Evaluation Of Regional Climate Simulations For Agroenvironmental Applications In Northeastern Algeria

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***Abstract*—Climate variability and climate change have important implications for agroclimatology, agroecosystems, agricultural vulnerability, environmental sustainability, and water-resource management, particularly in semi-arid regions of North Africa. This study evaluates the performance of two regional climate model configurations, CCMA-CanESM2/RCA4 from Africa-CORDEX and ICHEC-EC-EARTH/RCA4 from Euro-CORDEX, in simulating daily precipitation and air temperature at Souk Ahras station in northeastern Algeria during the period 1982–2005. The effectiveness of statistical bias correction using the Distribution Mapping (DM) method is assessed by comparing raw and corrected simulations with observational data. The objective is to identify reliable climate datasets that can support future agroclimatic and environmental assessments.**

The results indicate that air temperature was generally better reproduced than precipitation in the raw simulations, with initial biases of −0.09 °C for CCMA-CanESM2/RCA4 and −0.17 °C for ICHEC-EC-EARTH/RCA4. After DM bias correction, temperature biases decreased to approximately 0.00 °C for both configurations, demonstrating the effectiveness of the method in reducing systematic errors. However, precipitation exhibited a more variable response to correction. The corrected ICHEC-EC-EARTH/RCA4 configuration achieved a residual bias of approximately −1% to −5%, whereas the corrected CCMA-CanESM2/RCA4 configuration retained a bias exceeding 30%. These findings demonstrate that the performance of regional climate models and bias correction methods depends on the climatic variable and model configuration, highlighting the importance of local validation and complementary statistical evaluation.

Reliable climate data are essential for agroclimatology and for assessing agricultural vulnerability to climate variability and climate change. They also provide a scientific basis for investigating the effects of climatic conditions on agroecosystems, supporting environmental sustainability, and improving water-resource management. Although this study does not directly measure agricultural productivity or ecosystem responses, its findings can support future research on climate-related risks to agricultural systems and the sustainable management of natural resources.

Overall, this study highlights the importance of evaluating regional climate models and applying model-specific bias correction to produce reliable climate datasets for agroclimatology and environmental assessment in northeastern Algeria. The results provide a foundation for future studies addressing agricultural vulnerability, agroecosystem resilience, environmental sustainability, and water-resource management under climate change in North Africa.

***Keywords*—Climate variability; agroclimatology; agroecosystems; agricultural vulnerability; environmental sustainability; water-resource management; regional climate models; bias correction; climate change.**

A. Introduction

Climate change poses major challenges to North Africa, a region particularly vulnerable to rising temperatures, changes in precipitation patterns, recurrent droughts, and extreme climatic events (IPCC, 2021). These changes can significantly affect water availability, hydrological processes, and the management of water resources, making the accurate assessment of climate variability and future climate conditions essential. In this context, reliable climate simulations are needed to better understand regional climatic characteristics and support hydrological assessments and climate-impact studies. However, the reliability of climate projections at the regional scale depends not only on the performance of the climate models used but also on their ability to reproduce observed climatic conditions.

Regional Climate Models (RCMs), particularly those developed within the Coordinated Regional Climate Downscaling Experiment (CORDEX) framework, provide valuable information on regional climate variability by representing climatic processes at a finer spatial resolution than Global Climate Models (GCMs). Nevertheless, CORDEX simulations may exhibit systematic biases when compared with observations, especially in the representation of precipitation and temperature. These biases can affect the reliability of simulated climatic variables and introduce uncertainties into subsequent hydrological and climate-impact assessments. Therefore, evaluating model performance against observed data is an essential step before using regional climate simulations in impact-oriented applications.

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Bias correction methods are commonly applied to reduce systematic differences between simulated and observed climate variables. Among these methods, Distribution Mapping (DM) adjusts the statistical distribution of simulated data to improve its agreement with the observed distribution. Its performance, however, may vary depending on the climatic variable, the characteristics of the model configuration, and the local climatic conditions. Temperature and precipitation may respond differently to correction because their statistical properties and sources of model error differ. Consequently, a correction method that performs well for temperature does not necessarily provide equally reliable results for precipitation. Previous studies have highlighted the importance of evaluating bias correction performance and its implications for climate-related applications (Pastén-Zapata et al., 2020; Miralha et al., 2021; Yersaw et al., 2024; Erkol et al., 2024).

Within this framework, the present study evaluates the performance of two CORDEX regional climate model configurations at Souk Ahras, in northeastern Algeria, over the period 1982–2005. The configurations considered are CCMA-CanESM2/RCA4 from Africa-CORDEX and ICHEC-EC-EARTH/RCA4 from Euro-CORDEX. Daily precipitation and temperature simulations are compared with observational data to assess the ability of both configurations to reproduce local climatic conditions. The evaluation is conducted before and after applying the Distribution Mapping (DM) bias correction method, allowing the performance of the raw simulations to be compared directly with that of the corrected datasets.

The results indicate that the raw CCMA-CanESM2/RCA4 simulation underestimates precipitation, with a bias of −7%. For temperature, the raw simulations exhibit relatively small biases of −0.09 °C for CCMA-CanESM2/RCA4 and −0.17 °C for ICHEC-EC-EARTH/RCA4. Following DM correction, temperature biases decrease to approximately 0.00 °C for both configurations, indicating a substantial improvement in their agreement with observations. However, the correction of precipitation produces contrasting results. The corrected CCMA-CanESM2/RCA4 configuration retains a precipitation bias exceeding 30%, whereas the corrected ICHEC-EC-EARTH/RCA4 configuration achieves a bias of approximately −1% to −5%. This difference highlights the variable effectiveness of the DM method and demonstrates that its performance depends on the climate model configuration and the variable being corrected.

Overall, this study aims to assess the capacity of the DM method to improve daily precipitation and temperature simulations at the local scale and to compare its effectiveness between two CORDEX configurations. The findings emphasize that bias correction should not be considered equally effective for all climate variables or model configurations. Instead, local validation is necessary to determine whether corrected simulations adequately reproduce observed climatic conditions. Such an assessment is particularly important before using CORDEX outputs in hydrological modelling and climate-impact studies, where residual biases in precipitation and temperature may influence the reliability of the results (Pastén-Zapata et al., 2020; Miralha et al., 2021; Yersaw et al., 2024; Erkol et al., 2024).

I. Methods

A. Study area and data set

The study evaluates CCMA-CanESM2/RCA4 (Africa-CORDEX) and ICHEC-EC-EARTH/RCA4 (Euro-CORDEX) at Souk Ahras station, northeastern Algeria Fig.1, Tab.II during 1982–2005, using daily precipitation and air-temperature observations from ANRH Tab.I as reference data (Zeroual et al., 2019; Bichet et al., 2020). Model performance was assessed using the BIAS indicator, with positive values representing overestimation and negative values underestimation (Mulugeta et al., 2020; Ranjan et al., 2022). The Distribution Mapping (DM) method was then applied to correct systematic biases, using a gamma distribution for precipitation and a Gaussian distribution for temperature. Raw and corrected simulations were compared using BIAS to evaluate the effectiveness of the correction method (Tan et al., 2020; Pastén-Zapata et al., 2020; Miralha et al., 2021; Tamene & Chala, 2021).

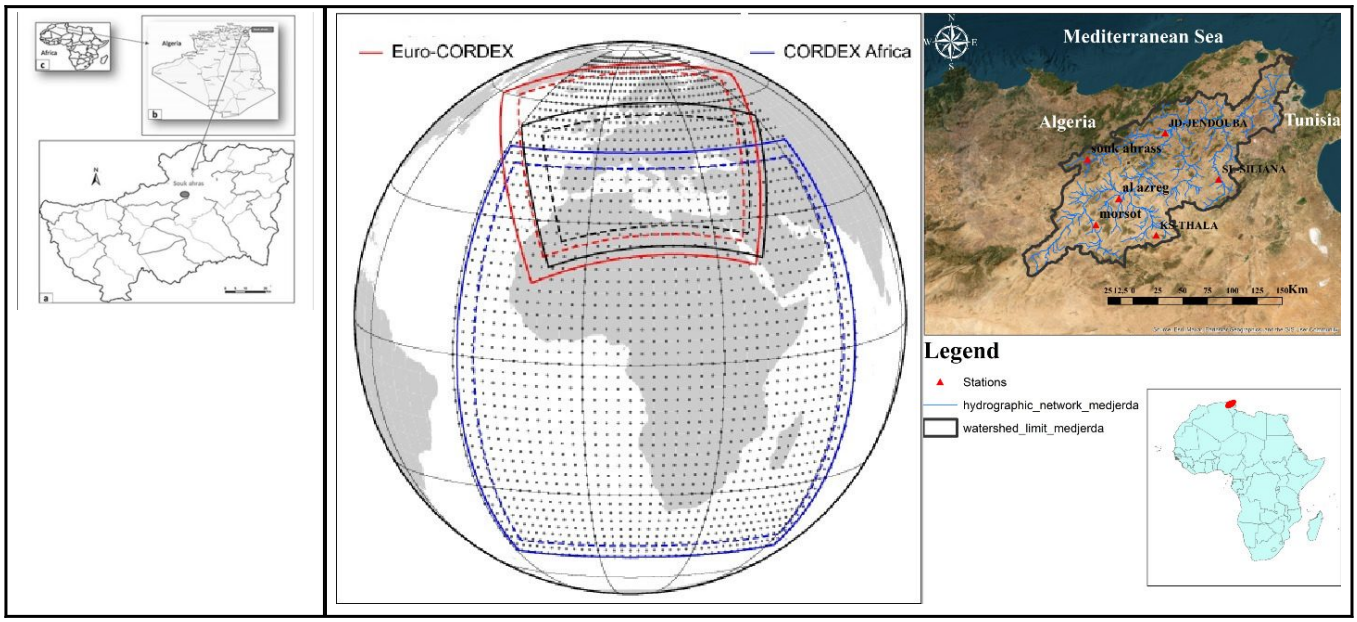


Fig .1: Geographical Cordex domains of climate models (Brands et al., 2013) and location of Souk Ahrass

TABLE I.
CHARACTERISTICS OF THE METEOROLOGICAL STATIONS IN THE STUDY AREA

Stations	Long (°)	Lat (°)	Altitude (m)	Source	Observed-Period
Souk Ahrass	7.9	36.26	590	ANRH	1982-2005

TABLE II.
SELECTED REGIONAL CLIMATE MODEL CONFIGURATIONS FROM THE AFRICA-CORDEX AND EURO-CORDEX DOMAINS

GCM-RCM	CORDEX domain	Spatial resolution
CCMA-CanESM2/RCA4	Africa-CORDEX	0.44° × 0.44° (approximately 50 km)
ICHEC-EC-EARTH/RCA4	Euro-CORDEX	0.11° × 0.11° (approximately 12.5 km)

1) Criterion for the Evaluation of Regional Climate Models (RCMs)

The BIAS is a statistical indicator used to quantify the systematic difference between regional climate model simulations and observed meteorological data. In this study, it is applied to evaluate the ability of the selected climate models to reproduce precipitation and air temperature at the Souk Ahras meteorological station during the reference period 1982–2005. A positive BIAS indicates that the model overestimates the observed values, whereas a negative BIAS indicates an underestimation. Values close to zero indicate a smaller systematic difference and therefore a closer agreement between simulations and observations. The BIAS is widely used in climate-model evaluation because it provides a simple and direct measure of systematic model error (Mulugeta et al., 2020; Ranjan et al.,2022).

The mean bias is calculated as follows:

$BIAS=(X_{sim}-X_{obs})/X_{obs}$ Eq (1)

Where:X_{obs}, X_{sim} are recpectively the average observed and simulated data (in our case precipitations and temperatures).

The BIAS is calculated separately for precipitation and air temperature for each of the two selected model configurations. The results are evaluated first using the raw model simulations and subsequently after applying the Distribution Mapping (DM) bias-correction method, allowing the effectiveness of the correction procedure to be quantified.

B. Bias correction method

Bias correction is essential for improving the reliability of climate data used in climate-change impact assessments (Tan et al., 2020). In this study, the Distribution Mapping (DM) method was selected to reduce systematic biases in climate simulations, particularly under Mediterranean and semi-arid conditions (Erkol et al., 2024; Madani et al., 2024)

- .**Distribution Mapping (DM)**

Bias correction improves the reliability of regional climate simulations by reducing differences between simulated and observed data (Tan et al., 2020). In this study, Distribution Mapping (DM) was applied to precipitation and temperature at Souk Ahras during 1982–2005 to adjust model distributions to observations. Its effectiveness under Mediterranean and semi-arid conditions has been reported in previous studies (Erkol et al., 2024; Madani et al., 2024).

$f_\gamma(x\backslash\alpha,\beta)=x^{\alpha-1}1/\beta^{\alpha}*\Gamma(\alpha)*e^{(-x)/\beta}$; $x\geq0$; $\alpha,\beta>0$ Eq (2)

With $\Gamma(\alpha)$ is the Gamma function; et α et β are the shape and scale parameter, respectively.

Regarding temperature, the DM method typically applies a Gaussian (normal) distribution, with location and scale parameters assumed to correspond to the optimal temperature distribution.

$f_N(x\backslash\mu,\sigma^2)=1/\sigma*\sqrt{(2\pi)}*e^{(-(x-\mu)^2)/2\sigma^2}$; $x\in R$ Eq (3)

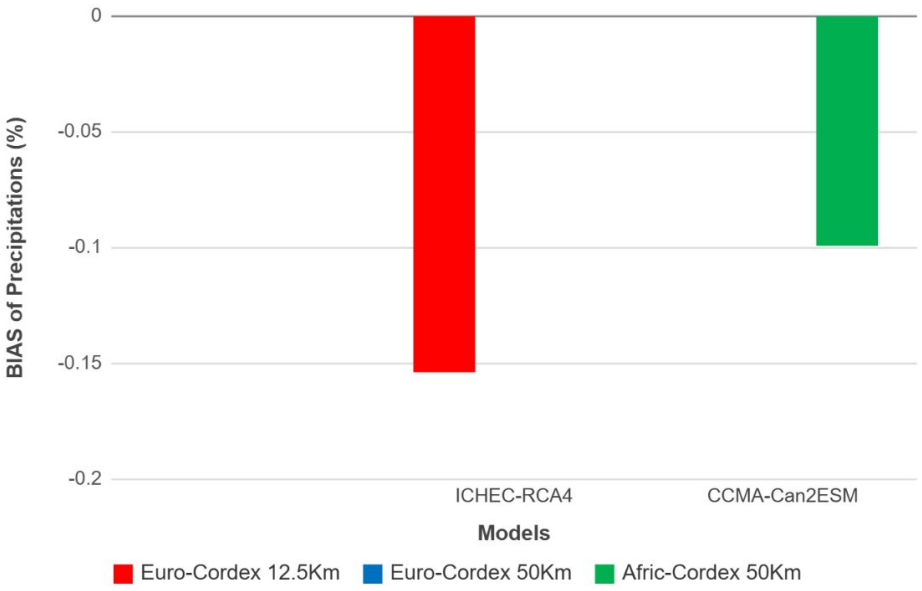
Where μ et σ are respectively determined by the mean deviation and the standard deviation.

1) Results and Discussion

2) Comparative Analysis of Raw Precipitation Simulations

Fig. 2. shows the raw precipitation biases at Souk Ahras during 1982–2005 for the CCMA-CanESM2/RCA4 Africa-CORDEX and ICHEC-EC-EARTH/RCA4 Euro-CORDEX configurations. The CCMA-CanESM2/RCA4 simulation presents a bias of −7%, indicating a slight underestimation of observed precipitation. Differences between the two configurations may result from model formulation, atmospheric forcing, and the representation of regional precipitation processes, which are particularly complex in the Mediterranean region (Demory et al., 2020; Dimri, 2021; Chelkeba, 2021). The persistence of systematic bias highlights the need for statistical correction. Therefore, the Distribution Mapping (DM) method is subsequently applied to assess its effectiveness in reducing precipitation discrepancies.

Fig .2: Comparison of raw precipitation simulations from the Africa-CORDEX and Euro-CORDEX models at Souk Ahras station (1982–2005).



3) Comparative Analysis of Raw Temperature Simulations

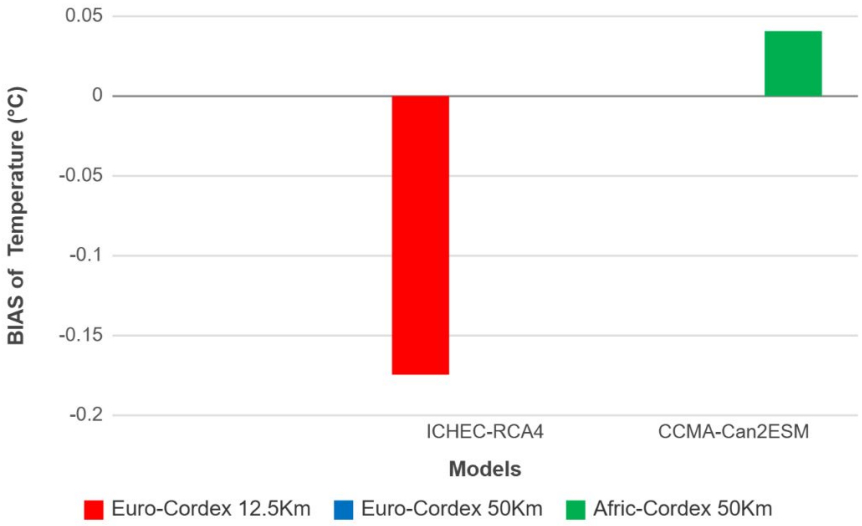


Fig. 3. shows slight temperature underestimation at Souk Ahras, with biases of −0.09 °C for CCMA-CanESM2/RCA4 and −0.17 °C for ICHEC-EC-EARTH/RCA4 during 1982–2005. Both biases are below 0.2 °C, indicating a close agreement with observations and providing a baseline for the DM correction.

Fig .3: Comparison of raw temperature simulations from the Africa-CORDEX and Euro-CORDEX models at Souk Ahras station (1982–2005).

C. Performance of Bias-Corrected Regional Climate Models During the Historical Period (1982–2005)

The application of the Distribution Mapping (DM) bias-correction method, based on the adjustment of gamma distributions for precipitation and Gaussian distributions for temperature, was used to reduce the systematic discrepancies between the regional climate model simulations and the observations at Souk Ahras station. The corrected simulations were then evaluated over the historical period 1982–2005 to assess the effectiveness of the correction procedure.

1) Comparative Analysis of Bias-Corrected Precipitation Simulations

Fig. 4. shows contrasting precipitation biases after DM correction: the CCMA-CanESM2/RCA4 bias remains >30%, while ICHEC-EC-EARTH/RCA4 shows a much lower residual bias of −1% to −5% (≈−2%). These results demonstrate that DM effectiveness depends on the model and climatic variable (Pastén-Zapata et al., 2020; Miralha et al., 2021; Tamene & Chala, 2021).

2) Comparative Analysis of Bias-Corrected Temperature Simulations

Fig. 5. shows that DM correction substantially reduces temperature biases, from −0.09 °C and −0.17 °C in the raw simulations to values close to 0.00 °C for both configurations. This indicates a strong agreement with observations and confirms the effectiveness of DM for temperature correction (Tan et al., 2020;

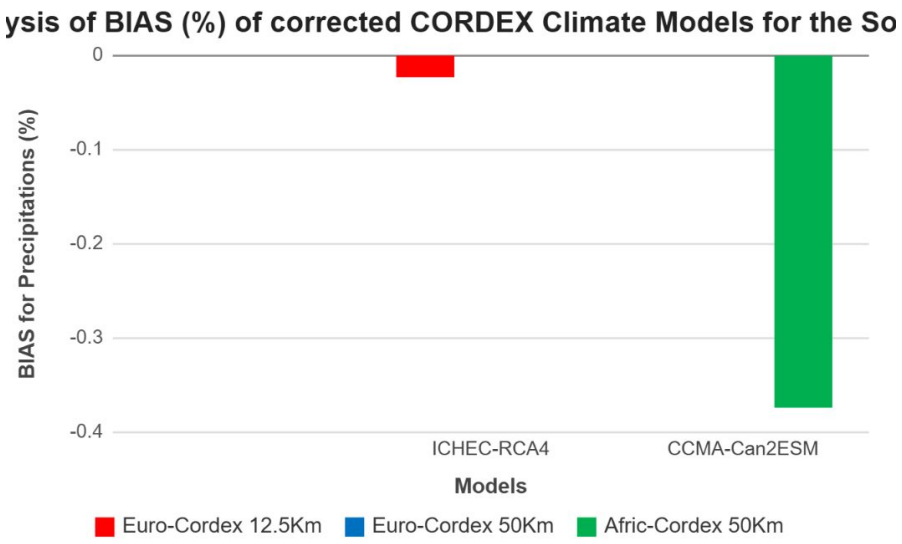


Fig. 4. Comparison of Bias-Corrected Precipitation Simulations at Souk Ahras Station (1982–2005).

Erkol et al., 2024; Madani et al 2024). Overall, Fig.5 confirms that DM considerably improves the representation of temperature at Souk Ahras and provides more consistent model outputs for subsequent climate variability and climate change impact analyses.

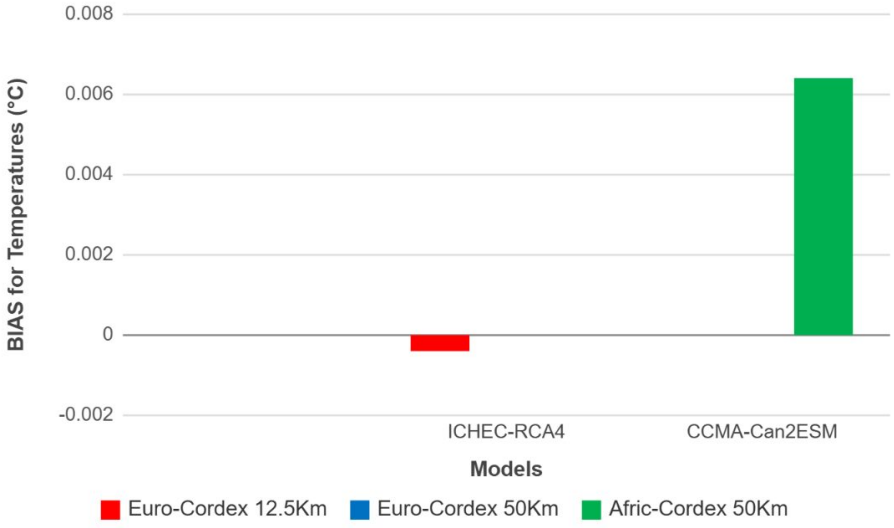


Fig. 5. Comparison of Bias-Corrected Temperature Simulations at Souk Ahras Station During the Historical Period (1982–2005).

D. Discussion

The evaluation of the CCMA-CanESM2/RCA4 configuration from Africa-CORDEX and the ICHEC-EC-EARTH/RCA4 configuration from Euro-CORDEX at Souk Ahras during 1982–2005 reveals differences in model performance depending on the climatic variable considered. Before bias correction, the CCMA-CanESM2/RCA4 configuration exhibits a precipitation bias of −7%, indicating a slight underestimation of rainfall. In comparison, the temperature biases are relatively small, reaching −0.09 °C for CCMA-CanESM2/RCA4 and −0.17 °C for ICHEC-EC-EARTH/RCA4. These results suggest that both configurations reproduce air temperature relatively well before correction, whereas precipitation presents greater discrepancies. Such differences may be associated with the characteristics of the driving global climate models, regional model configurations, and local climatic processes that influence the representation of precipitation and temperature (Demory et al., 2020; Mimeau et al., 2021; Zeroual et al., 2019; Bichet et al., 2020).

The application of the Distribution Mapping (DM) method produces contrasting results for precipitation. The corrected CCMA-CanESM2/RCA4 simulation retains a bias exceeding 30%, whereas the corrected ICHEC-EC-EARTH/RCA4 simulation achieves a substantially smaller residual bias, ranging from approximately −1% to −5%. This difference indicates that the effectiveness of statistical bias correction is not uniform across model configurations. Although DM can improve the statistical agreement between simulated and observed climate data, its performance depends on the initial characteristics of the simulations and the distribution of the variable being corrected. The contrasting precipitation results are consistent with the broader importance of evaluating correction methods according to the model configuration and the climatic variable

considered (Pastén-Zapata et al., 2020; Miralha et al., 2021; Tamene & Chala, 2021).

In contrast to precipitation, DM demonstrates a consistent improvement in temperature simulations for both configurations. The initial temperature biases of −0.09 °C for CCMA-CanESM2/RCA4 and −0.17 °C for ICHEC-EC-EARTH/RCA4 decrease to approximately 0.00 °C after correction. This substantial reduction indicates that DM is highly effective in reducing the mean temperature bias at the study site. The results are consistent with previous studies highlighting the potential of bias correction methods to improve the agreement between simulated and observed temperature data (Yersaw et al., 2024; Erkol et al., 2024; Madani et al., 2024).

The different responses of precipitation and temperature to DM emphasize the need to assess the performance of bias correction methods separately for each climatic variable. In particular, a near-zero temperature bias does not necessarily imply that the corrected simulations reproduce all aspects of the observed temperature distribution accurately. Similarly, the remaining precipitation bias in the CCMA-CanESM2/RCA4 configuration suggests that additional evaluation is required before this dataset can be used in applications sensitive to rainfall estimates. Moreover, because bias is the main evaluation indicator considered here, the results primarily describe systematic differences in the evaluated simulations and do not, by themselves, establish improvements in all aspects of model performance.

Overall, the findings demonstrate the importance of local model validation and model-specific bias correction when using CORDEX simulations in northeastern Algeria. The contrasting performance of the two configurations highlights the need to select climate datasets according to their demonstrated ability to reproduce the climatic variable of interest. This is particularly relevant for water-resource management, hydrological modelling, and climate-impact assessments, for which precipitation and temperature biases can influence the reliability of subsequent analyses.

E. Conclusion

This study evaluated two regional climate model configurations, CCMA-CanESM2/RCA4 from Africa-CORDEX and ICHEC-EC-EARTH/RCA4 from Euro-CORDEX, for the simulation of daily precipitation and air temperature at Souk Ahras, northeastern Algeria, during 1982–2005. The evaluation compared raw simulations with observations and examined the effect of the Distribution Mapping (DM) bias correction method, using bias as the principal performance indicator.

The results show that the raw CCMA-CanESM2/RCA4 configuration exhibits a precipitation bias of −7%, while the raw temperature biases are −0.09 °C and −0.17 °C for CCMA-CanESM2/RCA4 and ICHEC-EC-EARTH/RCA4, respectively. Following DM correction, temperature biases decrease to approximately 0.00 °C for both configurations, demonstrating the effectiveness of the method in reducing systematic temperature errors. However, the correction of precipitation yields contrasting outcomes. The corrected CCMA-CanESM2/RCA4 simulation retains a bias exceeding 30%, whereas the corrected ICHEC-EC-EARTH/RCA4 simulation presents a substantially smaller residual bias of approximately −1% to −5%.

These findings demonstrate that the effectiveness of DM varies according to the climatic variable and the regional climate model configuration. Although the method substantially improves the mean temperature bias, its performance for precipitation is less consistent. Consequently, the application of bias correction should be followed by a systematic evaluation of the corrected datasets to determine their suitability for specific applications.

The study highlights the importance of local validation and the careful selection of regional climate simulations before their use in hydrological modelling, water-resource management, and climate-change impact assessments in North Africa. Further evaluation using additional statistical indicators would help establish whether the improvements in bias are accompanied by improvements in other aspects of the simulated climate. In particular, the contrasting precipitation results underline the need to verify the residual errors of each configuration before using corrected precipitation data in impact-oriented applications. Overall, the findings provide a basis for assessing the suitability of CORDEX simulations for local climate applications in northeastern Algeria and reinforce the importance of model-specific bias correction (Zeroual et al., 2019; Bichet et al., 2020; Pastén-Zapata et al., 2020; Miralha et al., 2021; Tamene & Chala, 2021; Yersaw et al., 2024; Erkol et al., 2024; Madani et al., 2024).

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DATA AVAILABILITY STATEMENT

freely downloadable

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