



# Assessment of future changes in downscaled temperature and precipitation over the Casablanca-Settat region (Morocco)

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## Abstract

Our study aimed to assess future climate changes in the region of Casablanca-Settat using downscaled outputs of two General Circulation Models (GCMs): the Canadian model (canESM2) and the National Centre for Meteorological Research (France) model (CNRM-CM5). These future climate changes were assessed through precipitation, minimum and maximum daily temperatures on annual and seasonal scales for three weather stations located at Casablanca-Settat region (Morocco). The temperature and precipitation changes are evaluated for two future periods: 2036–2065 (near term) and 2071–2100 (long term) relative to the present climate (1972–2001) using two emission scenarios RCP4.5 and RCP8.5. The results, evaluated according to the two above mentioned scenarios with respect to the baseline period 1972–2001, show a significant decrease for future projections of total rainfall, with percentages varying from one model to another. This decrease in precipitations affects all seasons. Concerning temperatures, the two models agree on a significant increase especially more marked during the summer and autumn. The decrease of rainfall and the increase of temperatures are in good agreement with the forecasts of the Intergovernmental Panel on Climate Change (IPCC, Climate change 2014: synthesis report. In: Core Writing Team, Pachauri RK, Meyer LA (eds) Contribution of working groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, 2014).

**Keywords** Casablanca-Settat region (Morocco) · Precipitation · Temperature · Future climate projections · Downscaled data

## Introduction

Nowadays, Human influence on the climate system is clearly established so that anthropogenic greenhouse gases emissions are the highest ever observed (IPCC 2014; Riedacker 2003). Recent climate change has had broad impacts on people and the natural environment. Climate change has been observed since about 1950 in several extreme weather and climate events; some of these changes have been attributed to human activities, including a decrease in cold extremes, an increase in heat extremes, a rise in extreme sea level and

an increase in episodes of heavy precipitation in various regions (IPCC 2014).

For millions of years, the greenhouse effect has kept the Earth at a mild average temperature and has contributed favourably to the development of life. Greenhouse gases include carbon dioxide, methane, chlorofluorocarbons, ozone and nitrous oxide. Conversely, there are also particles, called aerosols, which have an opposite effect to that of greenhouse gases; they contribute to cooling the atmosphere (De Menech 2013).

Two strategies are proposed to deal with climate change: mitigation and adaptation. The mitigation strategy takes the form of an intervention aimed at reducing the sources of greenhouse gases; adaptation is an adjustment of natural or human systems in response to present or future climatic stimuli or their effects (IPCC 2001; Galliot 2013). In order to be able to develop these adaptation strategies, it is necessary to make assessments of the potential impacts of climate change on all sectors, which requires the availability of more relevant climate information than

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that provided by low-resolution General Circulation Models (GCMs), most of which have spatial resolutions ranging from 200 to 300 km. Indeed, GCMs provide a good representation of the climate on a global scale but are very limited in terms of regional or local climate. Some phenomena may not be adequately represented (Lepage et al. 2011); therefore, impact models require resolutions of at least 50 km in many cases; hence the need for a downscaling method: statistical or dynamical.

Dynamical downscaling methods allow obtaining local scale climatological information from outputs of GCMs models using the following: Area-Limited models (Giorgi and Mearns 1991; Leung et al. 2003; Wang et al. 2004), high-resolution GCMs (Cubasch et al. 1995), or variable-resolution GCMs (Gibelin and Déqué 2003; Fox-Rabinovitz et al. 2001; McGregor et al. 2002).

Statistical downscaling methods consist in establishing a relationship linking one or more variables characterizing the state of the atmosphere (such as the geopotential at 500 hPa) on a large scale known as "predictive" variables to one or more local climate variables (such as precipitation or temperature at a given location) known as "predicted" variables or predictands (Wilby and Wigley 1997). Since these methods are inexpensive and less computationally demanding in comparison with dynamical downscaling method, they have been widely employed by several studies on climate change (Crane and Hewitson 2006; Souvignet et al. 2010; Sunil et al. 2020; Thiha et al. 2020; Tarekegn et al. 2021).

Chu et al. (2010) carried out a statistical downscaling study on daily mean temperature, evaporation and precipitation using 11 weather stations in China. Abbasnia and Toros (2016) presented the projection of future changes in maximum temperatures using the statistical downscaling model on seven selected stations in Iran during two future periods (2041–2070 and 2071–2099). Moses and Gondwe (2019) used the statistical downscaling model to simulate changes in monthly maximum temperatures for three future periods (2011–2040, 2041–2070 and 2071–2099) at four weather stations in Botswana based on the Hadley Centre Couple Model Version 3 (HadCM3) outputs. Rahimi et al. (2018) analysed the performance of two downscaling methods using two GCMs. Daily minimum temperature data of 50 meteorological stations located across the entire country were used. Hassan and Nile (2021) employed the statistical downscaling model to simulate changes in the maximum and minimum temperatures in southwest Iraq during the period 2020–2099 by using two GCMs at seven meteorological stations based on the observed period 1979–2018. Bessah et al. (2018) evaluated the minimum and maximum temperatures in the Pra River Basin (Ghana) at the near future period 2020–2049 based on the observed period 1981–2010. All these studies showed a temperature increase and rainfall decrease in future projections.

The future precipitation and temperature projections were examined for the medium (RCP4.5) and high (RCP8.5) emission scenarios (Guivarch and Rozenberg 2013). On the other hand, it is pointed out that the choice of scenarios is strongly conditioned by its availability at the different platforms (Mondon and Imbard 2013). This literature review reveals that no statistical study has been found using downscaling method in order to predict more accurately climate change scenarios over Casablanca-Settat region (Morocco).

According to the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2014), a particularly significant rise in temperature over the Moroccan Atlantic coast and mainly over Casablanca-Settat region was shown with a warming of 1–1.25 °C for the period 1901–2012. As far as rainfall is concerned, it decreased by 10–15% for the same period. Future climate projections in the said region for the twenty-first century show that the average annual temperature would have a more marked increase. Thus, at the end of the twenty-first century, for scenario RCP4.5 the increase in mean annual temperature will be between 1.4 and 2 °C for the period 2081–2100 compared to the reference period 1986–2005 and for scenario RCP8.5 the increase will be between 3 and 5 °C. On the other hand, average annual precipitation will decrease in most of the region. This decrease in precipitation will be between 10 and 20% for the RCP4.5 scenarios and a decrease of 30–40% for the RCP8.5 scenarios. The number of rainy days will decrease and the risk of drought will increase. The IPCC (2013), in its 5th report, concluded with great certainty that human influence is the main cause of the warming observed since the middle of the twentieth century.

Morocco, like all countries, is concerned by at least one of the two aspects (mitigation and adaptation) and is, therefore, obliged to urgently implement adaptation actions to minimize the negative impacts of climate change on populations and ecosystems.

In this paper, available downscaled data from two GCMs under RCP4.5 and RCP8.5 scenarios are first assessed with respect to a reference historical period using rainfall and temperature data from three meteorological stations located on Casablanca-Settat region. These downscaled data are next used to evaluate future climate change on these climatic parameters. The two horizons used are as follows: 2036–2065 which represents the near term, and 2071–2100 which represents the long term. The results of future thermal and rainfall changes have been evaluated with respect to a reference period, according to the two above-mentioned scenarios.

## Study area

The study area is one of the major city in Morocco which is located on the North Atlantic coast of this country (Fig. 1). The elevation is 150 m above sea level, covers an area of

19,448 km<sup>2</sup> and has a population of 6.862 million with a density of 353 inhabitants per km<sup>2</sup> following a census done in 2014 by Moroccan government.

According to a study carried out at the Moroccan General Direction of Meteorology in 2019, during the period 1979–2018, moderately dry years are the most dominant compared to severely and extremely dry years with a percentage of 15% in the Casablanca-Settat region. Due to its proximity to the Atlantic Ocean, the climate is mild, sunny and especially wet; with weak to temporarily moderate winds, the annual average maximum temperature is 21.5 °C; the minimum is around 13.3 °C, characterized by an average rainfall of 422.3 mm per year. The warming of the climate in this region during the period 1961–2008 was found to be clear both on an annual and summer scale (Driouech et al. 2010). The summer trend is an increase in average temperature of around 0.3 °C per decade.

## Data and methodology

The daily precipitation and temperature data from the three meteorological stations taken from the database of the Moroccan General Direction of Meteorology were used to assess the downscaled data: Casablanca and Nouacer (1972–2001); El Jadida (1982–2001).

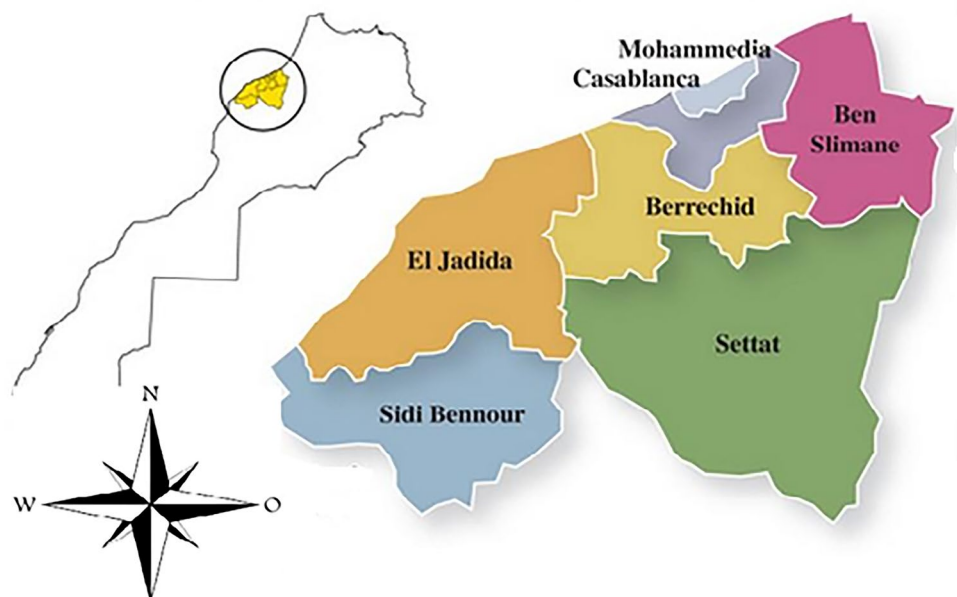
The downscaled data used in the present study are extracted from the Nasa Earth Exchange Global Daily Downscaled Projections (NEX-GDDP 2015) dataset created by NASA. These data include the daily maximum and minimum temperatures as well as daily precipitation for

the periods 1950 to 2005 (Retrospective Run), and 2006 to 2100 (Prospective Run), with a horizontal resolution of 0.25° × 0.25° over the entire globe. These data are a set of climate projections derived from simulations of 21 GCMs of CMIP5 under the two scenarios RCP4.5 and RCP8.5. The downscaling method used to create the NEX-GDDP dataset is a daily variant of the monthly Bias Correction/Spatial Disaggregation (BCSD) method described in Wood et al. (2002, 2004). This variant method uses daily GCMs outputs to produce the corresponding daily downscaled values. During the downscaling process, retrospective simulations serve as baseline data and are compared with observational climatic data. The relations derived from the comparison are then applied for the downscaling of future climate projections (Prospective Run). The observational climatic data used by NASA are taken from the Global Meteorological Forcing Dataset (GMFD). In this study, we chose two GCMs representing the diversity of Coupled Model Intercomparison Project (CMIP5) models: the Canadian Second Generation Earth System model canESM2 (Chylek et al. 2011), and the National Center of Meteorological Research (France) coupled global climate model version 5 CNRM-CM5 (Volodire et al. 2013). Future climate change was determined through the daily outputs of the RCP4.5 and RCP8.5 scenarios. The characteristic of canESM2 and CNRM-CM5 models are presented in Table 1.

As a reminder, the CMIP5 is a project to compare the results of climate models, set up by the World Climate Research Program (WCRP). It defines a standard experimental protocol for the study of coupled ocean–atmosphere models. It offers a basic experimental framework within the

**Fig. 1** Map of the provinces and prefecture of the Casablanca-Settat region Source: Ministry of the Interior (2015)

### Casablanca-Settat Region



framework of the 5th assessment report of the IPCC (2013) (AR5). It includes projections for the twenty-first century as well as decadal prediction experiments with more than 20 atmosphere–ocean general circulation models around the world. These coupled climate models were implemented to carry out a set of global simulations covering the historical period 1971–2005 as well as the twenty-first century 2021–2100 on the basis of the different Representative Concentration Pathway (RCP) scenarios proposed (IPCC 2013). The horizontal resolution of the CMIP5 models varies between  $0.75^\circ \times 0.75^\circ$  and  $3.75^\circ \times 3.75^\circ$  (Belda et al. 2015). The typical number of vertical layers is around 30–40 layers for the atmosphere and 30–60 layers for the ocean (note that some high-resolution models may have 80 or more vertical levels in the atmosphere) (IPCC 2014).

In this study, downscaled data are compared against observations over a historical period. First, we use the Bias and the Root-Mean-Square Error (RMSE) at annual and seasonal scales. Then, a comparison of the seasonal cycles of temperature and the accumulated of precipitation generated by the models with those observed is carried out to judge their capacity to reproduce the seasonal cycles at the local scale.

## Results

### Evaluation of downscaled data using observations

Table 2 presents the results of the statistical parameters Bias and RMSE of cumulative precipitation, minimum and maximum temperatures during the period of 1972–2001 on Casablanca and Nouaceur weather stations and 1982–2001 on El Jadida station.

The Bias value for the minimum temperature varies between  $-1.7$  and  $1.4$  °C (Table 2), with the highest value being recorded in the Casablanca zone mainly in summer and the lowest value in Nouaceur in spring; this is due to the strong Bias of the minimum temperature in this zone. The Bias of maximum temperature varies between  $-2$  °C and  $2$  °C; the highest value was found at Nouaceur mainly in autumn and the lowest value is at El Jadida in the summer season. The RMSE of maximum and minimum temperatures

is slightly low; it fluctuates around  $1$  °C and  $2$  °C, except for a few high values at Nouaceur in Spring and Autumn.

Concerning the cumulative precipitation on an annual scale, the Bias value varies between  $0.0$  and  $0.3$  mm per day. The most significant Bias is recorded at El Jadida while the lowest Bias is calculated for Casablanca and Nouaceur. On the seasonal scale, there are as many negative as positive values. The positive Bias is recorded in summer. The RMSE is generally low in almost all weather stations; it varies between  $0.05$  and  $1.4$  mm per day.

Taking into account the aforementioned results, we retain the downscaled data from the two climate models (canESM2 and CNRM-CM5) used here show a fairly good performance in terms of bias and mean squared errors.

The downscaled data from climate models canESM2 and CNRM-CM5 globally reproduce the seasonal cycle of observed temperatures, with a slight overestimation of minimum temperatures and underestimation of maximum temperatures for the weather stations of Casablanca and El Jadida and the opposite case for the weather station of Nouaceur (Fig. 2). With regard to the evaluation of the models in terms of rainfall, the curves of the evolution of monthly precipitation show that the two models canESM2 and CNRM-CM5 generally reproduce the same shape of the seasonal cycle of observed precipitation more in winter than in summer (Fig. 2).

### Impact of climate change on the climate variables

The precipitation and the daily temperature (maximum and minimum) changes was obtained from the downscaling of RCP4.5 and RCP8.5 scenarios from canESM2 and CNRM-CM5 models. The goal is the identification of the future variation of climatic parameters with high confidence level. The results of the comparison between the current climate and the simulated future climate are shown in Fig. 3. In order to determine the possible evolutions of climate variables in the context of a climate change, the climate of the period 1972–2001 was considered as current climate (C) and was compared to the climate of the periods 2036–2065 and 2071–2100, which are considered as future climate (F) predicted using the two models canESM2 and CNRM-CM5. The objective was to determine a range of variation of these climate parameters in the future. The results of the comparison are presented in the following tables.

According to a seasonal and annual analysis, we can notice that the two scenarios studied show practically the same trend with an increase in the minimum and maximum daily temperatures (Fig. 3). This increase is more pronounced during summer and autumn. However, the magnitudes of increases are less pronounced in winter and spring. On average and towards the end of the twenty-first century, the minimum and maximum daily temperatures will increase

**Table 1** Characteristic of the canESM2 and CNRM-CM5 models. Source: Climate change in Australia, <https://www.climatechangeinaustralia.gov.au/en/>

Model	Oceanic horizontal resolution (lat x lon)	Atmospheric horizontal resolution (lat x lon)
CanESM2	$1.4^\circ \times 0.9^\circ$	$2.8^\circ \times 2.8^\circ$
CNRM-CM5	$1.0^\circ \times 0.8^\circ$	$1.4^\circ \times 1.4^\circ$

**Table 2** Bias and RMSE results on a seasonal and annual scale

Meteorological parameters			Accumulated precipitation		Minimum temperature		Maximum temperature	
Statistical parameters			Bias (mm/day)	RMSE (mm/day)	Bias (°C)	RMSE (°C)	Bias (°C)	RMSE (°C)
Casablanca	Winter (D–J–F)	CanESM2	– 0.05	1.34	1.21	1.74	0.09	0.75
		CNRM-CM5	0.26	1.39	1.32	1.95	0.14	1.13
	Spring (M–A–M)	CanESM2	– 0.11	0.67	1.10	1.50	– 0.89	1.24
		CNRM-CM5	– 0.17	0.62	1.28	1.83	– 0.63	1.29
	Summer (J–J–A)	CanESM2	0.03	0.07	1.32	1.66	– 2.05	2.26
		CNRM-CM5	0.03	0.07	1.43	1.79	– 1.96	2.16
	Autumn (S–O–N)	CanESM2	– 0.08	0.80	1.06	1.56	– 0.90	1.41
		CNRM-CM5	– 0.15	0.80	1.16	1.89	– 0.74	1.40
Annual	CanESM2	– 0.05	0.44	1.18	1.42	– 0.94	1.05	
	CNRM-CM5	0.00	0.44	1.31	1.67	– 0.79	1.02	
Nouaceur	Winter (D–J–F)	CanESM2	– 0.49	1.31	– 1.54	2.03	0.51	1.03
		CNRM-CM5	– 0.18	1.20	– 1.43	2.02	0.56	1.43
	Spring (M–A–M)	CanESM2	– 0.20	0.74	– 1.70	2.04	0.19	3.99
		CNRM-CM5	– 0.26	0.67	– 1.53	2.04	1.18	1.94
	Summer (J–J–A)	CanESM2	0.03	0.07	– 0.91	1.40	1.61	2.06
		CNRM-CM5	0.03	0.07	– 0.80	1.33	1.71	2.13
	Autumn (S–O–N)	CanESM2	0.89	0.96	– 1.37	1.91	2.09	4.85
		CNRM-CM5	– 0.40	0.86	– 1.28	2.02	1.41	2.03
Annual	CanESM2	– 0.25	– 0.23	– 1.37	1.56	1.16	1.31	
	CNRM-CM5	– 0.19	0.43	– 1.24	1.54	1.30	1.57	
El Jadida	Winter (D–J–F)	CanESM2	0.27	0.89	0.44	0.93	– 0.87	0.87
		CNRM-CM5	0.87	1.14	0.78	1.13	– 0.71	1.03
	Spring (M–A–M)	CanESM2	– 0.13	0.51	0.92	1.00	– 1.40	1.30
		CNRM-CM5	– 0.10	0.39	1.33	1.31	– 0.97	1.06
	Summer (J–J–A)	CanESM2	0.04	0.05	1.26	1.16	– 2.16	1.83
		CNRM-CM5	0.04	0.05	1.43	1.32	– 2.00	1.71
	Autumn (S–O–N)	CanESM2	0.35	0.58	0.42	0.73	– 1.69	1.56
		CNRM-CM5	0.44	0.79	0.64	1.00	– 1.49	1.49
Annual	CanESM2	0.14	0.33	0.74	0.75	– 1.54	1.30	
	CNRM-CM5	0.33	0.40	1.03	1.00	– 1.31	1.18	

by about 2–4 °C for the RCP4.5 scenarios and by 3–6 °C for the RCP8.5 scenarios according to the canESM2 model: an increase of approximately 1–2 °C for the RCP4.5 scenarios and by 2–4 °C for the RCP8.5 scenarios according to the CNRM-CM5 model. The increase is sharper for the CanESM2 model. On a seasonal scale, the most significant increase is noticed in summer and autumn (Tables 3, 4).

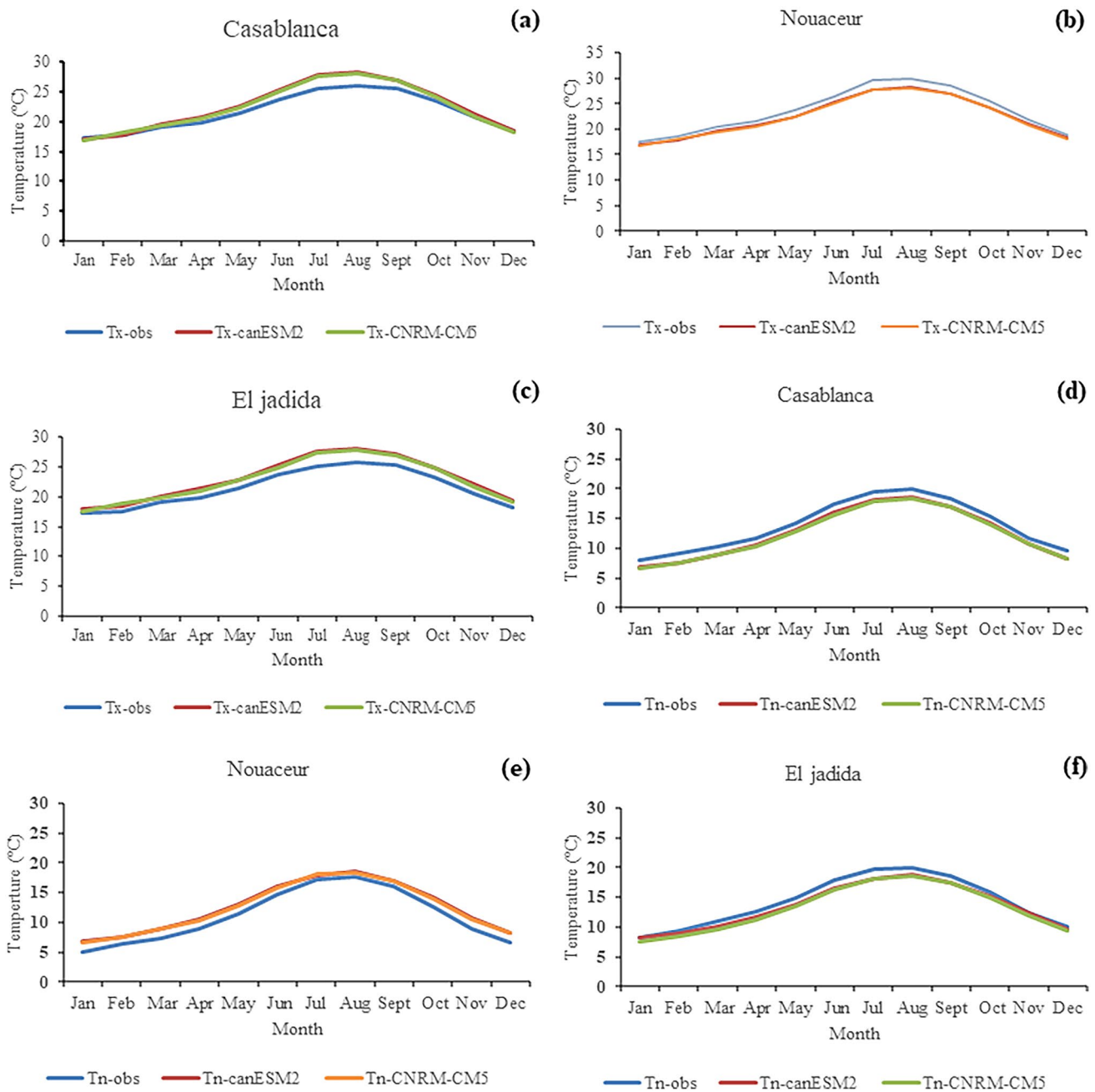
The comparison of precipitation variation between the current and future climate on an annual and seasonal scale shows a decrease (Fig. 3). In general, there is a decrease in annual precipitation of about 20–30% for to the RCP4.5 scenarios and about 20–40% for to the RCP8.5 scenarios according to the canESM2 model. A slight decrease of around 5% for the RCP4.5 scenarios and around 30% for the RCP8.5 scenarios according to the CNRM-CM5 model (Table 5) is observed. This remarkable decrease in rainfall affects all seasons, but the reduction in rainfall is

noticeable for winter and autumn and mainly according to the CanESM2 model.

### Discussion

The first objective of this study was to provide an overview of the links between climate change and its effects on practical parameters in the future in Casablanca-Settat region. The aim was to present the current risk linked to droughts in this studied area and to assess the possible evolutions in the twenty-first century in terms of frequency and intensity. In fact, the risk of drought observed in the twenty-first century could increase due to increasing temperatures and decreasing precipitation.

The results of this study, using the canESM2 model, show an increase in minimum and maximum daily temperatures



**Fig. 2** The reproduction seasonal cycle of observed and model parameters. **a–c** Maximum daily temperature. **d–f** Minimum daily temperature. **g–i** Precipitation

of around 2–4 °C for the RCP4.5 scenarios, from 3 to 6 °C for the RCP8.5; the CNRM-CM5 model shows an increase in minimum and maximum daily temperatures of around 1–2 °C for the RCP4.5 scenarios, from 2 to 4 °C for the RCP8.5. These results are confirmed by the Intergovernmental Panel on Climate Change in the assessment report (IPCC 2001, 2007, 2014). Regarding cumulative daily precipitation, our results predict a decrease in precipitation on an annual and seasonal scale of about 20% to 30%.

This study could be useful to identify and predict climate-related vulnerabilities for health in the Casablanca-Settat region. It first will seek to quantify the relationships that exist between health and climate and then to make predictions of morbidity rates for the future climate of the region. To do this, we will, in a future work in progress, study the morbidity sequences for a given period in parallel with the chronological series of several climatic parameters (temperature, precipitation, etc.) in order to establish statistical

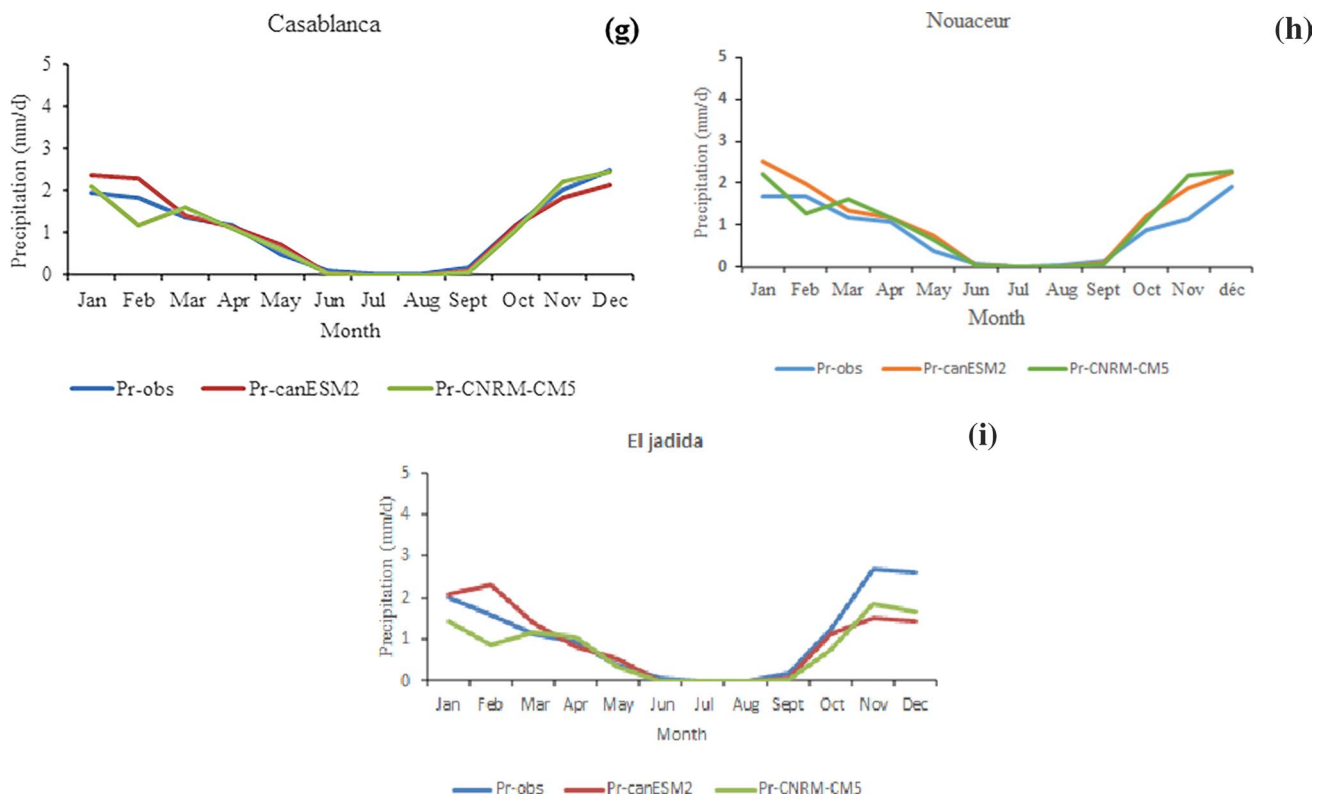


Fig.2 (continued)

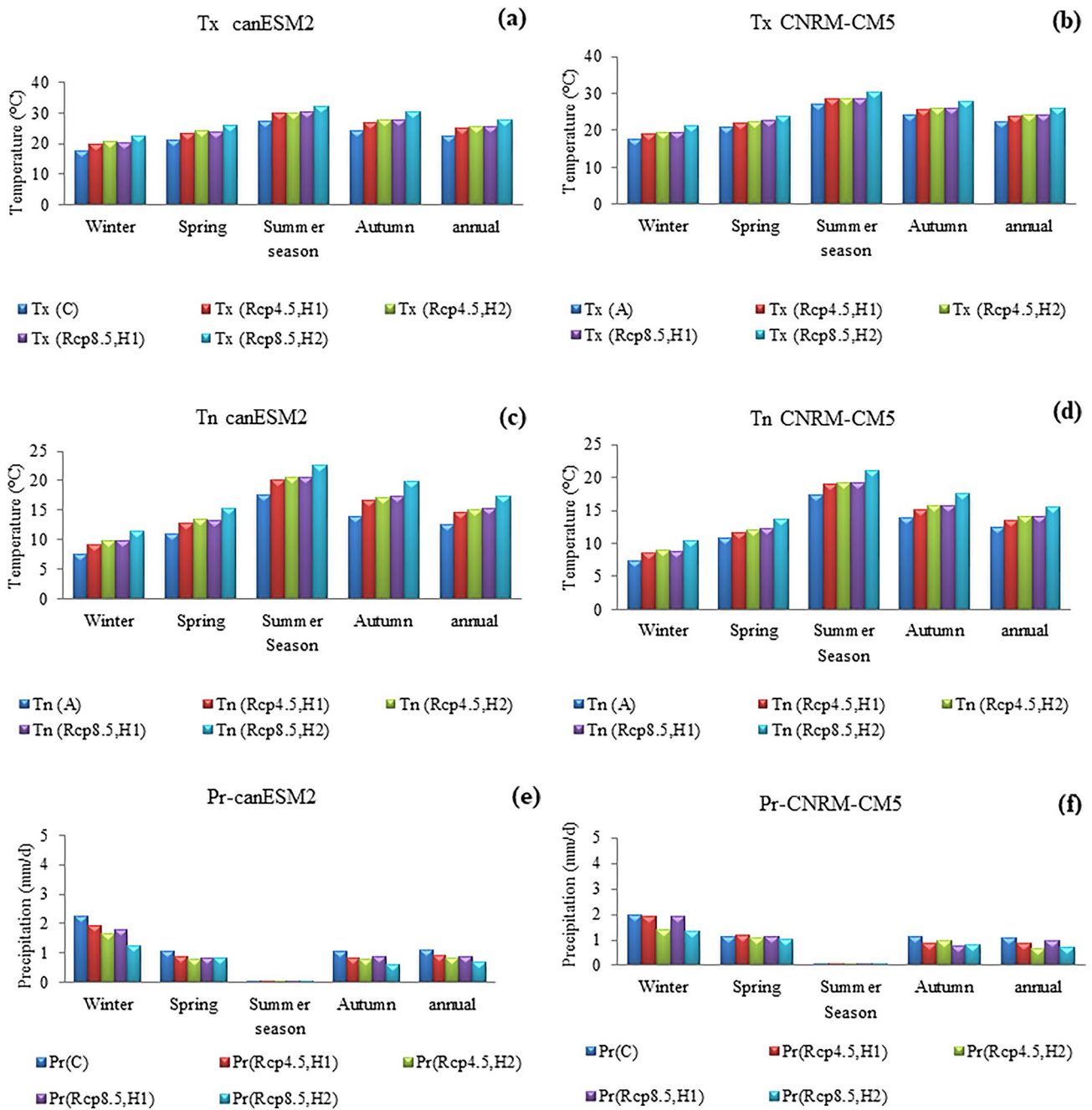
models. These models will use simulated future regional climate data to establish variations in morbidity future periods.

### Conclusion

In this study, we first carried out a statistical study on down-scaled data of maximum daily temperature, minimum daily temperature and daily precipitation accumulations from two GCMs models canESM2 and CNRM-CM5 on the Casablanca-Settat Region under the RCP4.5 and RCP8.5 scenarios. These data were first evaluated against observational data from three weather stations distributed in the region: Nouaceur, Casablanca and El Jadida for a reference period and were, therefore, statistically analysed for the periods 2036–2065 and 2071–2100.

Our results revealed that the annual and seasonal average precipitations have an almost general tendency towards the decrease, especially for winter and autumn rains, and

that, on the other hand, the climate of grand Casablanca-Settat has a general tendency towards drying out since the temperature will increase significantly during the period (2036–2100). The amplitude of increase is more important for the CanESM2 model than the CNRM-CM5 model. The climate warming affects the year as well as the seasons. Most trends in annual mean temperature rise will be between 2 and 5 °C. These trends are in agreement with the work of the Intergovernmental Panel on Climate Change (IPCC 2001, 2007, 2014) and also with the study that was carried out by (Born et al. 2008) who estimated for the period 1960–2050 trends of 1.37–1.75 °C in winter and in summer respectively on this region.



**Fig.3** Comparison of the variation in climatic parameters between the current and future climate over the city of Casablanca. **a, b** Maximum daily temperature. **c, d** Minimum daily temperature. **e, f** Precipitation



**Table 3** Variation of the maximum daily temperature between current and future climate

Models		CanESM2				CNRM-CM5			
Scenarios		RCP4.5		RCP8.5		RCP4.5		RCP8.5	
Horizons		H1	H2	H1	H2	H1	H2	H1	H2
Regions	Seasons	F-C	F-C	F-C	F-C	F-C	F-C	F-C	F-C
Casablanca	Winter (D–J–F)	2.0	2.8	2.7	4.7	1.3	1.6	1.6	3.6
	Spring (M–A–M)	2.2	3.0	2.7	4.8	1.0	1.4	1.7	3.1
	Summer (J–J–A)	2.6	3.0	3.2	5.2	1.6	1.8	1.7	3.6
	Autumn (S–O–N)	2.6	3.3	3.4	6.1	1.5	1.8	2.1	3.8
	Annual	2.4	3.0	3.0	5.2	1.4	1.7	1.8	3.6
El Jadida	Winter (D–J–F)	1.7	2.5	2.3	4.3	1.1	1.4	1.3	3.2
	Spring (M–A–M)	1.9	2.6	2.4	4.3	0.8	1.2	1.4	2.7
	Summer (J–J–A)	2.2	2.6	2.7	4.5	1.4	1.5	1.5	3.2
	Autumn (S–O–N)	2.3	3.0	3.0	5.6	1.2	1.5	1.7	3.3
	Annual	2.1	2.7	2.7	4.7	1.2	1.4	1.5	3.1
Nouacer	Winter (D–J–F)	2.0	2.8	2.7	4.7	1.4	1.7	1.7	3.7
	Spring (M–A–M)	2.2	3.0	2.8	4.8	1.0	1.4	1.8	3.2
	Summer (J–J–A)	2.6	3.1	3.2	5.2	1.5	1.7	1.6	3.5
	Autumn (S–O–N)	2.7	3.4	3.5	6.2	1.5	1.9	2.1	3.8
	Annual	1.2	1.9	1.9	4.1	0.1	0.4	0.5	2.2

H1 horizon 2036–2065, H2 horizon 2071–2100, F future climate, C current climate

**Table 4** Variation of the average minimum daily temperature between current and future climate

Models		CanESM2				CNRM-CM5			
Scenarios		RCP4.5		RCP8.5		RCP4.5		RCP8.5	
Horizons		H1	H2	H1	H2	H1	H2	H1	H2
Regions	Seasons	F-C	F-C	F-C	F-C	F-C	F-C	F-C	F-C
Casablanca	Winter (D–J–F)	1.7	2.3	2.3	3.9	1.1	1.6	1.4	2.9
	Spring (M–A–M)	1.9	2.5	2.3	4.4	0.9	1.4	1.6	2.9
	Summer (J–J–A)	2.5	3.0	3.1	5.1	1.5	1.8	1.7	3.6
	Autumn (S–O–N)	2.6	3.2	3.4	5.9	1.2	1.9	1.9	3.7
	Annual	2.1	2.7	2.8	4.8	1.3	1.7	1.7	3.3
El Jadida	Winter (D–J–F)	1.6	2.2	2.2	3.7	1.1	1.5	1.3	2.8
	Spring (M–A–M)	1.8	2.4	2.1	4.1	0.9	1.4	1.4	2.7
	Summer (J–J–A)	2.2	2.6	2.7	4.5	1.3	1.5	1.5	3.2
	Autumn (S–O–N)	2.4	3.0	3.2	5.6	1.2	1.8	1.8	3.5
	Annual	1.9	2.5	2.5	4.4	1.2	1.6	1.6	3.1
Nouacer	Winter (D–J–F)	1.7	2.2	2.3	3.9	1.1	1.5	1.4	2.9
	Spring (M–A–M)	1.9	2.6	2.4	4.4	1.0	1.4	1.6	2.9
	Summer (J–J–A)	2.5	3.0	3.1	5.1	1.5	1.8	1.8	3.6
	Autumn (S–O–N)	2.6	3.2	3.4	5.9	1.3	1.9	1.9	3.8
	Annual	3.5	4.1	4.2	6.2	2.4	2.9	2.9	4.5

H1 horizon 2036–2065, H2 horizon 2071–2100, F future climate, C current climate

**Table 5** Variation of the average daily precipitation between current and future climate

Models		CanESM2				CNRM-CM5			
Scenarios		RCP4.5		RCP8.5		RCP4.5		RCP8.5	
Horizons		H1	H2	H1	H2	H1	H2	H1	H2
Regions	Seasons	F–C	F–C	F–C	F–C	F–C	F–C	F–C	F–C
Casablanca	Winter (D–J–F)	– 15	– 26	– 21	– 44	– 1	16	1	– 31
	Spring (M–A–M)	– 17	– 26	– 21	– 22	4	– 4	– 2	– 10
	Summer (J–J–A)	00	00	00	00	00	00	00	00
	Autumn (S–O–N)	– 21	– 25	– 17	– 42	– 23	– 15	– 31	– 29
	Annual	– 17	– 26	– 20	– 38	– 6	2	– 9	– 25
El Jadida	Winter (D–J–F)	– 16	– 28	– 23	– 41	– 2	18	8	– 30
	Spring (M–A–M)	– 17	– 20	– 20	– 25	13	– 1	3	– 11
	Summer (J–J–A)	00	00	00	00	00	00	00	00
	Autumn (S–O–N)	– 29	– 31	– 23	– 55	– 31	– 18	– 28	– 32
	Annual	– 20	– 27	– 22	– 42	– 7	2	– 4	– 26
Nouacer	Winter (D–J–F)	– 34	– 60	– 48	– 99	– 2	33	1	– 60
	Spring (M–A–M)	– 18	– 28	– 24	– 25	3	– 4	– 2	– 12
	Summer (J–J–A)	00	00	00	– 1	00	– 1	00	– 1
	Autumn (S–O–N)	– 21	– 26	– 17	– 44	– 25	– 17	– 35	– 33
	Annual	6	– 4	2	– 19	14	22	11	– 6

*H1* horizon 2036–2065, *H2* horizon 2071–2100, *F* future climate, *C* current climate

## Declarations

**Conflict of interest** The authors declare that they have no conflict of interests between each other.

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