# Iberian Peninsula under Climate Change

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This entry presents the results of a systematic review of temperature and precipitation extremes over the Iberian Peninsula, focusing on observed changes in temperature and precipitation during the past years and what are the projected changes by the end of the 21st century. The purpose of this entry is to assess the current literature about extreme events and their change under global warming. Observational and climate modeling studies from the past decade were considered in this entry.

Keywords: extremes ; extremes indices ; temperature and precipitation extremes ; climate change ; bias correction ; regional climate modeling

## 1. Introduction

There are indications that climate change is responsible for most of the change in risk associated with weather-related disasters over Europe [1]. Simultaneously, the increase in the frequency and intensity of Europe's extreme events has been well documented in several studies (e.g., [2][3]). The Paris Agreement is the global answer to minimize the risk from climate change by setting up a long-term common threshold of warming of the planet below 2 °C, preferably to 1.5 °C, compared to pre-industrial levels. To achieve this limiting temperature, serious economic and social transformations must occur to achieve climate neutrality by mid-century. However, according to the latest climate update issued by the World Meteorological Organization (WMO), there is a likelihood that the 1.5 °C warming will be temporarily reached in the next 5 years.

Although extreme events are part of the natural climate variability, the observed changes in extreme events are linked with the intensification of the event, such as an increase in extreme temperature (cold or hot) or an increase in the number of precipitation events in some regions [4]. Temperature and precipitation are expected to be affected by changes in their variability as they are two of the elements of the climatic system. Hence, most of those studies focus on temperature and precipitation.

These facts prompt several studies about climate change and climate variability on the IP and/or Europe yielding a significative high number of studies. The IP is particularly vulnerable to climate change due to its geographic location and climatic characteristics, and it is one of the areas where extreme temperature episodes, such as heat waves and cold spells, are expected to increase in frequency in the future [5][6][7][8].

## 2. Analysis on Research Results

Recent literature suggests that projections of extreme temperature events increase at a faster rate than global mean surface temperature increases (e.g., [9]), while others point to a linear relationship between the mean response of the intensity of temperature extremes in climate models to changes in the global mean temperature (e.g., [10][11], regardless of the considered emissions scenario [12][10].

In a warming scenario, it is almost certain that increases in the frequency and magnitude of daily warm temperature extremes and decreases in the frequency and magnitude of daily minimum temperature extremes might occur this century [13]. So, it is expectable that extreme weather phenomena related to air temperatures, such as heatwaves and cold spells, are likely to change towards higher maximum temperatures and more hot days [14][15][7][16][17].

Nevertheless, RCMs are still a trustworthy tool to provide more detailed representations of past and present-day climate and climate variability, in particular, for events located in the tails of the distribution. For example, a RCM study from [18] covering a number of geographical domains (Africa, Central America, South America, India, and the Mediterranean) concluded that the added value of using RCMs is the improved representation of high precipitation events. The ability of models to represent extreme events has been the object of investigation for some time. The authors of [19] carried out simulations within the EURO-CORDEX project, using a multi-model ensemble with different resolutions (12 km and 50 km), driven by ERA-Interim for a 20-year period. The authors showed that simulation of extreme temperature is sensitive to the convection and microphysics schemes. Most models exhibit an overestimation of summertime temperature extremes in Mediterranean regions and an underestimation over Scandinavia.

In multi-physics ensembles models, the same model is used for climate simulations using a variety of microphysics schemes or a combination of schemes. Generally, the resulting dispersion amplifies under the future scenario leading to a large drift accompanying the mean change signals, as large as the magnitude of the mean projected changes and analogous to the spread obtained in multi-model ensembles. Moreover, the sign of the projected change varies depending on the choice of the model physics in many cases [20].

## 3. Summary

The present study was a comprehensive review of the latest decade of published research about extreme weather and climate extremes over the Iberian Peninsula (IP) and explored the methods and climate change indicators used in observational and modeling studies for the historical climate and 21st-century projections. Considering the amount of information presented in the Results section, **Table 1** and **Table 2** highlighted the major findings.

**Table 1.** Summary of changes observed in the Iberian Peninsula over the last 50 years for temperature and precipitation.

| | Type of Change Already Observed | Documented Findings | References |
|---|---|---|---|
| Extremes based on daily temperature | How much has mean surface air temperature in the IP increase in the last decades? | 0.75 °C to 1.5 °C relative to 1850–1900 | [14][15][21][5][6][22][23][24][25][26][16][27][28][29][30][31] |
| | Higher maximum temperatures | +0.15 °C to +0.54 °C per decade | |
| | Hot to extreme hot days | +0.8 days to +6 days per decade | |
| | Tropical nights | +0.24 days +6 days per decade | |
| | Warm spells | +0.25 days to +10 days per decade | |
| | Higher minimum temperatures | +0.27 °C to + 0.49 °C per decada | |
| | Cold to extreme cold days | –0.91 days to –1 day per decade | |
| | Cold nights | –1 day per decade | |
| Extremes based on daily precipitation | Mean total precipitation | –44.60 mm per decade | [1][2][32][33][34][35][36][37][38][39][40][41][42][43][44][45][46][47][48][49][50][51][52][53][54] |
| | Precipiation intensity | –0.19 mm per decade | |
| | Above 99th percentile | +1.17 mm per decade | |
| | Fraction above 95th percentile | +0.30% per decade | |
| | RX1D | +0.25 mm per decade | |
| | RX5D | –2.29 mm per decade | |
| | Very to extremely wet days | –0.43 to –1.69 days per decade | |

**Table 2.** Summary of projected changes for temperature and precipitation over the Iberian Peninsula for the 21st century.

| | What Are the Climate Models Projections for the IP for the 21st Century? | Findings | References |
|---|---|---|---|
| Based on daily temperature | Mean surface air temperature | Mean and maximum temperatures are projected to increase around 2 °C (4 °C) for the 2046–2065 (2081–2100) period in all seasons and scenarios. Summer temperature can increase up to 6 °C to 8 °C by the end of the century. | |
| | Minimum temperature | Increased minimum temperatures in all seasons and scenario with mean annual temperature increases up to 2 °C. | |
| | Maximum temperature | Annual maxima temperature increases up to 4 °C annual maxima reaching more than 8 °C at a 2 °C warming level | |
| | Hot to extreme extreme hot days (tmax >40 °C) | 10 to 60 days/year for mid century | |
| | Summer days (Tmax> 25 °C) | Up to 30 to 60 more days for mid-century and the end of century, respectively | |
| | Tropical nights | On average 60 to 100 more tropical nights days by the end of the century | |
| | Heatwaves | Yearly average number of heat waves increases by seven to ninefold by 2100. Up to a mean of six more heatwaves (three to 10-fold more heatwaves). In cities the number of heatwaves per year will increase on average from 10 (present) to 38 in mid-century and 63 by the end of the century. | [55][14][15][21][4][5][6][8][56][57][58][59][22][23][12][60][61][10][62][63][24][25][64][65][66][9][26][16][67][27][17][28][29][68][69][70][18][71][30][72][54][31][73] |
| | Heatwaves frequency | 100 events in the 2071–2100 period (more than 3 per year) will cover the whole country | |
| | Heatwaves duration | Most frequent length rises from 5 to 22 days throughout the 21st century with 5% of the longest events will last for more than one month. Mean duration up to 10 days (triple in relation to historical period). Possibility of mega/extreme heatwaves (temperatures exceeding the 40 °C most days and some consecutive days of more than 45 °C, in particular for the central-south IP. | |
| | Heatwaves intensity | Half of the heat waves will be stronger than the extreme heat wave of 2003; increases up to 4 °C (triple duration in historical period) reaching the end-of-century with mean intensity up to 6 °C (5 times than the hsitorical period) | |
| | Cold days/cold spells/frost days/cold nights | Almost disappears due to strong reductions in minimum temperature | |
| | Frost days | Reduction up to 80 days during the 21st century | |
| | Exposure area to hot extremes | Projected to increase | |
| Based on daily precipitation | Annual precipitation | Reductions up to10% to 15% for mid-century and 20% to 40% at a 2 °C warming level more prominent in southern areas | |
| | Summer precipitation | Reduction of up to 80% by end-of-century with median decreases of 11% for Spain | [1][2][55][4][56][57][59][12][60][61][10][74][63][64][65][66][13][9][17][32][33][34][35][36][68][37][38][75][39][40][41][42][43][44][45][46][69][70][76][71][72][54][73] |
| | Winter precipitation | Increase | |
| | Spring precipitation | Decrease | |
| | Autumn precipitation | Slighty decreases | |
| | Precipitation events (duration)/wet days | Redution across all seasons | |

|  | What Are the Climate Models Projections for the IP for the 21st Century? | Findings | References |
|---|---|---|---|
| **Extreme precipitation indicators *** | **Daily precipitation** | **reduction** | |
| | **RX5day** | **Slight increase up to 5% towards 0% at a 2 °C warming level** | |
| | **Winter heavy precipitation** | **Increases shown in different MIPs projects change from 7% to 14%. Signal also present for spring but less evident in summer and autumn** | |
| | **Extreme precipitation** | **Increase** | |
| | **Exposure area to mean and heavy precipitation** | **Annual reductions up to 20% to 40%** | |
| | **Wet days** | **Decreases up to 60% fewer days** | |
| | **Dry days** | **Dryness trend more pronunced by the end of century** | |

* Climate change indices are recommended by the Expert Team on Climate Change Detection and Indices (ETCCDI) (see http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.html, accessed on 3 September 2021) defined by the World Climate Research Program's Expert Team on Climate Change Detection and Indices.

Globally, major significant findings point to a global past warming trend that most likely will continue the ongoing years. This consistent warming trend can also be found in hot extremes. Warming greater than the global average (between 0.8 °C and 1.2 °C) has already been experienced in some regions and seasons. The IP is also experiencing warming consistent with other regions and magnitude. Information on present warming relative to different past periods allows us to say that in the last decades, the IP warmed by 0.75 °C to 1.5 °C relative to pre-industrial (1850–1900) and at a faster pace than the global mean surface temperature of 0.87 °C [55].

Projections point for increases of 1.5 °C for mid-century [55], with regions such as the IP expecting greater changes of up to 8 °C [15], with severe hot days and a notable reduction in cold extremes [14][15][23][11][26][16][75].

Recent studies have highlighted that projections for extreme temperature events increase at a faster rate than mean temperature [9], while others referred to a linear relationship between the intensity of the mean response of extreme temperature and changes in the global mean temperature [66][26].

The effects of global warming on precipitation are not so clear as for temperature and depend on the region. Globally, heavy precipitation is increasing, confirming theory and early model results [1]. In some regions, heavy precipitation events are related to large-scale dynamic features, such as frontal systems, which implies dynamic changes, such as the expansion of the Hadley cells or shifts in the storm tracks, may substantially alter the heavy precipitation response [1].

Overall, a reduction in mean precipitation for southern Europe [55] is expected, although [1] showed changes in the frequency of extreme events (increases) along with increases in the contribution of extreme precipitation to total precipitation. The number of days with very heavy precipitation over Europe has increased [1]. This behavior is also shown for the Mediterranean region [62][63], independently of the warming scenario, and appears to be specific to heavy precipitation [11]. One major concern for the IP is related to droughts. The region is highly vulnerable to dryness, and in recent years, there has been evidence of a drying trend [11].

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