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Assessment of performance of the regional climate model (RegCM4.6) to simulate winter rainfall in the north of Morocco: The case of Tangier-Tétouan-Al-Hociema Region

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ABSTRACT

We examine the performance of the regional climate model RegCM v4.6 to simulate spatial variability of precipitation in the northwestern region of Morocco during the winter of 2009–2010. Simulations cover 24 months from 2009 to 2010 with 30 km as a horizontal grid. We use NCEP reanalysis as forcing data and for better comparison of results, observed precipitations derived from CRU, CHIRPS, and CMORPH data. Results indicate that, on the whole, the RegCM4 model represents appropriate regional aspects of rainfall over the study area but underestimates precipitations over mountainous and Mediterranean regions of the study area (Case of Tangier-Tétouan-Al-Hociema Region) which is probably due to poor representation of orography in the Model and some aspects of local Mediterranean climate. Projected precipitations are also examined in this work in comparison with the reference period of 1970–2005, with simulations performed by RegCM 4.6 regional model for the period 2023–2099 under scenarios RCP4.5 and RCP8.5, forced by HadGEM2-ES General Circulation Model. Results show a decrease in precipitations mean for (2023–2099) for both RCP4.5 and RCP8.5 scenarios over the study area in comparison with the historical period (1970–2005), with a significant decrease under RCP8.5 scenarios. This work proves that the RegCM v4.6 model can be used for regional climate prediction, particularly for the spatial distribution of precipitation, but for sectorial applications and impact studies, the Model outputs should be bias corrected.

1. Introduction

Climate change is currently one of the most critical global challenges, with significant effects being experienced worldwide [1]. The Middle East and North Africa (MENA) region, in particular, is expected to become hotter and drier due to climate change, this vulnerable region is highly susceptible to extreme weather events, such as storms, heat waves, heavy rainfall, flash floods, and rising sea levels, all of which are escalating due to climate change, as noted in the International Panel on Climate Change (IPCC) Sixth

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Assessment Report (AR6) [1,2]. It should be noted that, Climate change is well known today as the biggest challenge on the planet [3–5] The effects of climate change on the frequency and intensity of extreme precipitation events have recently received a lot of attention due to their significant social, economic, and environmental consequences [6]. Then, providing an accurate estimation of future changes in these extreme events is crucial for responsible decision-making in the management of flood risk [7]. Morocco is an example of a country within the Mediterranean region that has been significantly impacted by climate change [8,9]. However, Morocco has a relatively uneven distribution of rainfall, which is marked by considerable yearly variability, and is likely to produce more extreme precipitation events [10]. Where the vulnerability of the populations to extreme hydrological events is significant [11, 12]. Recently due to the global phenomena of global warming, Morocco with an arid environment has experienced a dramatic change in its climate, which had a significant impact on important sectors [11–13], such as agriculture, water resources, and the overall economy [14]. High Moroccan precipitation tends to coincide with large negative anomalies of the North Atlantic Oscillation (ONA). Moreover, previous research on precipitation in Morocco has mainly focused on the inter-annual variability and the links with large-scale circulation such as the NAO index, to make future projections for water resource-related problems [14–18]. Therefore, the study of rainfall distribution and future trends is an essential task for better planning and managing water resources, especially in a region where the vulnerability of the populations to extreme hydrological events is high [11,12]. The need for a regional understanding of precipitation variability in northern Morocco seems to be very important to better forecast floods occurrence and develop efficient mitigation methods. The Tangier-Tétouan-Al-Hociema region in the north of Morocco is particularly vulnerable to these changes, as it relies heavily on agriculture and has experienced a decline in winter rainfall in recent years. Various events causing human losses and economic damages have been reported in recent years particularly in the north of Morocco during 2009–2010 (Rabat, Tanger, Tétouan, Nador, and Casablanca …). The floods in Morocco primarily result from intense precipitation events, and the susceptibility of major Moroccan urban centers to extreme precipitation and flooding has escalated over the past two decade [19,20]. In addition, the strong temporal variability of precipitation is also the cause of either abundant droughts or extreme floods, particularly during the winter period (IPCC, 2007, 2013, 2014a, 2014b). As well as important changes in climate characteristics are evidenced by several studies focusing on climate trends at regional and local scales [21,23–27]. The simulation of precipitation patterns in Northern Morocco presents a significant challenge for regional climate models owing to the region's highly variable spatial and temporal rainfall conditions [28]. According to Driouech et al. (2009), they recommended the use of downscaling techniques in order to more accurately replicate the Moroccan climate, as the region is heavily impacted by orographic features. Thus, future climate change forecasts on a local and regional scale are manifested as the first essential step before any intervention. Climatic models seem the best approach to studying these predictions of future climate scenarios and for monitoring the risks of climate change. To our knowledge, there isn't any research currently available to assess the performance of the RegCM to simulate winter precipitation in northern Morocco. The first one was done in the framework of this study. In scientific literature, the majority of relevant research tends to center on Europe, Asia, or Africa, with even fewer studies addressing future projections. Notably, the year 2009–2010 remains notable for the inundating and destructive flooding (2739 mm of rainfall) that occurred in the northern region of Morocco.

In this paper, the Regional Climate Model has been used to simulate winter precipitation in the north of Morocco (Case Tangier-

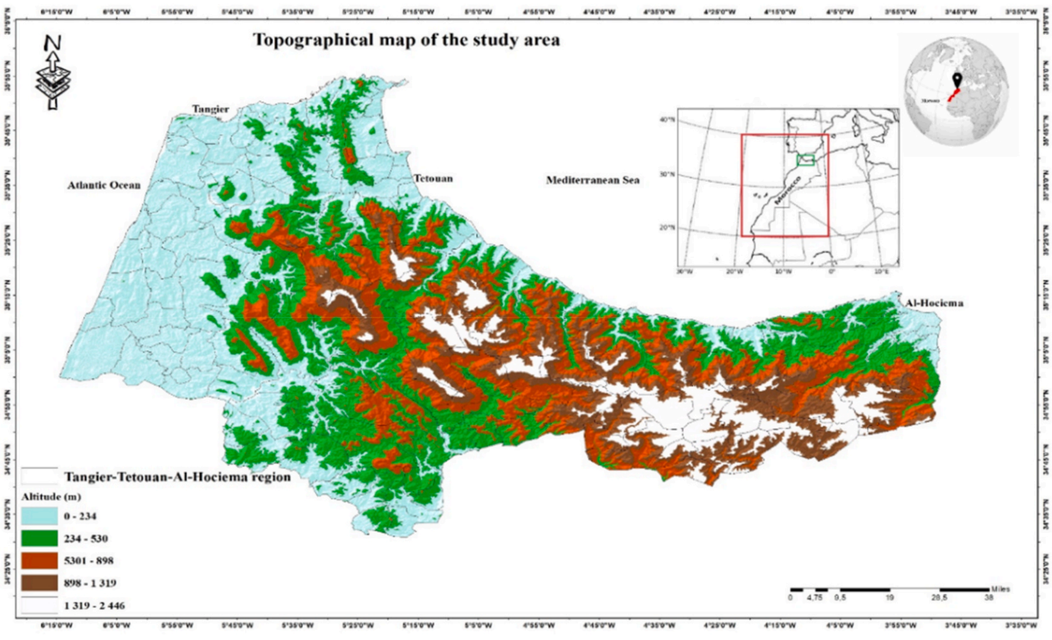

Fig. 1. Location and elevation (m) of the study area. The RegCM simulation domain used is boxed in red. Focused region (Northern Morocco) boxed in green (Tangier-Tétouan-Al-Hociema Region). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Tétouan-Al-Hociema region) during the winter season of 2009–2010, DJF (December-January-February). To do this, we will use RegCM v4.6 to verify the performance and the ability of this model to simulate heavy rainfall, focused particularly on the spatial distribution of precipitation (extreme events). Considering that the analyses will focus on the rainy season from December to February (DJF). Nonetheless, a short-term simulation was run for this period from 1st January 2009 to December 30, 2010. Note that, to have longer regional RegCM simulations this requires solid climate data and supercomputers.

Finally, anomalies of projected mean precipitation simulated by RegCM4.6 for the period 2023–2099 and the historical period 1970–2005 are also analyzed for the study area under the RCP4.5 and RCP8.5 scenarios. Assuming a world with a constantly growing population, both of these scenarios entail high levels of greenhouse gas emissions [29,30]. Thus, this study aims to evaluate the ability of the RegCM4.6 to accurately simulate winter rainfall in the Tangier-Tétouan-Al-Hociema region and to identify potential sources of error in the model. We will compare model outputs with observed rainfall data from the region, and assess the performance of the model in reproducing key features of the winter rainfall regime including RCP scenarios.

2. Data and methodology

For the simulation, we used the RegCM (Regional Climate Model) software, which is a climate modeling tool used to simulate future climate conditions at the regional level. We applied it in the study area to simulate the spatial variability of precipitation between 2009 and 2010 on a 30 km grid. The data used were sourced from the GHCN (Global Historical Climatology Network-Monthly), specifically the CRU_TS dataset, CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data), and CMORPH (Technique for the morphing of CPC Climate Prediction Center from NOAA).

2.1. Study area

Morocco is a North African country (Fig. 1) with a high degree of climate variability due to its geographical location. The climate of Morocco is characterized by a Mediterranean climate along the northern coast and a semi-arid to arid climate in the rest of the country. The country experiences hot and dry summers, with maximum temperatures that can exceed 40° Celsius, and cool to cold winters, with minimum temperatures that can drop below freezing. Precipitation also varies considerably across regions, with average annual precipitation ranging from less than 100 mm in desert regions to over 1000 mm in mountainous regions. Most of the precipitation falls during the winter, with episodes of heavy rain that can cause flooding. Sandstorms are also common in the desert regions of Morocco. Due to these climate variations, Morocco faces significant challenges in water resource management and adapting to climate change [31,32].

According to the latest administrative division, the Tangier-Tétouan-Al Hoceima region (35° 46′ 00″ N, 5° 48′ 00″ W) includes 2 prefectures and 6 provinces. The region covers an area of 17,262 km^2, i.e. 2.42% of the country's total area (HCP, 2018).

The region is part of the Mediterranean climate, which is very heterogeneous as a result of three factors: altitude, latitude and the proximity of the ocean. The far North-West, particularly the Tangier-Tétouan-Al Hoceima region and thanks to its altitude and its triple maritime frontage, study region is one of the most watered areas in Morocco (more than 1000 mm) in addition a location where floods are a particular risk from natural disasters.

2.2. Observational precipitation data

The study of climate and its variability absolutely requires the acquisition of reliable observational data in the region of interest. For this purpose the RegCM4 model outputs are compared with three sets of observational precipitation data: CRU [33], CHIRPS [34] and CMORPH [35].

2.2.1. CRU (climatic research unit)

The CRU_TS series of data sets consist of monthly time series of precipitation, daily maximum and minimum temperatures, cloud cover, and other variables covering Earth's land areas. The data set is gridded to 0.5 × 0.5-degree resolution, based on analysis of over 4000 individual weather station records. Many of the input records have been homogenized.

2.2.2. CHIRPS

(Climate Hazards Group InfraRed Precipitation with Station data) is a 30+ year quasi-global rainfall dataset. CHIRPS incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring.

2.2.3. CMORPH (NOAA CPC MORPHing technique)

CMORPH This dataset consist of 0.25-degree resolution daily global Climate Prediction Center (CPC) morphing method (CMORPH) precipitation data. CMORPH is the CPC Morphing technique, which derives precipitation estimates from low orbiter satellite microwave observations.

2.3. Description of the model RegCM-4.6 and experimental setup

In this study, we assess the performance of the Regional Climate Model (RegCM4.6) in simulating winter rainfall in the Tangier-Tétouan-Al-Hociema region. The RegCM4.6 is a widely used model that has been applied in numerous studies to assess climate change impacts at regional scales. The model uses a high-resolution grid to simulate climate variables and incorporates physical processes such as atmospheric dynamics, radiation, and land surface processes. While this model is considered reliable, it is important to recognize the associated mechanisms and sources of error that can affect simulation results. One of the most important associated mechanisms for the RegCM model is the choice of spatial and temporal resolution. Fine resolution may allow for better representation of physical processes, but it also results in a significant increase in demand for computing resources. Moreover, excessively fine resolution may result in overrepresentation of certain processes, leading to simulation errors. Another potential source of error for the RegCM model is the selection of physical parameters used to represent processes in the model. These parameters may vary depending on weather conditions and geographic characteristics of different regions, which can lead to simulation errors. Therefore, it is important to carefully select appropriate physical parameters for each region and each simulation. Moreover, Boundary conditions: RegCM uses boundary conditions that represent the global climate system's state outside the regional domain. These boundary conditions can be obtained from global climate models, reanalysis data, or observations.

The regional climate model (RCM) RegCM is originally developed by the National Center for Atmospheric Research (NCAR), is regarded as the first restricted area model created for long-term regional climate modeling, and is chosen as one of the RCMs used for the Coordinated Regional Climate Downscaling Experiment (CORDEX) [36,37]. Primitive equation model is a 3 dimensional, sigma vertical coordinate [38], based on the performance of various physical parameterization options noted in previous studies. In addition, a sizable community has used this model for numerous regional climate research and it can be applied to any region of the World to run climate simulations on grid sizes ranging from 10 to 90 km, In this study, we will use the latest version of Hydrostatic RegCM4.6.1 [39]. with radiative transfer Community Climate Model version 3(CCM3) [40,41], and subgrid-scale moisture scheme [42]. Planetary boundary layer scheme (PBL), [43]. Convective parametrization schemes [44]. Zeng ocean surface schemes [45]. However the land surface processes are described via model the Biosphere Atmosphere Transfer Scheme (BATS) of [46]. Following global climate change IPCC scenario code (RCP) Representative Concentration Pathways [47,48] represent four potential future changes in anthropogenic GES emissions that could influence the climate. From the most optimistic RCP 2.6 (High mitigation to the most pessimistic RCP8.5 (High increase), through the intermediate RCP4.5 and RCP 6 (Emissions mitigation). These scenarios are designed to follow the Special Report on Emissions Scenarios (SRES), defined by the IPCC in 2000. For our case, we analyze simulations output of precipitations under both RCP4.5 and RCP8.5 scenarios. the simulation with RegCM4 has three basic steps: first, Pre-processing (setting up the simulation domain, prepare Terrestrial variables (including elevation, land use and sea surface temperature), Initial and Boundary Conditions (ICBC) meteorological data from General Circulation Model, physical parameterization. Second: running of the model. Lastly: Post-processing of the data output from the previous step.

Finally, it is important to note that the RegCM model is also sensitive to the quality of input data used. Poor quality data, such as missing or erroneous data, can lead to significant errors in simulation results. Therefore, it is essential to ensure that input data used for the model is of high quality and representative of the studied region.

2.4. Model configuration: detailed simulation name list

The summarize of the configuration used for RegCM4.6 illustrated in Table 1.

Table 1
List name configuration used for RegCM4.6 simulations.

Model	RegCM4.6.1
Simulation period	January 2009 to December 2010
Central point of domain	(32.4° N, 6° W)
Number of horizontal grid points	(160,160) grid points for (x,y)
Horizontal grid distance	30 km
Number of vertical levels	18 σ levels
Horizontal grid scheme	Arakawa B-grid
Time integration scheme	Split-explicit
Lateral boundary layer conditions	Relaxation, exponential technique
global analysis datasets used	NNRP1
Moisture scheme	Explicit moisture (SUBEX; Pal et al., 2000)
Boundary layer scheme	Holtslag PBL
Cumulus convection scheme	Emanuel (1991)
Soil Model	High resolution soil model (Dickinson,1993)
Topography	USGS (GTOPO30)
Surface Parameters	BATS1E *(Dickinson, 1993)*
Ocean Flux scheme	Zeng et al. (1998)
Type of Sea Surface Temperature used	OI_WK (OISST CAC Weekly Optimal Interpolation dataset)

3. Results & discussion

The results indicate the model simulations show small differences compared to observations in terms of rainfall. Generally, in numerous research, the regional climate model (RegCMv4) reasonably reproduced atmospheric changes in temperature and wind fields but showed relatively poor performance in the simulation of precipitation at different geographical locations and during different seasons [49–51].

Although simulation covers the entire domain of Morocco; but analysis of results in this study will focus only on the Northwestern part of Morocco. Seasonally averaged rainfall has been studied to evaluate the climatological response of winter precipitation during the period 2009–2010 (Fig. 2: a, b, c, d, e, f, g, h & i) shows the bias relative to mean simulated DJF (December-January-February) of 2009–2010 daily mean precipitation and DJF daily mean precipitation of three set of observational data (CRU, CMORPH, CHIRPS) for the same period. We note a positive bias for CRU-RegCM (up to 3.6 mm/day) and CHIRPS-RegCM (up to 5 mm/day), which indicate that RegCM4 model underestimate mean precipitation almost over the entire northwestern region but the bias is high over the extreme North of the study area and the Mediterranean coasts, which can be explained as poor representation of orography in RegCM4 model and some aspects of local Mediterranean climate. The bias between CMORPH and RegCM4 simulations (CMORPH-RegCM) is negative except over the extreme North of the study area and the Mediterranean coasts reaching +2 mm/day, which means that RegCM4 model over estimate precipitations. In fact, it is clear that overall the RegCM4 model represents the appropriate regional aspects of precipitation over the study area (RTTA). Taking account of the differences in the construction of the three observational data, the RegCM4 model underestimates precipitations in mountainous and Mediterranean regions, which is probably due to a poor representation of the orography in the model and some aspects of the local Mediterranean climate.

3.1. *Evaluation scores of the RegCM4.6*

The calculations of the monthly cumulative rainfall assessment scores of the RegCM4.6 model were represented by (Fig. 3 &

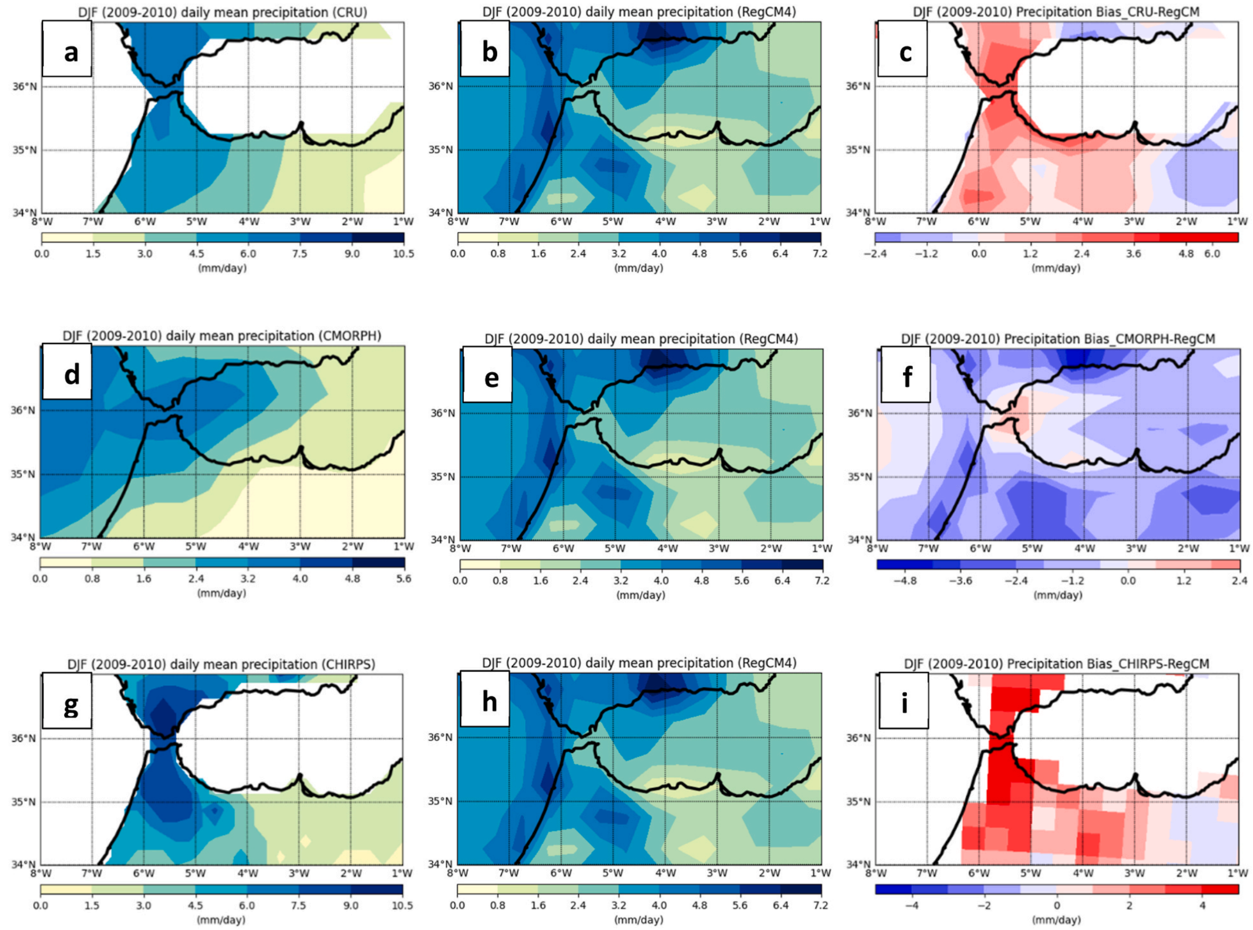

Fig. 2. Observed mean precipitation (CRU (a), CMORPH (d), CHIRPS (g)), RegCM4.6 simulated mean DJF precipitation (b,e,h) and Bias (Observed-Simulated) (CRU-RegCM) (c), (CMORPH-RegCM) (f), (CHIRPS-RegCM) (i).

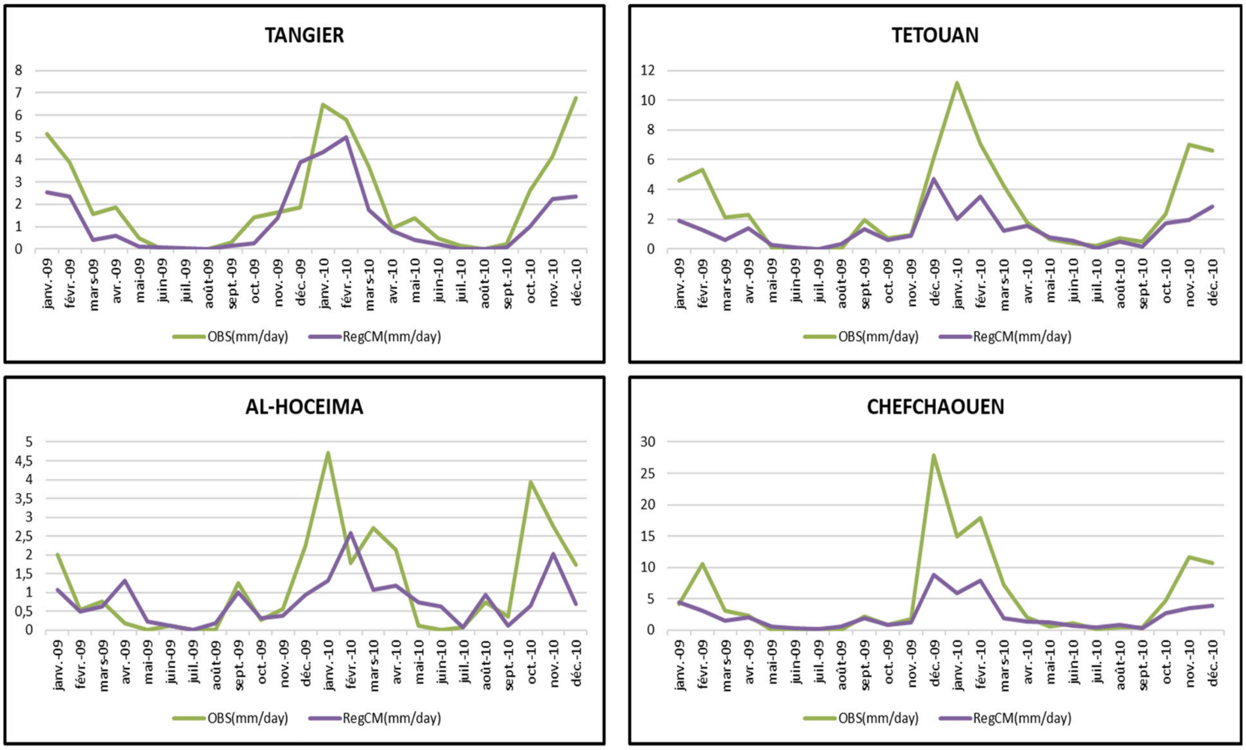

Fig. 3. Comparison of simulated precipitation results (RegCM) with observed data in Northern Morocco: Stations (Tangier, Tetouan, Al-Hoceima, and Chefchaouen).

Table 2
Bias, root mean square error (RMSE), and correlation coefficient of precipitation model simulated by RegCM.

Stations	BIAS (mm)	RMSE (mm)	Correlation coefficient
Tangier	−0,049	0240	0,838
Tétouan	−0,062	0305	0,759
Al-Houceima	−0,006	0029	0,555
Chefchaouen	−0,067	0327	0,944

Table 2), the validation scores include Bias, root mean square error (RMSE), and correlation coefficient. Then, using the correlation method, the association between the models and the observations can be determined. The correlation method of linear models provides information on the relationship between the model and observation data. If the correlation coefficient is closer to one, the model is considered to accurately represent the observations. Conversely, negative values indicate a weak or inverse relationship, while positive values indicate a strong or direct relationship [52]. Therefore, a positive correlation coefficient that is closer to one suggests that RegCM4 effectively simulates rainfall. Generally, the statistical properties of precipitation are the most difficult to reproduce and therefore the most uncertain in climate models, thus the results of the model evaluation scores calculations over the 24 months (2009–2010) indicate that the RegCM model underestimates precipitation, especially for the Chefchaouen, Tétouan and Al Hoceima areas. On the other hand, this confirms the fact that the RegCM model underestimates precipitation over the mountainous (Chefchaouen) and Mediterranean (Tetouan and Al Hoceima) regions, which can probably be explained by a poor representation of the orography in the model. The precipitation that occurred due to the Atlantic low pressure is forced by the west-facing mountains in the Chefchaouen area, causing heavy precipitation. Similarly, some storm episodes with heavy precipitation occurred in the Tétouan region and less in the Al Houceima region due to the focus of the orography which is oriented towards the east and acts as a cold front over the warm and humid Mediterranean.

The following table illustrates the results of the calculations of the monthly evaluation scores of the cumulative precipitation simulated by the RegCM model, over the 24 months of the period (2009–2010) in the north of Morocco (RTTA), for the following climate stations: Tangier, Tetouan; Al-Houceima and Chefchaouen.

According to Table 2, the difference between simulated and observed precipitation (BIAS) in northern Morocco, especially in Winter (DJF), is generally negative.

The validation of the RegCM model to simulate precipitation extremes is a difficult task, as reliable daily data comparable to the model outputs are not readily available. Furthermore, the use of station data for model validation is always limited due to problems with the availability of observations. Another type of information that is relatively useful for the validation of precipitation extremes is the reanalyses, covering the whole globe and allowing validation in places where sufficiently long observation series do not exist or are not available. The obvious advantage of reanalyses is that they are calculated on a grid and can then be compared with model outputs.

A comparison between the RegCM model and observation data (CRU) was also conducted in the north of Morocco (RTTA). The CRU data is developed independently and based mainly on satellite measurements and surface observations, respectively, at different spatial resolutions and is therefore only available on land. Generally, the results (Fig. 4) show an underestimation of precipitation in the model for the climatic stations: Tanger, Tétouan, Al-Houceima, and Chefchaouen.

The following table (**Table 3**) shows a comparison of the model-simulated precipitation results (Regcm) with the observed data (CRU).

3.2. RegCM4 precipitation projections

RegCM remains a valuable tool for studying the regional climate and for understanding how the climate may change in the future. Climate models are continuously improved and adjusted to take these limitations into account and to improve the accuracy of forecasts**.**

In this section, DJF mean precipitation simulated with RegCM4.6 for 2023–2099 were analyzed in comparison with historical period 1970–2005 (Fig. 5). We focus on the northwestern of Morocco. Fig. 5 shows the anomaly of winter mean precipitation projected by RegCM4.3 model for RCP4.5 and RCP8.5 scenarios. We note a clear negative bias over the entire north region for both RCP scenarios, which means a significant decreasing in mean precipitations amount for the projected period of 2023–2099. The decreasing is more important for rcp8.5 scenarios. The regions opposite the Atlantic has more negative bias then others regions for both scenarios. This can be explained by a decreasing in number of occurrences of precipitation episodes coming from the Atlantic, which is generally the case for northern Morocco during winter season.

The ensemble mean results indicate that extreme precipitation intensities will decrease in all future periods compared to simulations over the reference period 1970–2005 (Fig. 5). It is important to note that the ensemble mean results are based on climate models and greenhouse gas emission scenarios, which although widely accepted and used by the scientific community, still carry some degree of uncertainty. Regarding the decrease in extreme precipitation intensities in all future periods, this could have significant implications for ecosystems and communities that depend on precipitation for their survival and livelihoods. Therefore, it is important to continue research to better understand the implications of these climate changes and to develop appropriate adaptation strategies. The findings of this study will contribute to a better understanding of the performance of the RegCM4.6 in simulating winter rainfall in the north of Morocco, and will have implications for climate change adaptation strategies in the region. By improving our understanding of the potential impacts of climate change on winter rainfall in this region, we can better inform policy decisions and develop effective adaptation strategies to mitigate the impacts of climate change.

The results obtained indicate that the work carried out clearly meets the objectives and hypotheses stated at the beginning of this study in the introduction. Indeed, we have tried to follow a rigorous scientific approach, the method adopted in this study is essentially based on the simulation of the spatial variability of precipitation in the Tangier-Tétouan-Al Hoceima region (RTTA), and the use of precipitation data obtained from the CRU, CHIRPS and CMORPH datasets to evaluate the RegCM model. It thus comprises several

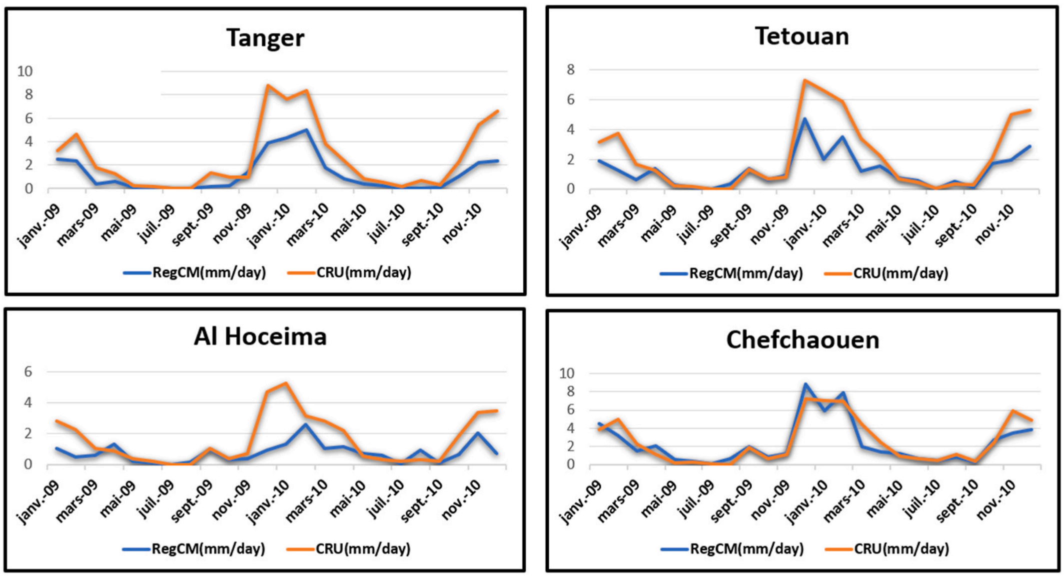

Fig. 4. Comparison of simulated precipitation results (RegCM) with observed data (CRU) in Northern Morocco: Stations (Tangier, Tétouan, Al-Hoceima, and Chefchaouen).

Table 3
Comparison of model-simulated precipitation results (RegCM) with observed data (CRU): Bias, RMSE, and model correlation coefficients.

Stations	BIAS (mm)	RMSE (mm)	Correlation coefficient
Tangier	**−0,005**	**0023**	**0,95**
Tétouan	**0,002**	**0,01**	**0,9**
Al-Houceima	**−0,007**	**0034**	**0,63**
Chefchaouen	**0.01**	**0.07**	**0,91**

According to Table 3, the difference between simulated and observed precipitation (BIAS) in northern Morocco is generally heterogeneous.

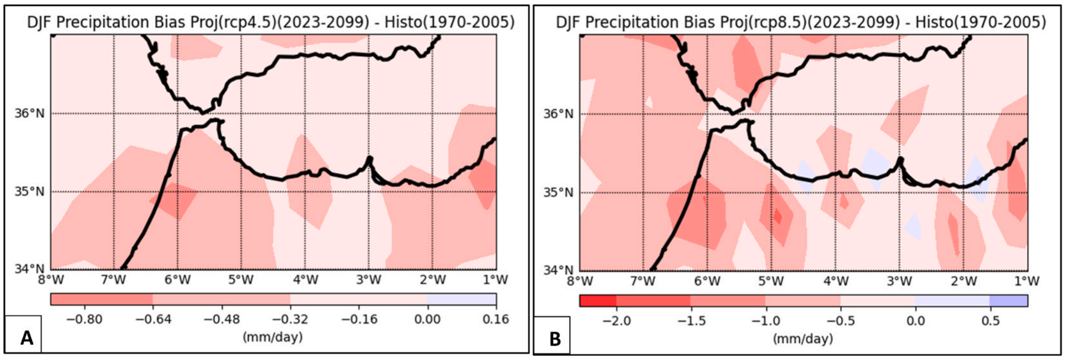

Fig. 5. Anomaly of winter (DJF) mean precipitation projected by RegCM4.3 model and Historical period (1970–2055) under RCP4.5 (A) and RCP8.5 (B) scenarios.

complementary approaches carried out within a multidisciplinary framework.

4. Conclusions & perspective

The present study employs RegCM4.6 simulation technique to investigate rain variability in extreme weather conditions during the winter season (DJF) for a period of two years (2009–2010) in Morocco's northern region (Tangier-Tetouan-Al-Hociema). The simulations implemented grid spacing of 30 km, made use of NCEP data gridded at 2.5° and were compared with three different observational databases to evaluate the performance of the technique.

Given the acknowledged status of climate change as the foremost long-term peril to the northern region, we have conducted an assessment of model simulation over the past interval across the northern region of Morocco, with the purpose of testing the model's appropriateness in predicting the future climate. The primary outcomes and deductions are succinctly synthesized as follows.

- ✓ We have tried to capture the rainfall extreme over north morocco occurred on 2009/2010 reference period (winter period with high precipitation in the extreme north of Morocco).
- ✓ The ability of the model to obtain realistic precipitation pattern is analyzed in a way that the result will help us to further use the output of the RCM for climate change impact assessment especially on water resources.
- ✓ It was found during the validation of the model results with the current climate that the RegCM4 model underestimates precipitations especially over mountainous region.
- ✓ Model output needs a bias correction in order to use it in impacts studies or water resources planning. Therefore, a bias correction step is essential.
- ✓ We suggest the study of sensitivity of RegCM4 model output to different forcing data and different grid spacing.
- ✓ In Futures studies, we will examine the performance of RegCM4 in simulating extreme temperature with sensitivity studies to different radiative schemes.
- ✓ The RegCM climate model is an important tool for understanding future climate trends and impacts of climate change at the regional level.
- ✓ It is important to consider associated mechanisms and potential sources of error to ensure reliable and accurate simulation results.

Author contribution statement

Imane BOULAHFA: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Mohamed ElKharrim; Mustapha MAÂTOUK; Khadija ABOUMARIA: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Mohamed Beroho; Rachid El Halimi: Performed the experiments; Contributed reagents, materials, analysis tools or data.

Abdeladim Batmi: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.
Naoum Mohamed: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Data availability statement

Data will be made available on request.

Statements and declarations

The authors confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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