A quantile-quantile approach for the adjustment of RCM outputs to local scales: application to Platja de Palma, Spain

Homar V. [1], A. Amengual [1], R. Romero [1], S. Alonso [1, 2] and C. Ramis [1]

(1) Grup de Meteorologia, Departament de Física, Universitat de les Illes Balears (UIB), Palma de Mallorca, Spain
(2) Department of Global Change Research, Institut Mediterrani d'Estudis Avançats, (IMEDEA; CSIC-UIB), Palma de Mallorca, Spain

victor.homar@uib.es

INTRODUCTION

In the framework of the Consortium of Platja de Palma –an agreement signed by the Balearic Islands Government and the Ministry of Industry, Commerce and Tourism of the Spanish Government for the redesign and suitability to the needs of the 21st century of this important tourist resort (http://consorcioplayadepalma.es)–, we analyse the effects of climate change on this key socioeconomic emplacement. The tourist activities developed in the System of Platja de Palma (SPdP), one of the major resorts in the whole Mediterranean region, are entirely devoted to a tourism mass model and, therefore, are very closely linked to its climate (Fig. 1). Planning the socioeconomic opportunities in the mid- and long-term must necessarily take into account the possible evolution of the main atmospheric drivers. To this aim, daily observed series for SPdP are analysed. For the future projections, daily data generated by an ensemble of Regional Climate Models (RCMs) integrated in the European ENSEMBLES project were used. In order to adjust the RCM data to such local scale, a quantile-quantile correction has been applied to the regional projections. The adjusted series were analyzed to quantify the climate change signal. Results are discussed in terms of changes in the annual and seasonal mean regimes of the analyzed atmospheric variables and in the frequency of extreme events as well.

METHODOLOGY

Overview of the study area: present climatic and socioeconomic characteristics

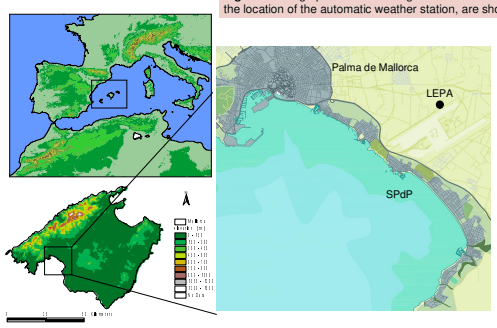

Figure 1. Geographical surroundings of SPdP. The main orographic features of the region, as well as the location of the automatic weather station, are shown (WMO code LEPA)

The climate of the Balearic Islands is characteristic of the western Mediterranean region. Mean annual rainfall amount is roughly 560 mm. Mean annual minimum and maximum temperatures are 12.8 ºC and 21.8 ºC (Homar et al., 2010).

SPdP is located in the southwestern coast of Mallorca, neighboring the city of Palma. Its main socioeconomic activities are related with the sun, sea and sand (3S) tourism mass model. The average of nights per year spent by visitors in the entire Palma county was over 8 million during the 1999-2008 period (INE, 2009).

Observations reveal an increase in the global averaged surface temperature close to 2.7 ºC for the period 1979-2005. Regarding precipitation, a redistribution across climatic areas is also detected over the globe. The total global precipitation is estimated to have diminished about 3% over 1979-2005 (IPCC, 2007). For the Balearic Islands, observations show a negative trend in the annual precipitation of 16.6 mm per decade for the period 1951-2006. Regarding temperatures, both maximum and minimum values increased at a rate of 0.51 ºC and 0.46 ºC per decade during 1976-2006 (Homar et al., 2010).

We explore projected changes of the most relevant meteorological parameters for carrying out suitable 3S leisure activities. Specifically, we have explored the shifts in the future annual and seasonal mean regimes as well as in the extreme climatic events. Both topics have a high social and economic interest, since the productive enterprise developed in tourist regions are strongly linked to its climatology, being extremely sensitive to extreme weather impacts.

Input data and quantile-quantile adjustment

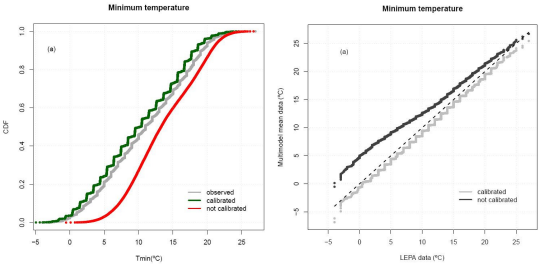

Figure 2. Observed, raw and calibrated multimodel mean CDFs and quantile-quantile (Q-Q) plot for the minimum temperature. It is worth noting that observed and calibrated minimum temperature appears staggered owing to the effect of the numerical truncation to the nearby integer for the first years of measurements.

Observations have been obtained from the automatic weather station of the Spanish Meteorological Agency (AEMET) at Palma's international airport (LEPA; 39.37 ºN, 2.43 ºE). To characterize the evolution of the meteorological variables over SPdP, complete daily series of minimum and maximum temperatures, accumulated precipitation, mean relative humidity, mean cloud cover and mean wind speed for the entire 1973-2008 period have been used (Fig. 1).

Regarding the future projections, we have used the regional simulations database available from the ENSEMBLES European project run under the SRES A1B scenario (http://ensembles-eu.metoffice.com). Even if dynamical downscaling improves the representation of regional features, some important local inaccuracies still remain owing to insufficient resolution and the uncertainties found in the parameterization of small scale forcings.

We present a quantile-quantile calibration method that amends mean, variability, and shape errors in the simulated cumulative distribution functions (CDFs) of the climatic variables. The procedure consists of calculating the changes, quantile by quantile, in the CDFs of daily RCM outputs between a control and successive future time-slices. These changes are rescaled in basis of the observed CDF for the same control period, and then added –quantile by quantile– to these observations to obtain new calibrated future CDFs that convey the climate change signal (Fig.2; Amengual et al., 2011).

RESULTS

Changes in annual mean and extreme regimes

Mean regimes	present (1973-2002)	early (2010-39)	mid (2040-69)	late (2070-99)
T min (ºC)	10.1	10.6	11.7	12.8
T max (ºC)	22.3	23.0	24.1	25.3
pcp (mm)	463.3	496.0	457.8	431.5
Hr (%)	77.1	74.3	72.1	70.5
clt (%)	43.7	40.6	39.4	38.5
wss (ms^{-1})	2.9	2.7	2.7	2.7

Figure 3. Annual observed and multimodel simulated mean regimes of the climatic variables for the present, early, mid and late 21st century time-slices.

Figure 3 shows increments of 2.7 ºC and 3.0 ºC for the minimum and maximum temperatures and the later 21st century with the subsequent further expansion of the diurnal temperature range in SPdP. Annual rainfall amounts are projected to fall by about -7% by the end of the century.

5% and 95% observed percentiles are defined as the thresholds for which we define a low and high extreme event, except for the low rainfall extreme, which is defined as a non-rainy event. Figure 4 illustrates the projected changes on the minimum and maximum extreme regimes (Tmin = 0.0 ºC and Tmax = 32.6 ºC). Temperatures are expected to shift towards higher values. A constant rise in the annual number of non-rainy days is projected, as well as a slight growth in the frequency of the extreme daily amounts.

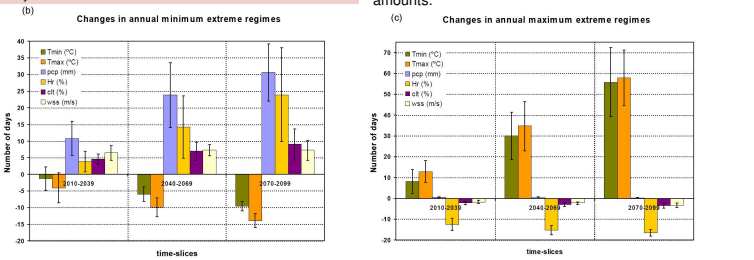

Figure 4. Extreme regimes shifts of the minimum and maximum temperatures (Tmin and Tmax), precipitation (pcp), relative humidity (Hr), cloud cover (clt) and wind speed (wss) for the early, mid and late 21st century time-slices. It is worth noting that the changes in the number of days are computed as the difference among the projected and present extreme days. Multimodel means and their standard deviation are shown.

Changes in seasonal mean and extreme regimes

Briefly, seasonal maximum temperatures show the highest growth rate in summer (3.9 ºC for the late 21st century, Fig. 5a). The frequency of extreme warm days (Tmax in summer > 35 ºC) is expected to steadily increase, almost achieving the 30 days per year for the late time-slice (Fig. 5b). The projected mean seasonal rainfall regimes indicate an early increase in the spring and autumn total amounts (Fig. 5c). The frequency of daily non-rainy and intense rainfall is expected to generally increase (Fig. 5d).

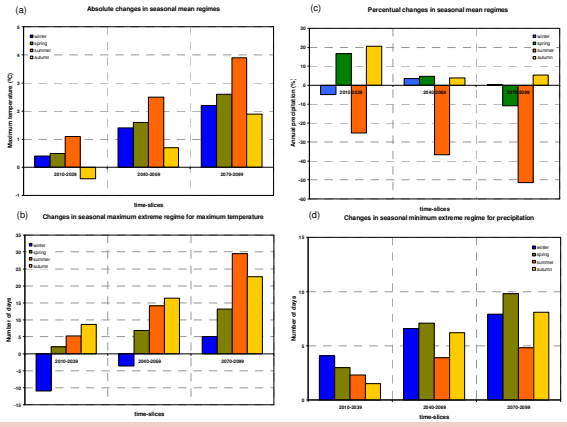

Figura 5. Seasonal multimodel mean regimes changes respect to present for maximum temperature and precipitation in the early, mid and late 21st century time-slices are shown as well as the number of high and low extreme days per season. Thresholds used to define these extremes are obtained for the present period and remain unchanged for the future time-slices. It is worth to note that the changes in the number of days are computed as the difference among the projected and observed extreme days.

CONCLUSIONS

- Observed and future projected daily series of the most relevant climatic variables for beach-based holidays have been analyzed. For the future projections, a multimodel ensemble strategy has been used to cope with the uncertainties arising from model errors and their boundary conditions
- To exploit this regional database correctly at such local scales, a quantile-quantile adjustment to individual RCM daily outputs has been applied. Results show an overall improvement in reproducing the present climate baseline when using corrected series instead of raw RCM outputs
- The projections have revealed important changes in the temperature regimes and an increase in the frequency of extreme warm days affecting SPdP in summertime. Results should help local authorities to implement future contingency plans and precautionary measures
- The changes found in the rainfall regimes should also imply a future update of the current water management plans. The projected rise in the frequency of both daily extreme –weak and intense– rainfalls will be a challenging task for hydrologic management.

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