Simulating extreme temperatures over Central Africa by RegCM4.4 regional climate model

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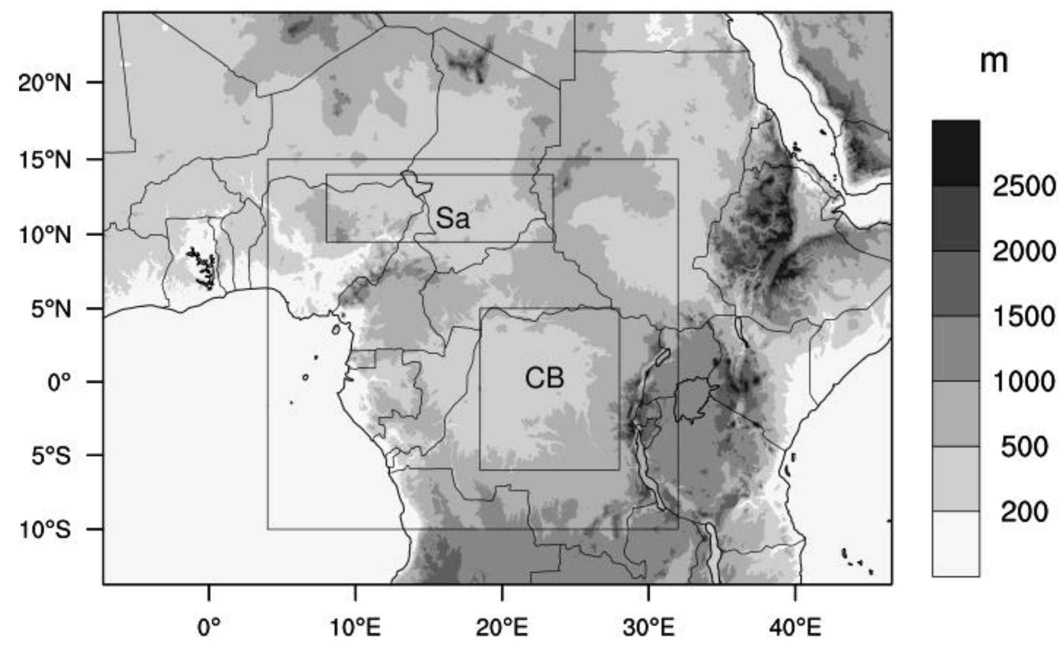
Abstract

Extreme temperatures, associated with global warming, raise concerns worldwide, particularly in Africa. This study assesses the RegCM4 climate model's performance in replicating extreme temperatures in Central Africa from 2002 to 2006, focusing on daily minimum and maximum temperatures. RegCM4 performs well with daily minimum temperatures but tends to overestimate daily maximum temperatures. Despite differences with ERA5 data, it remains useful for studying extreme temperatures, especially daily minimum temperatures and cold sequences in Central Africa.

1. Study area, data used and Methods

1.1. Study area

Fig. 1 : Surface elevation (units: m) of the simulation domain encompassing the study area (big box). Also shown are the two sub-regions used for more detailed analysis: zone 1 (9.5 ◦–14◦N, 8 ◦–23.5 ◦S) and zone 2 (6 ◦S–5 ◦N, 18.5 ◦E–28◦E).



1.2. Data

- **ERA-Interim with a resolution of 0.15◦ × 0.15◦ over the period 1981–2005.**
- **ERA5 with a resolution of 0.25◦ × 0.25◦ over the period January 1940 to present.**

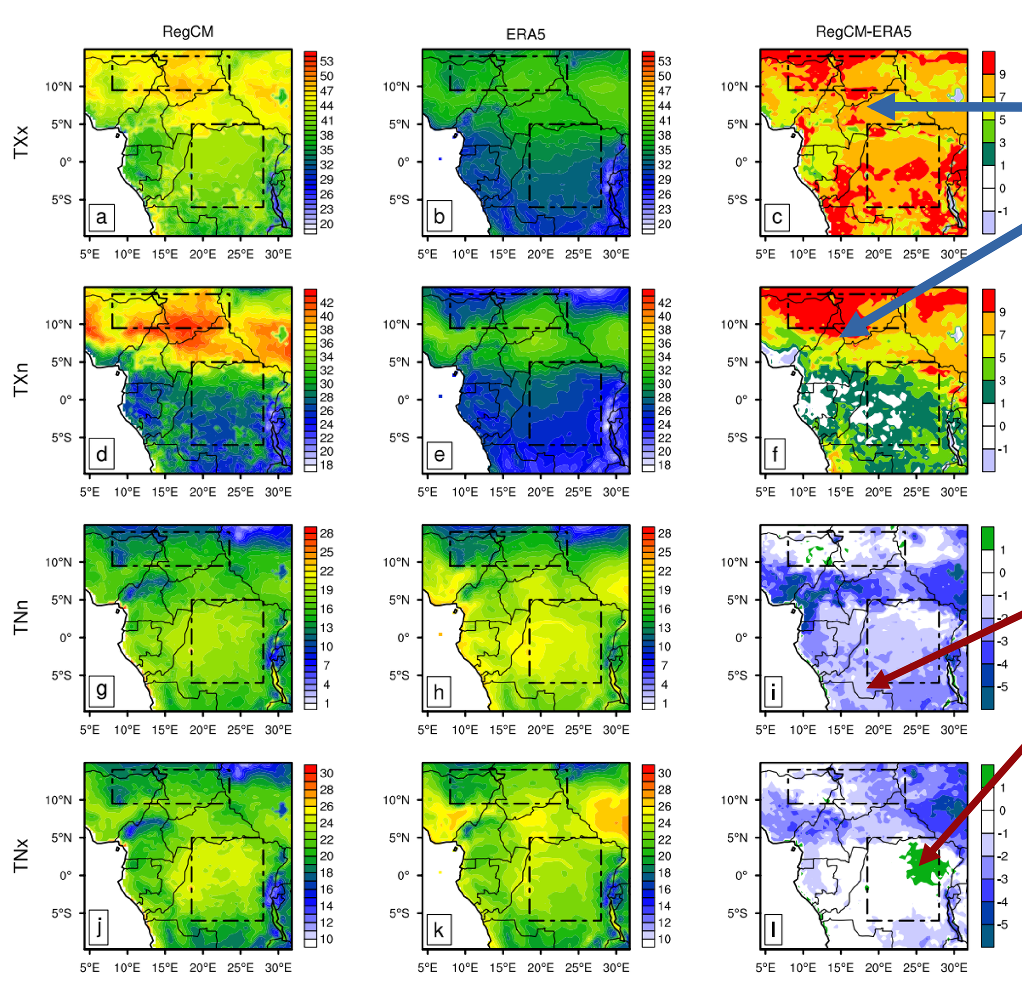
1.3. Extreme temperature indices used

Table 1. List of precipitation extreme indices used in this study.

	Name	Acronym	Units
Intensity indices	Monthly maximum value of daily maximum temperature	TXx	°C
	Monthly minimum value of daily maximum temperature	TXn	°C
	Monthly minimum value of daily minimum temperature	TNn	°C
	Monthly maximum value of daily minimum temperature	TNx	°C
Duration indices	Warm Spell Duration Indicator	WSDI	Day
	Cold Spell Duration Indicator	CSDI	Day

2. Results

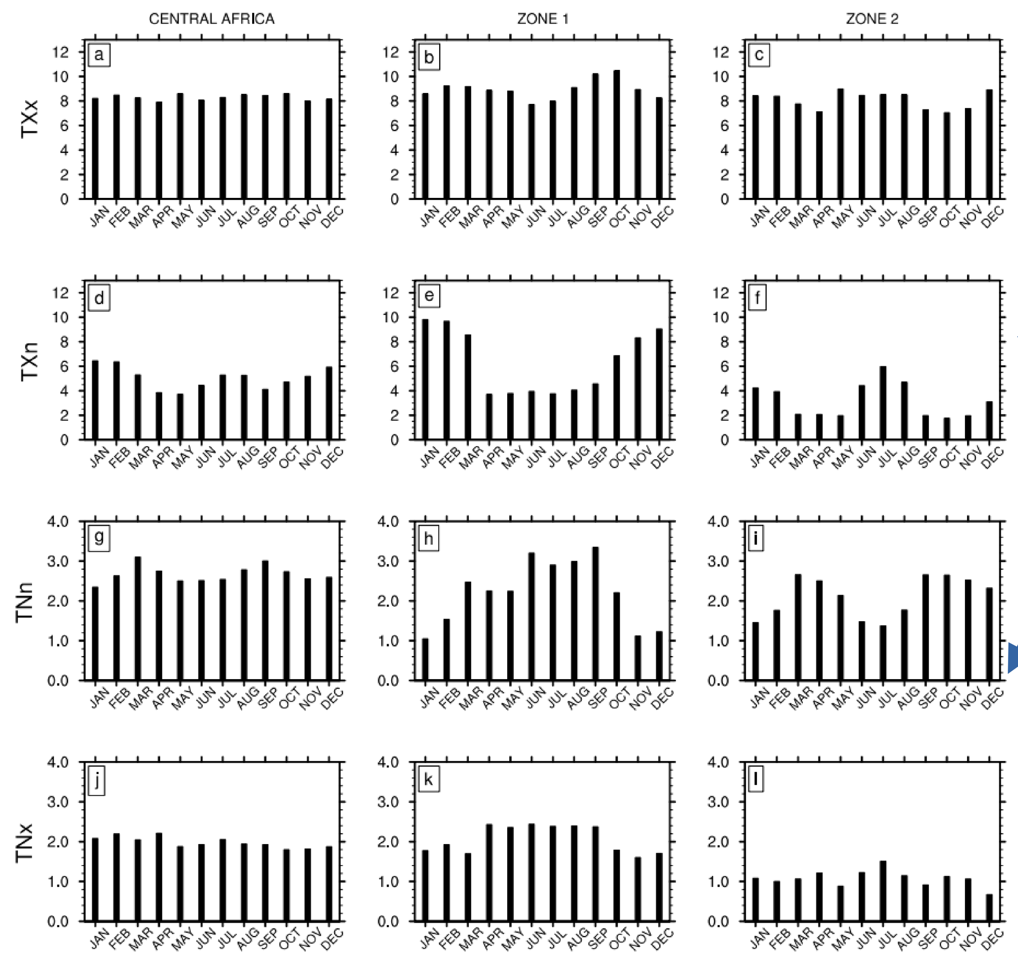
2.1. Intensity indices



TXx and TXn : Very pronounced warm bias of up to 10°C, particularly in the first sub-region.

TNn and TNx : cold bias not exceeding 4 ◦C is obtained.

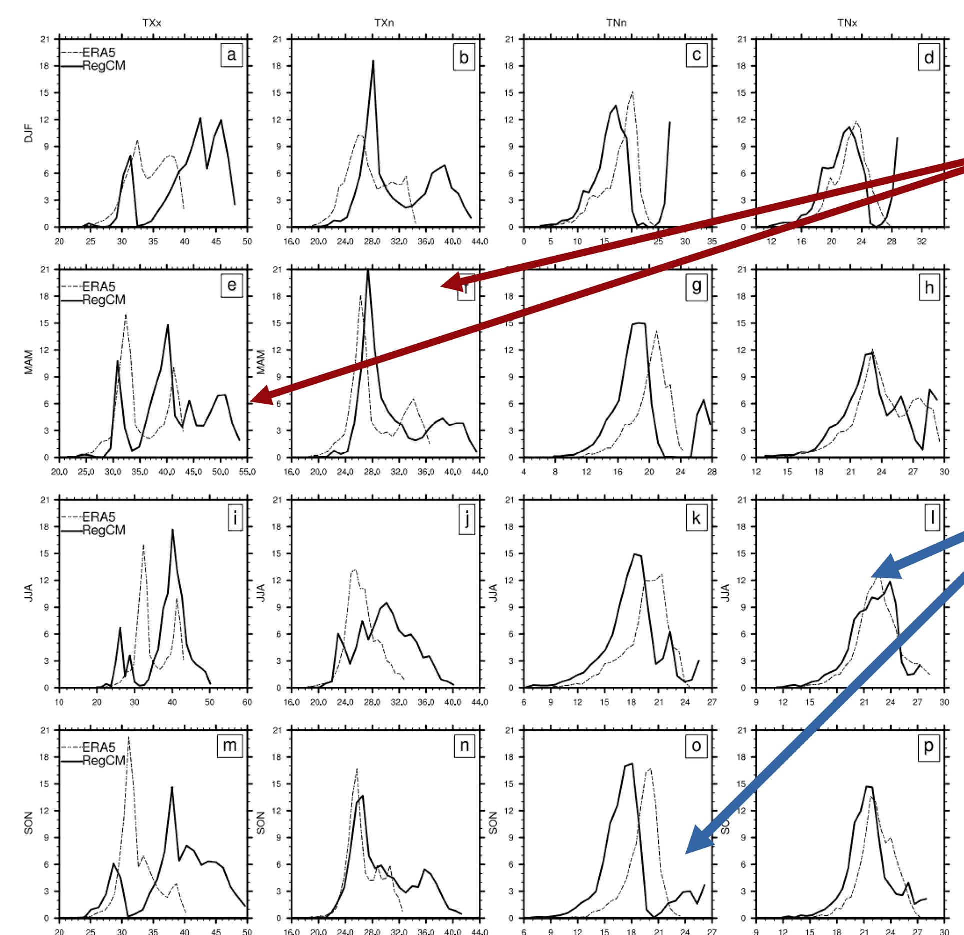
Fig. 2 Spatial distributions during DJF season of TXx, TXn, TNn and TNx indices from RegCM (1st column) ERA5 (2nd column) and bias RegCM-ERA5 (3rd column). Unit is ◦ C



- **The other seasons are similar to the DJF season, regardless of the area.**

The model becomes less robust as the temperature increases

Fig. 3 Histogram of the RMSE of TXx, TXn, TNn and TNx intensity indices in Central Africa (first column), zone 1 (second column) and zone 2 (third column). Unit is ◦ C



Probability patterns for daily maximum temperature indices from both are similar up 32°C.

This similarity is more pronounced for indices related to daily minimum temperatures

Fig. 4 Probability density function of TXx, TXn, TNn and TNx intensity indices for (a–d) DJF, (e–h) MAM (i–l) JJA and (m–p) SON seasons over central Africa

Table 2. Seasonal correlation coefficient (R) of intensity indices for Central Africa (CA), Zone 1 (Z1) and Zone 2 (Z2)

Region	DJF			MAM			JJA			SON		
	CA	Z1	Z2	CA	Z1	Z2	CA	Z1	Z2	CA	Z1	Z2
TX_X	0.78	0.73	0.70	0.91	0.84	0.63	0.78	0.9	0.55	0.84	0.80	0.61
TX_N	0.78	0.84	0.76	0.88	0.60	0.51	0.73	0.79	0.80	0.85	0.79	0.43
TN_N	0.87	0.84	0.70	0.82	0.78	0.88	0.82	0.87	0.66	0.81	0.79	0.86
TN_X	0.78	0.76	0.68	0.88	0.82	0.73	0.76	0.91	0.53	0.82	0.8	0.84

R > 0.5, revealing that the model generally well reproduce intensity indices.

2.2 Duration indices

- **RegCM underestimates the number of warm sequence over region with hight topography such as Cameroon Highlands**

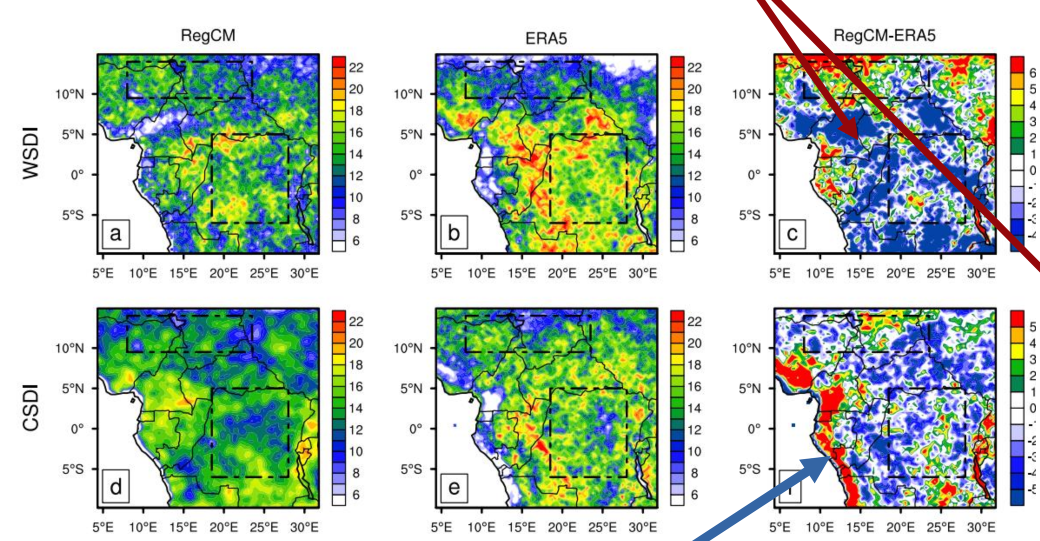


Fig. 5 Spatial distributions (annual) of the WSDI and CSDI duration indices from RegCM (1st column), ERA5 (2nd column) and RegCMERA5 bias (3rd column)

- **Around coastal region, simulated cold sequences are always overestimated.**

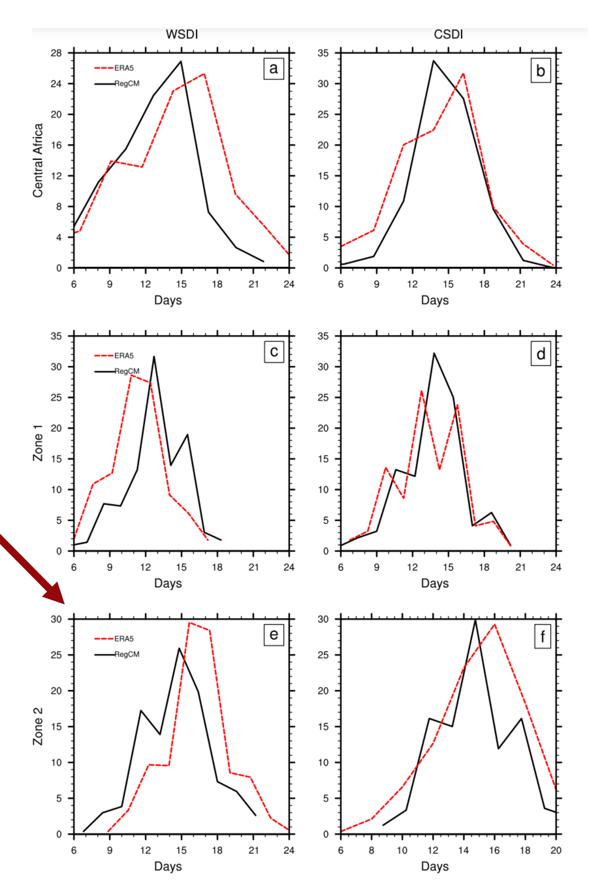


Fig. 6 Probability density function of warm and cold spell duration indicators (WSDI and CSDI duration indices) over (a, b) central Africa, (c, d) zone 1 and (e, f) zone 2

Conclusions

The findings pointed out that the RegCM4 capability to reproduce spatially intensity indices is independent to not only the two contrasted regions used in the study, but also seasons. This suggests that the mechanisms involve can not be linked to evaporation and evapotranspiration, since these two phenomena are differently accounted for in zones 1 and 2. the model generally well reproduce intensity indices, but much more with two extreme indices related to daily minimum temperatures. These model behaviors are associated to its capability to depict surface downward solar and thermal fuxes as well as surface sensible heat fux. RegCM4 simulates acceptably the probability of occurrence of both duration indices

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