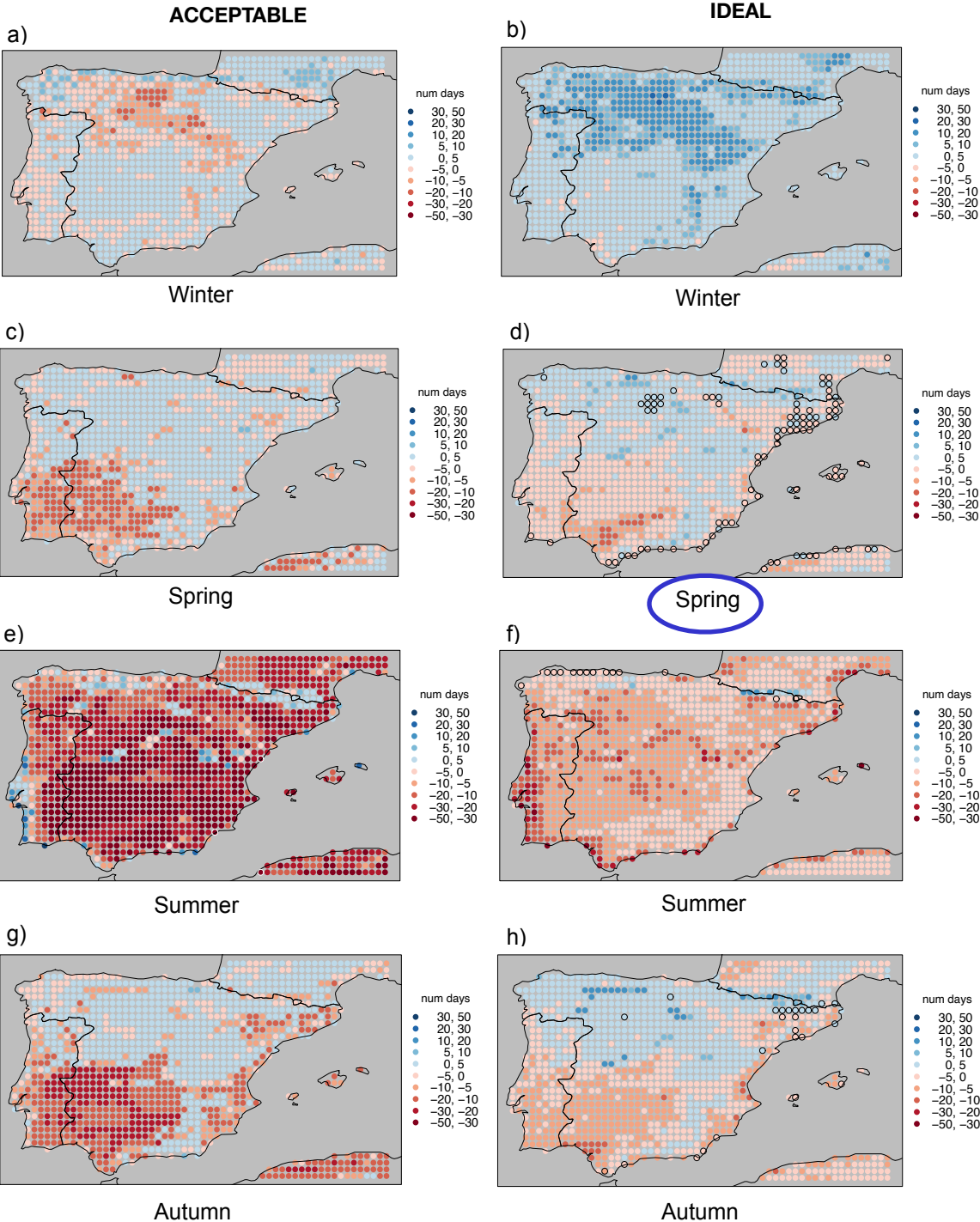
CIT						
1	2	3	4	5	6	7
Unacceptable			Acceptable		Ideal	



3. Results

CULTURAL Future change in climate potential

CIT						
1	2	3	4	5	6	7
Unacceptable			Acceptable		Ideal	

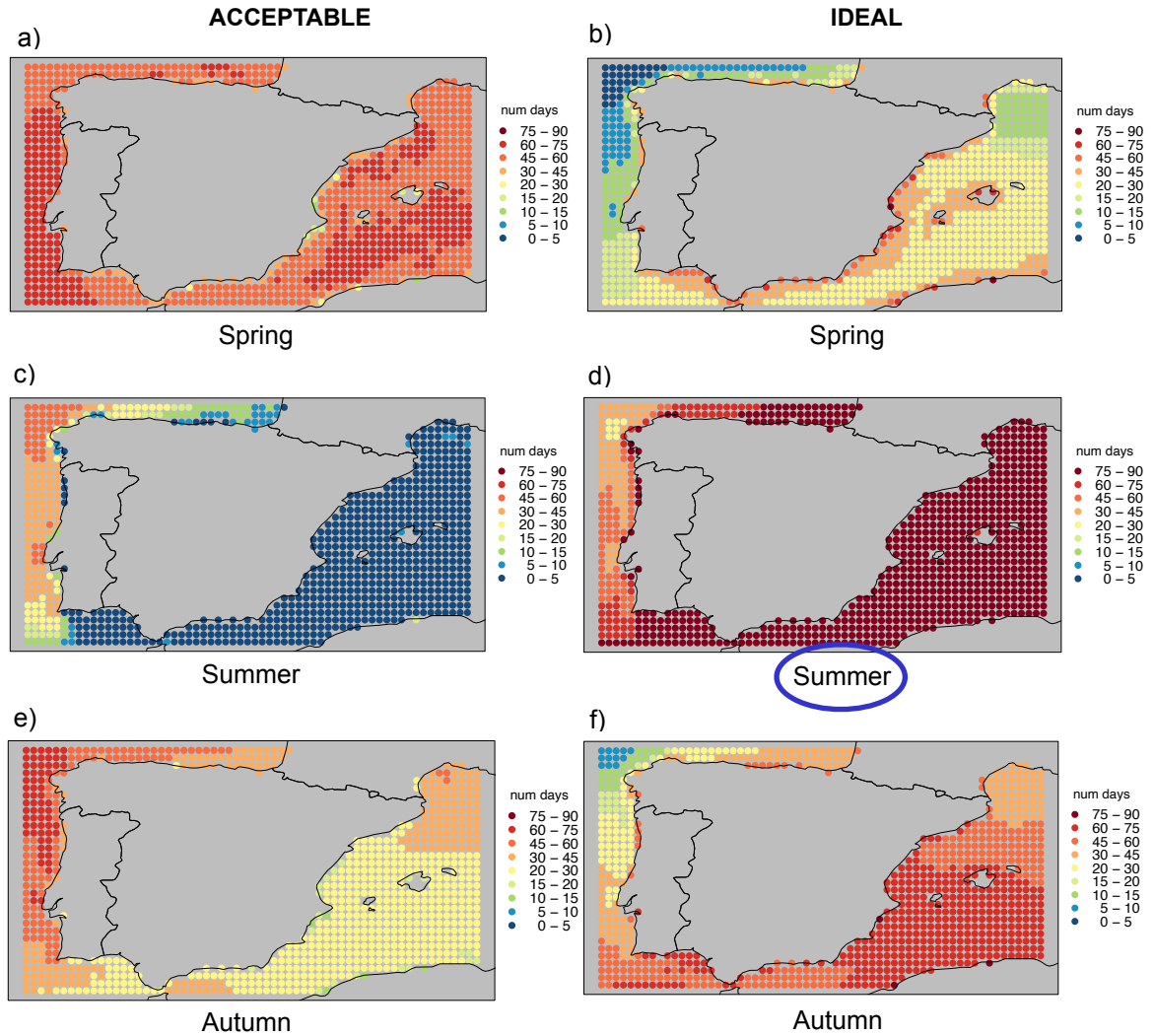


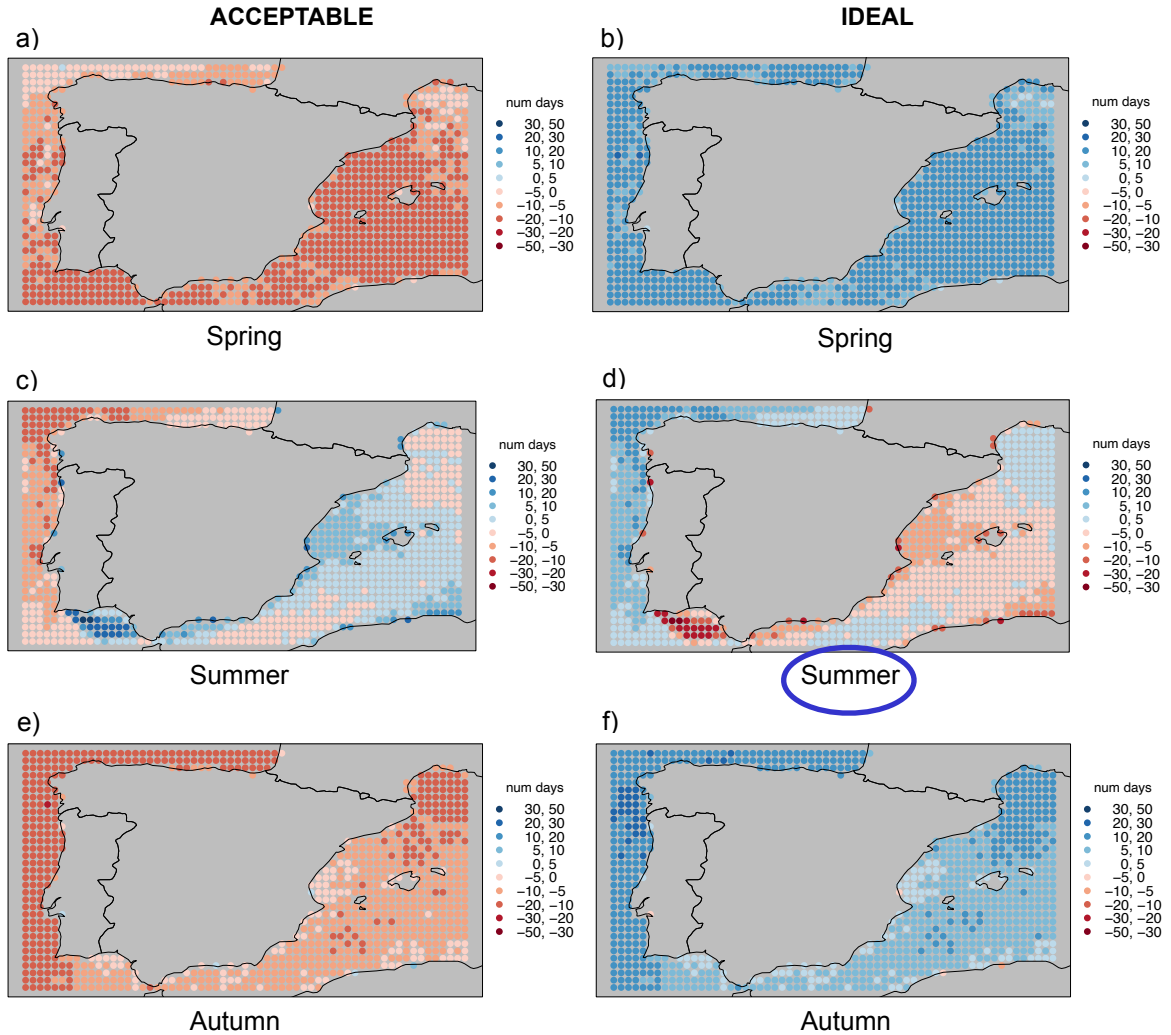
3. Results

SAILING

Present climate potential

CIT						
1	2	3	4	5	6	7
Unacceptable			Acceptable		Ideal	

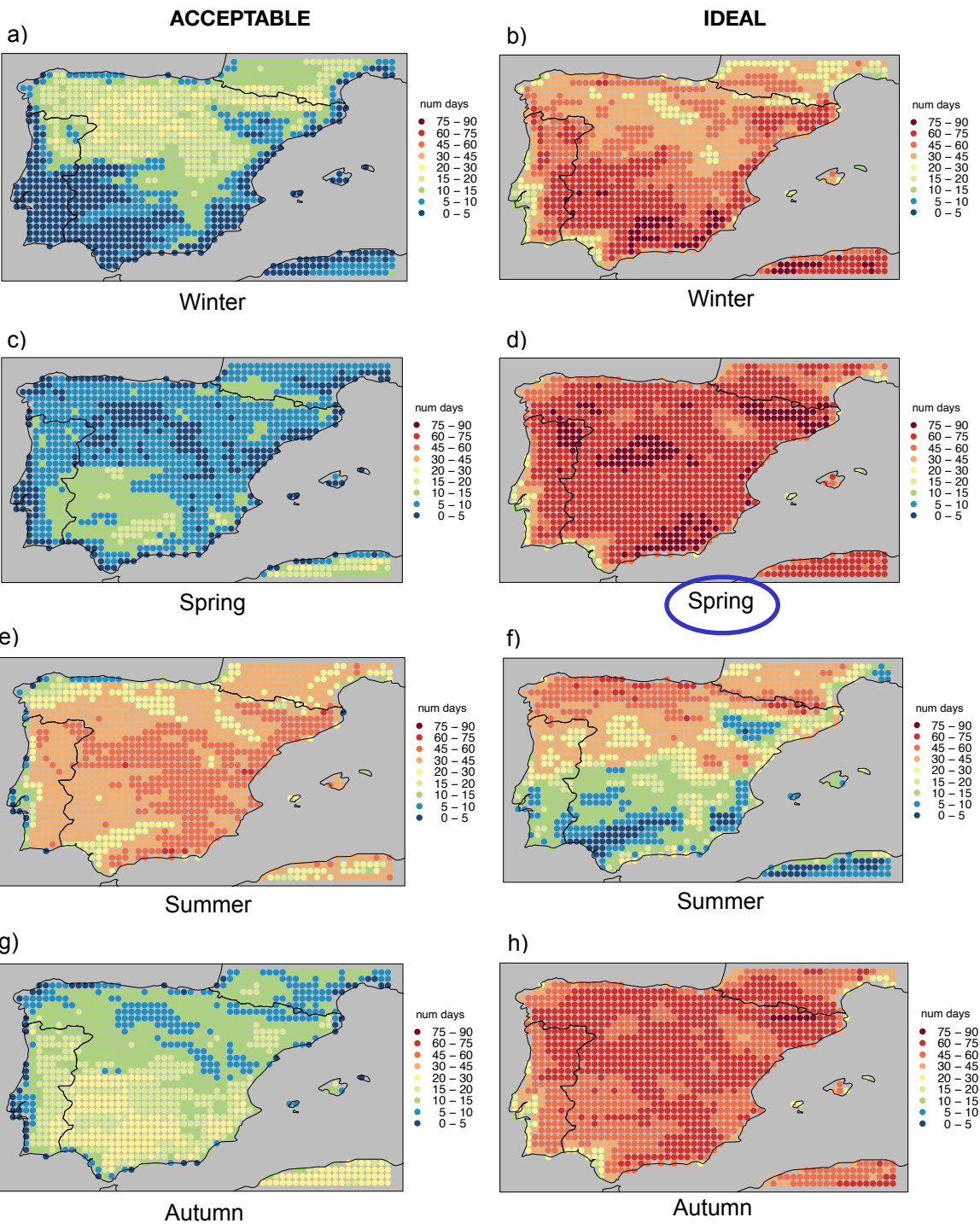




3. Results

GOLF Present climate potential

CIT						
1	2	3	4	5	6	7
Unacceptable			Acceptable		Ideal	

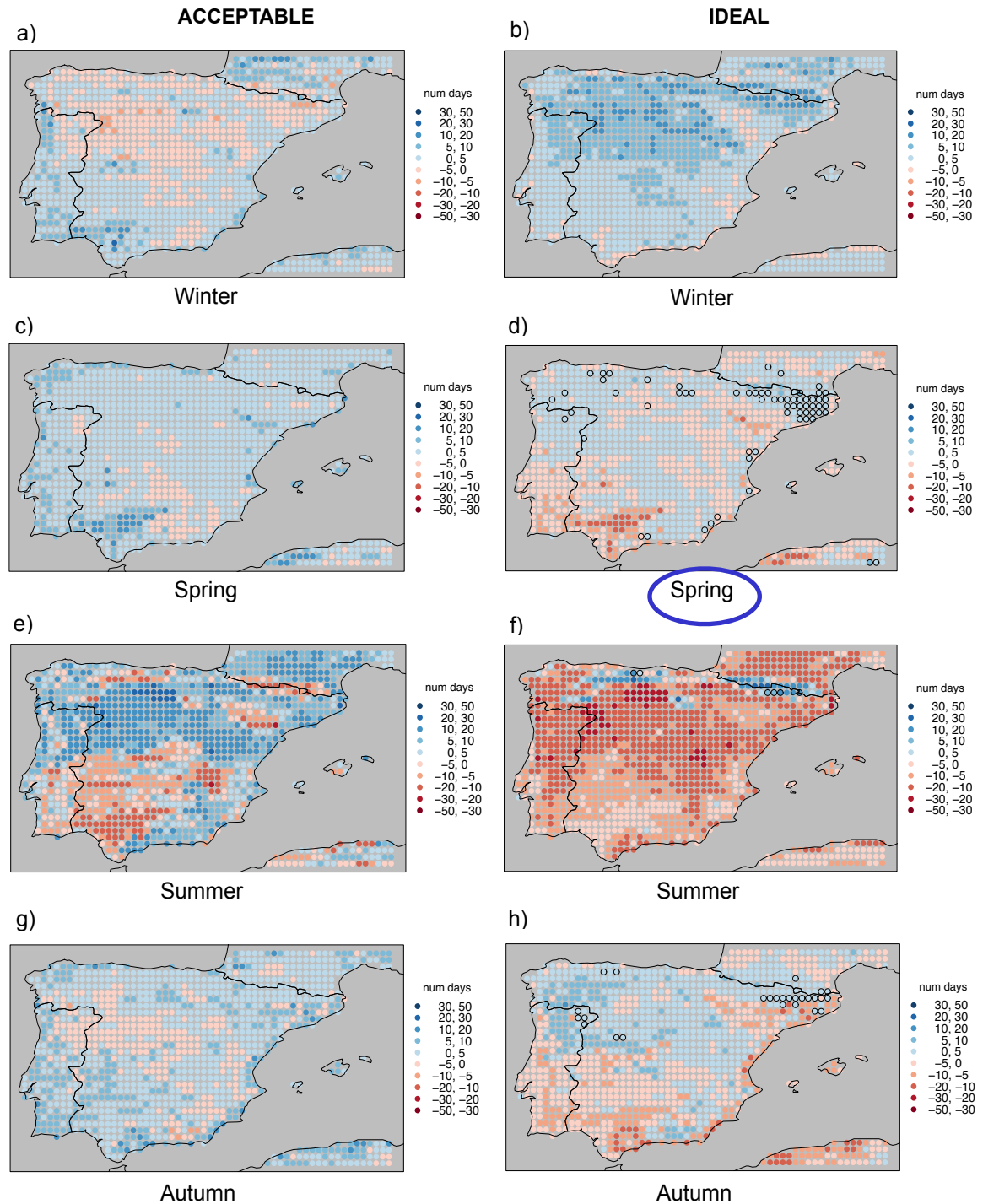


3. Results

GOLF

Future change
in climate potential

CIT						
1	2	3	4	5	6	7
Unacceptable			Acceptable		Ideal	

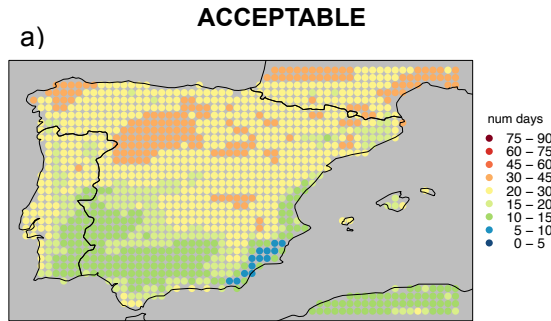


3. Results

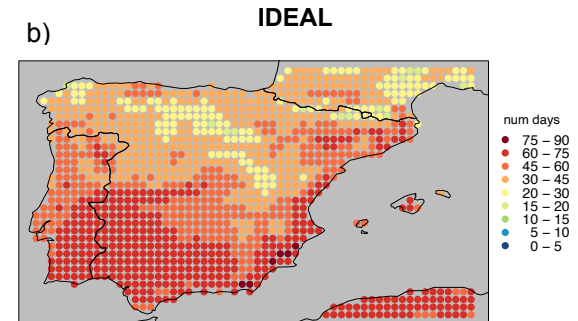
HIKING

Present climate potential

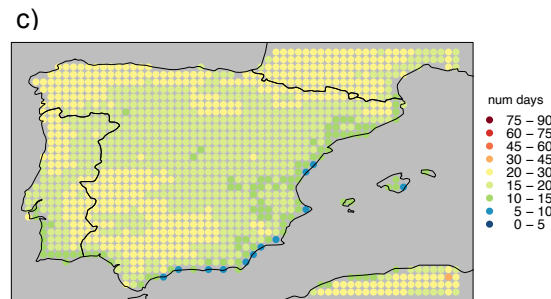
CIT						
1	2	3	4	5	6	7
Unacceptable			Acceptable		Ideal	



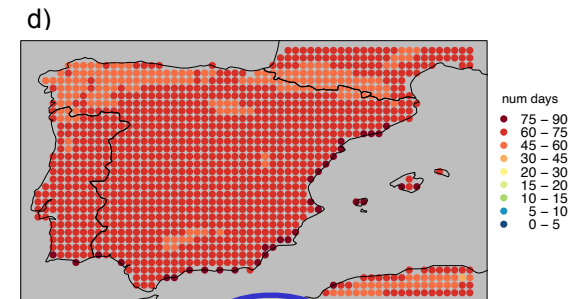
Winter



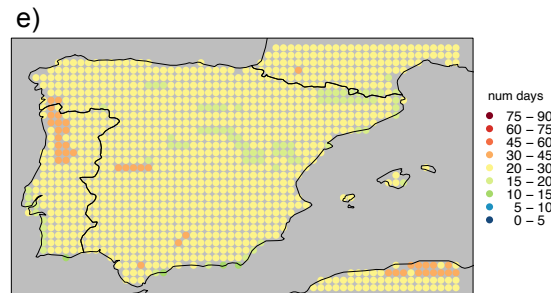
Winter



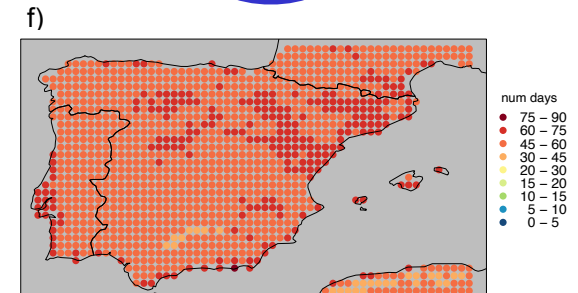
Spring



Spring



Autumn



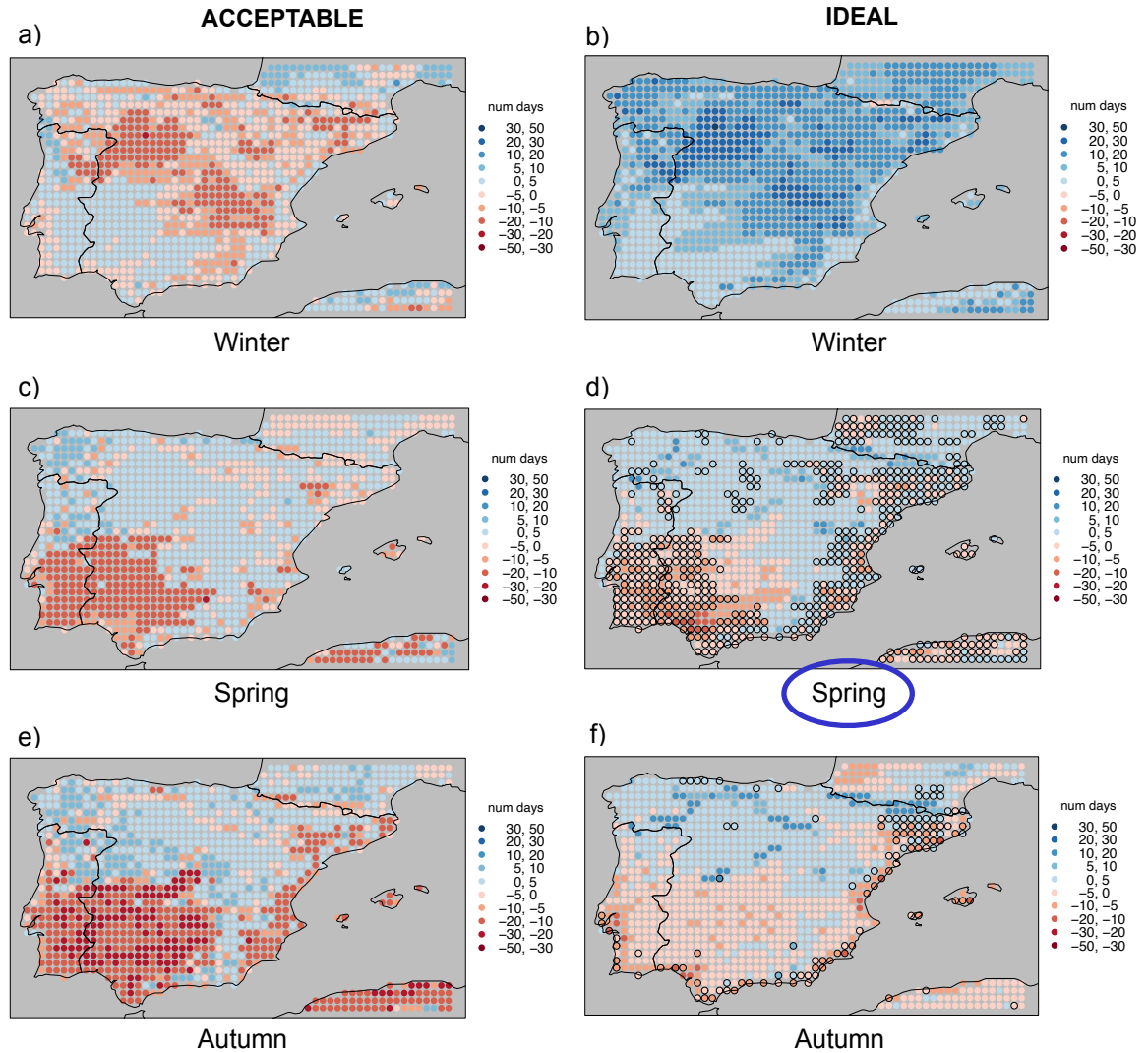
Autumn

3. Results

HIKING

Future change
in climate potential

CIT						
1	2	3	4	5	6	7
Unacceptable			Acceptable		Ideal	

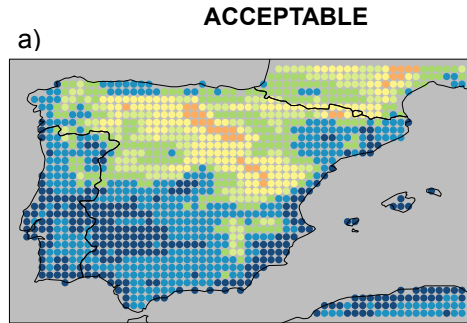


3. Results

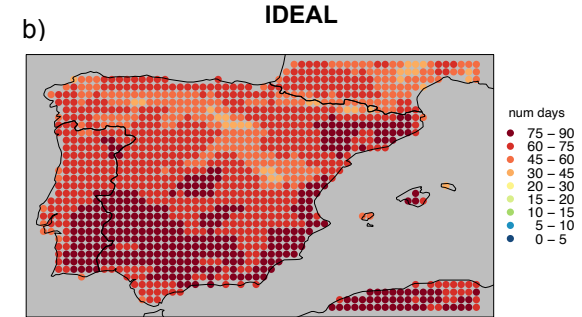
CYCLING

Present climate potential

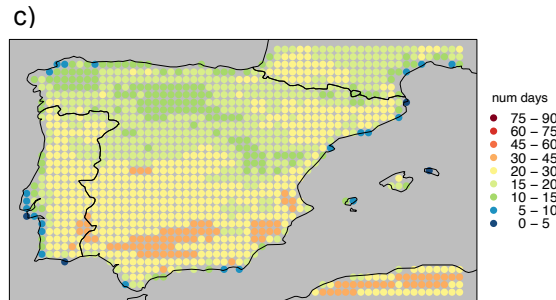
CIT						
1	2	3	4	5	6	7
Unacceptable			Acceptable		Ideal	



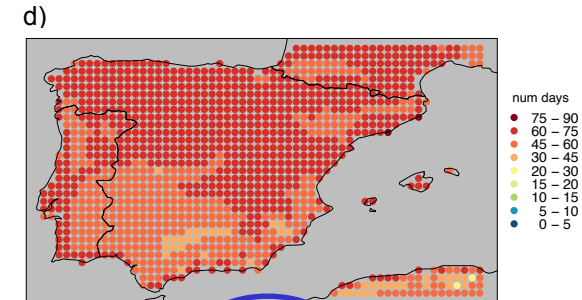
Winter



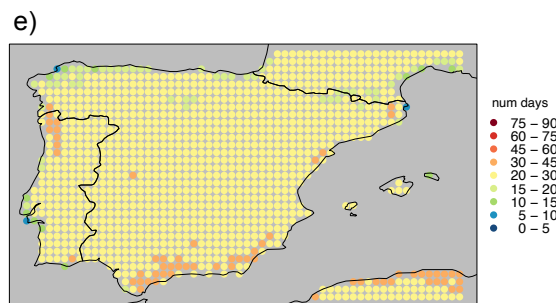
Winter



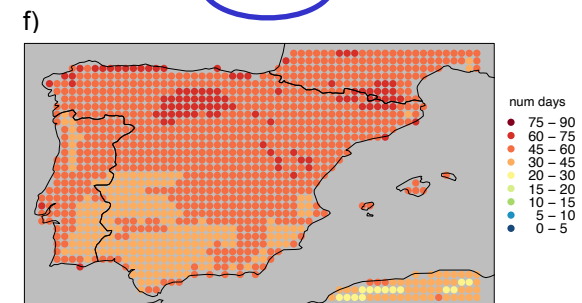
Spring



Spring



Autumn



Autumn

Figure 1 displays six maps of Spain, arranged in a 3x2 grid, showing the number of days with different temperature ranges for acceptable and ideal conditions in winter, spring, and autumn. The maps are labeled a) through f).

The maps are organized by season (rows) and condition (columns):

- Row 1 (Winter):** a) ACCEPTABLE, b) IDEAL
- Row 2 (Spring):** c) ACCEPTABLE, d) IDEAL
- Row 3 (Autumn):** e) ACCEPTABLE, f) IDEAL

Each map shows the number of days (num days) for various temperature ranges (num days) across the country. The legend for each map indicates the temperature ranges and the corresponding number of days:

- num days: 30, 50; 20, 30; 10, 20; 5, 10; 0, 5; -5, 0; -10, -5; -20, -10; -30, -20; -50, -30

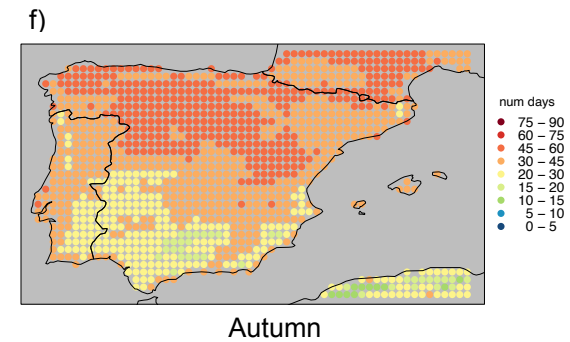
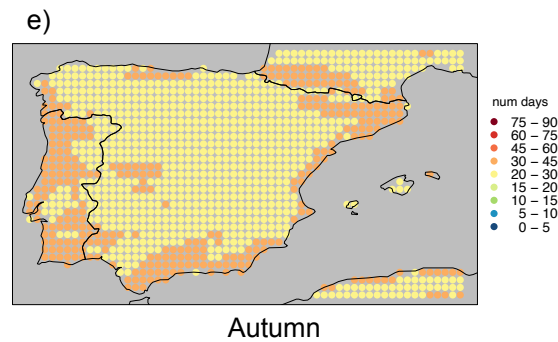
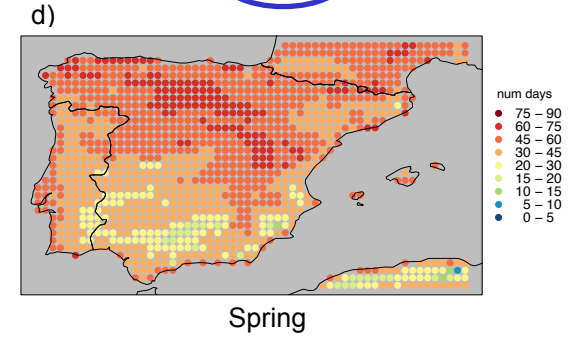
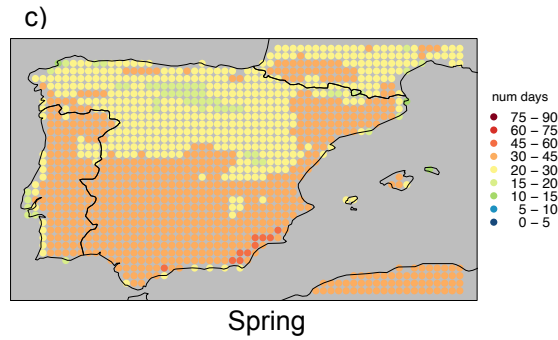
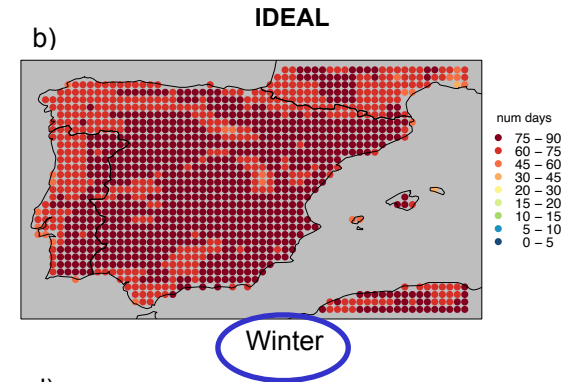
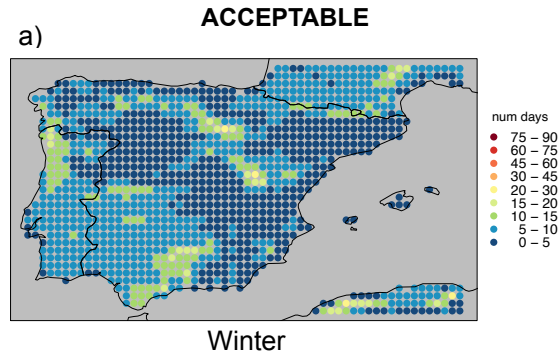
The maps show that the number of days with acceptable conditions (a, c, e) is generally lower than the number of days with ideal conditions (b, d, f) across all seasons. The 'Spring' map (d) has a blue circle around the word 'Spring'.

3. Results

FOOTBALL

Present climate potential

CIT						
1	2	3	4	5	6	7
Unacceptable			Acceptable		Ideal	

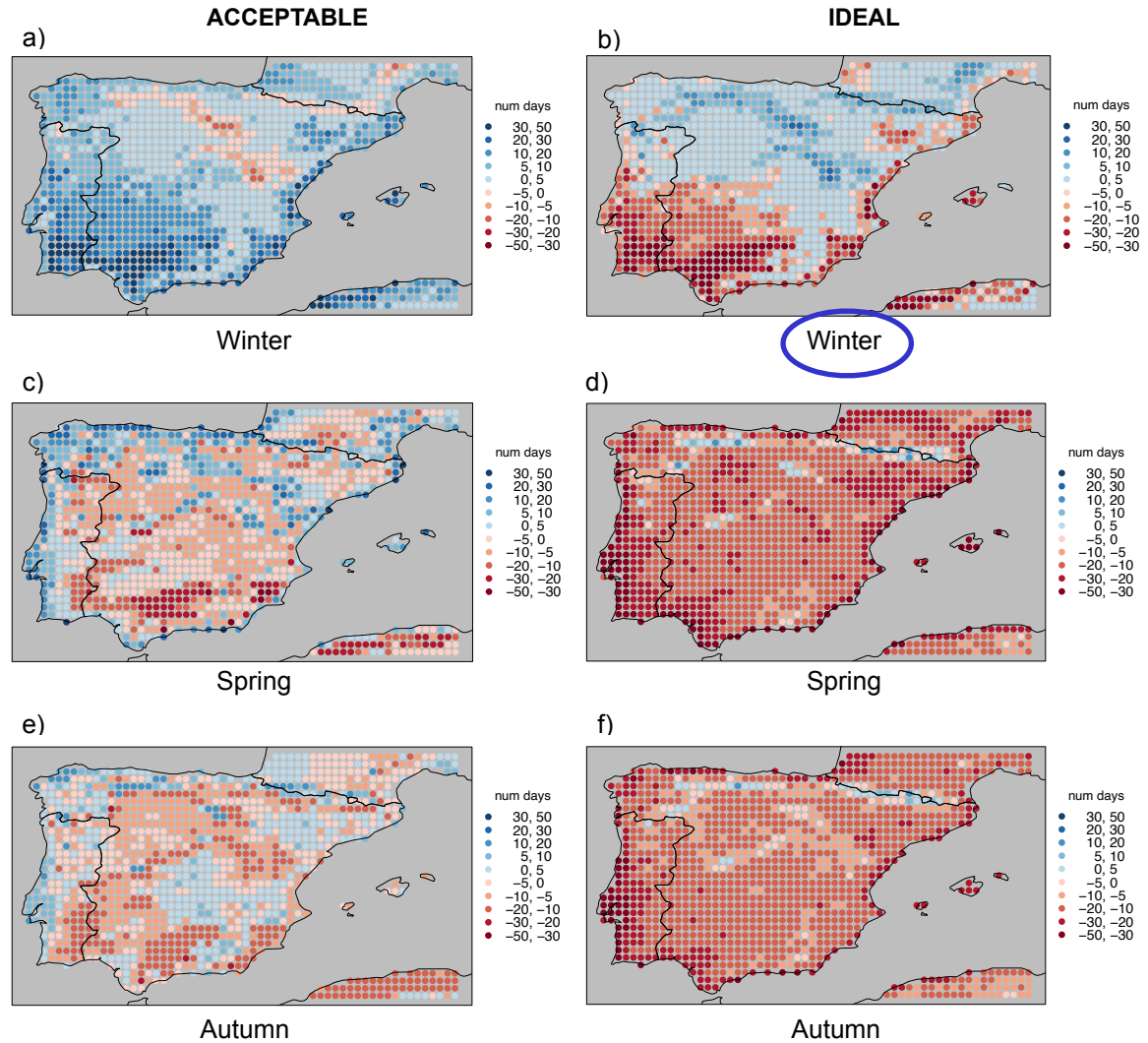


3. Results

FOOTBALL

Future change
in climate potential

CIT						
1	2	3	4	5	6	7
Unacceptable			Acceptable		Ideal	



4. Future work

- Use the whole of RCMs from the EURO-CORDEX project to compute the UTCI and compare shifts through ensemble mean strategies.
- Explore the seasonal CIT distribution across the Mediterranean which is the principal economic centre of the tourist activities in Europe.

Acknowledgements:

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Universitat
de les Illes Balears

A large tree stands as the central element, bisected vertically. The left half of the tree is vibrant and healthy, with a thick trunk and a full, rounded canopy of bright green leaves. It is set against a clear blue sky with scattered white clouds. Several small, dark butterflies are seen fluttering around the green foliage. The ground beneath this side of the tree is a lush, green field. The right half of the tree is starkly different: its trunk is thin and gnarled, and its branches are bare and skeletal. This side of the tree is set against a dramatic, fiery sky of orange and yellow, with a few dark, ominous clouds. The ground beneath this side is parched and cracked, showing deep fissures in the dry earth. The text "Thank you for your attention!" is superimposed over the center of the tree, spanning both halves.

Thank you for
your attention!