Bias-correcting the temperature extremes of Egypt using a high-resolution regional climate model (RegCM4)

By

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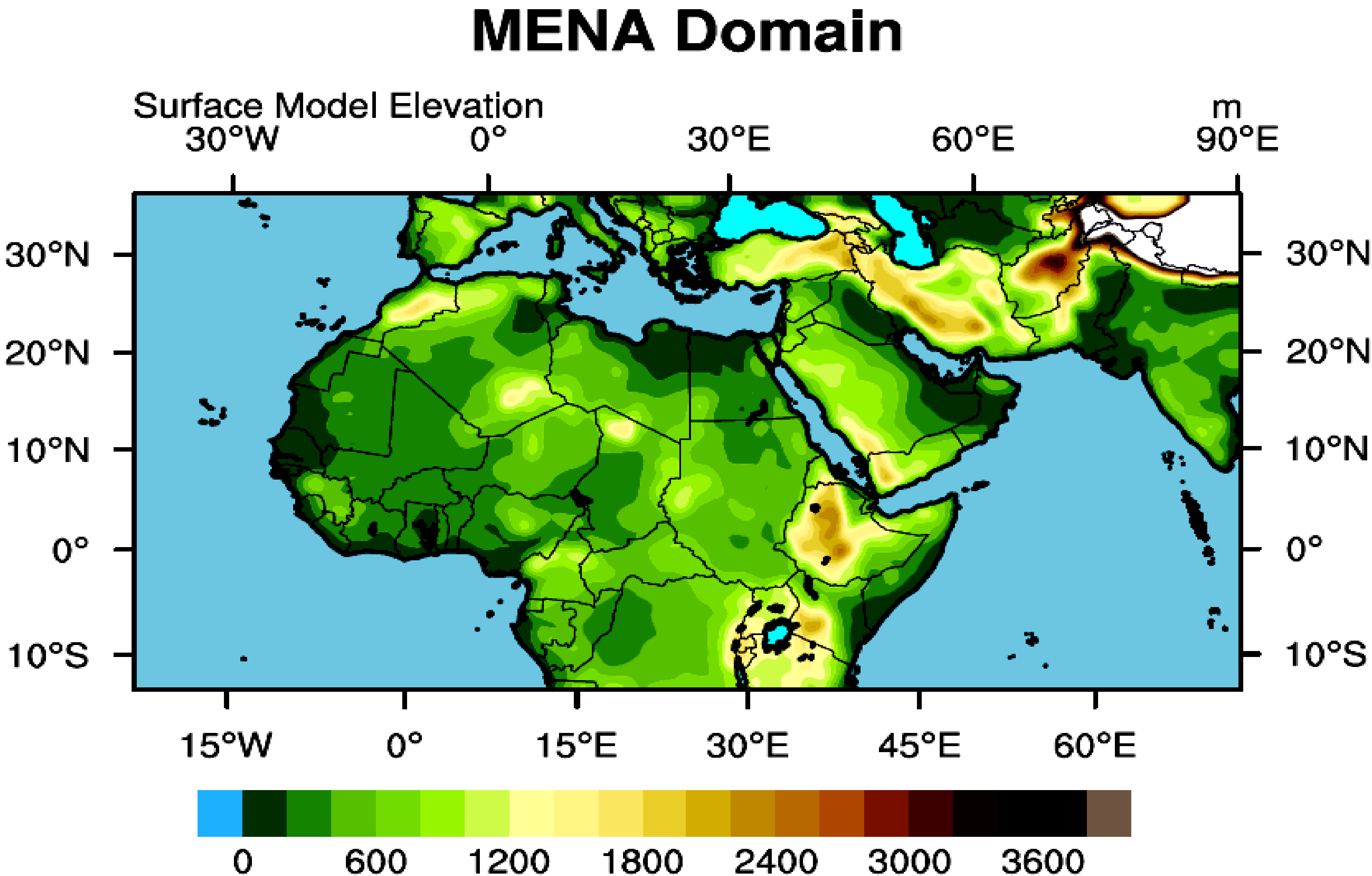
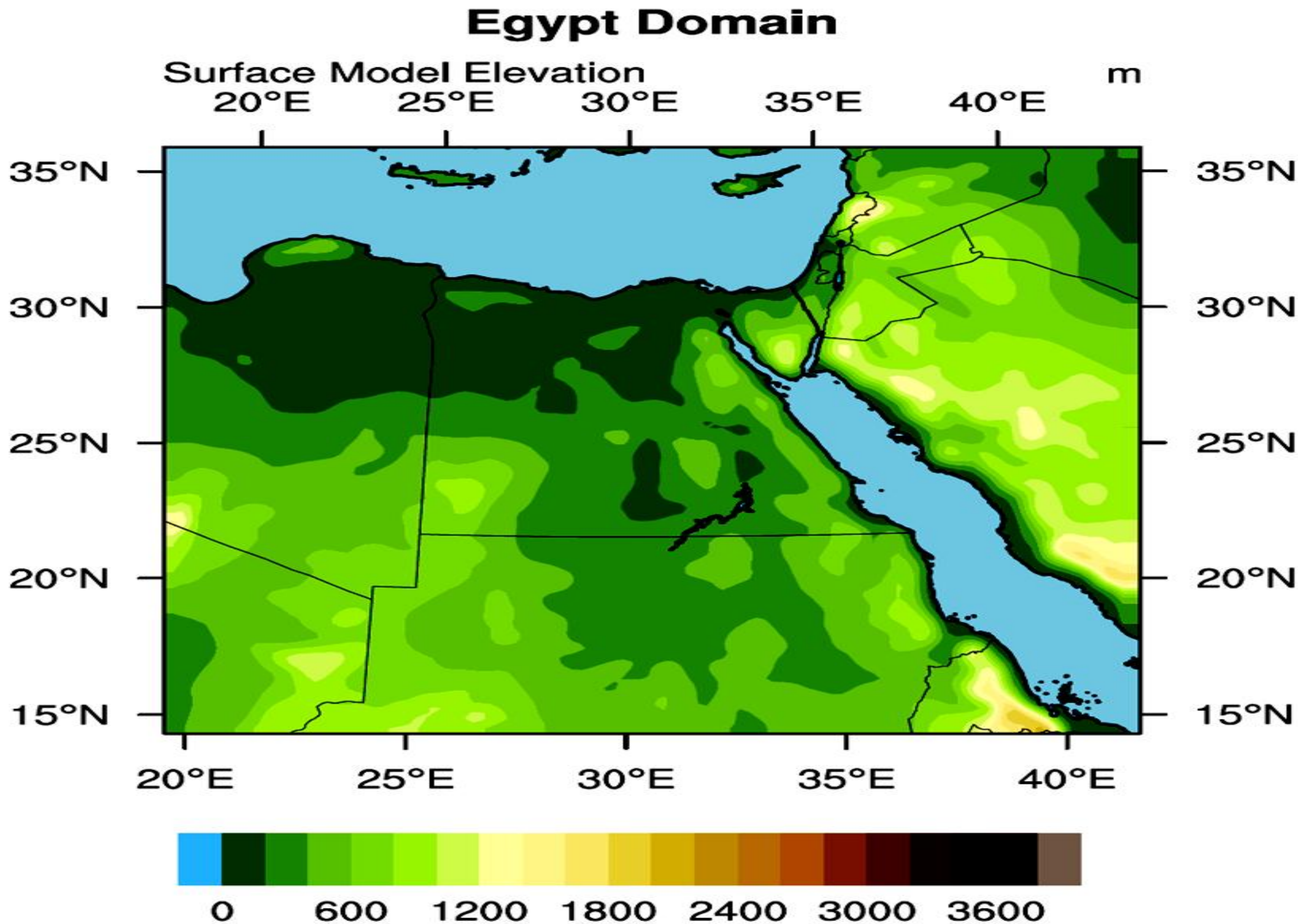
Abstract

- The regional climate model (RegCM4) was used to project the temperature extremes of Egypt for two future scenarios: Representative Concentration Pathway 4.5 and 8.5 (RCP45 and RCP85).
- To achieve this goal, the spatial pattern of the simulated temperature extremes was first examined. After that, the simulated temperature extremes were bias-corrected in the historical period with respect to in-situ observations using Linear-Scaling (LS) technique. Finally, the LS was used to correct the two future scenarios.
- The RegCM4 was downscaled by the medium resolution of the Earth System Model of the Max Planck Institute (MPI-ESM-MR) with 50 km horizontal resolution over Middle East and North Africa (MENA) and then nested over Egypt with 20 km horizontal resolution.
- The results showed that temperature extremes exhibit a notable increase under the RCP85 scenario more than the RCP45 scenario. Furthermore, the RegCM4 performance is remarkably improved when the LS method is used.
- Such performance is indicated by a low mean bias in the validation period compared to the evaluation period over majority of stations.
- Therefore, the RegCM4 can be used to project the temperature extremes using the LS over the location of interest.
- In addition, using multiple General Circulation Models (GCMs) is necessary to account for uncertainty associated with the atmospheric forcing.

Experiment design: 1 – Domain configuration




Egypt Domain
Surface Model Elevation
m
20°E
25°E
30°E
35°E
40°E
35°N
30°N
25°N
20°N
15°N
0
600
1200
1800
2400
3000
3600

Experiment Design : 2 – Physical configuration

Domain Dimension	Coarse domain (50 km with 235 grid points in the zonal direction and 121 grid points in the meridional direction, clat = 19.5, clon = 24.5); Nested domain (20 km with 121 in zonal and meridional direction, clat = 25.5, clon = 30.5)
Model Projection	Lambert-conformal
Lateral Boundary condition and SST	Max Planck Institute (MPI) with resolution 1.8 x 1.8 degrees Historical : 1981-2005 RCP45 and 85 : 2006-2100
Convection scheme	Grell over land and Emanuel over ocean
Radiation scheme	CCM3
Land surface scheme	Biosphere Atmosphere Transfer System (BATS)

Linear-Scaling (LS)

- In the present study, the RegCM4 output is bias-corrected using the LS with respect to the in-situ observation. The LS has been chosen for the following reasons: 1) it has been extensively used in various studies (Fang et al. 2015; Rocheta et al. 2017; Luo et al. 2018; Nashwan et al. 2020) and 2) the LS technique is characterized by its simplicity and improves the mean state of the variable of interest (e.g., temperature).
- LS is based on calculation of 12 monthly means from both the RCM and observations and a correction is applied for the variable of interest using the formula:

$$RCM_{new,(1)} = RCM_{(1)} + \left(OBS_{clim,(1)} - RCM_{clim,(1)}\right)$$

- RCMnew is the corrected temperature, RCM is the raw output from the model; OBSclim and RCMclim are the monthly climatology of the in-situ observation and the RCM respectively. To test the validity of the LS, the historical period is divided to two-time segments: 1985-1995 as the evaluation period, while 1996-2005 is considered as the validation period.
- After that, the bias-correction factor is used to correct the future scenarios over the location of interest. The RegCM4 model performance (before and after using the LS method), was quantified using the Mean bias (MB) as a statistical metrics.
- To reduce the uncertainty of the future temperature extremes, the bias correction factor (between the RegCM4 and observation in the reference period 1985-2005) was used for each location of the in-situ observation. After that, the bias-correction factor (of each month) is applied to the daily maximum and minimum air temperature (T_{max} and T_{min} respectively) of the period 2021-2100.
- Finally to examine the influence of the LS, a comparison is conducted for the Probability of Occurrence (POO) before and after applying the LS.

Results

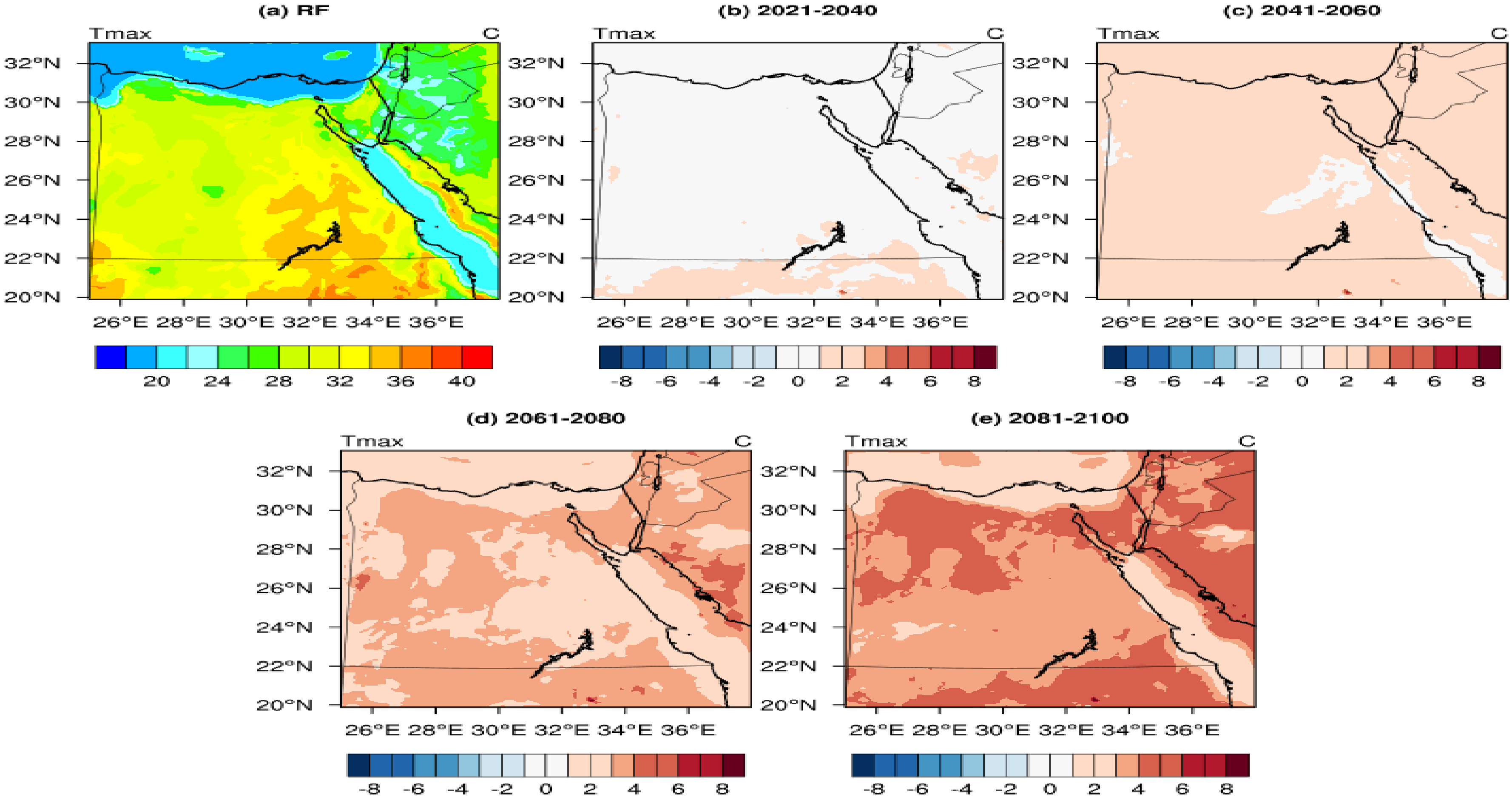


Figure 1 Maximum 2-m air temperature (hereafter T_{max}; in °C) over Egypt during 1985-2005 (RF) (a) and the potential change during the period 2021-2040 (b), the period 2041-2060 (c), the period 2061-2080 (d), the period 2081-2100 (e) according to the RCP85 scenario

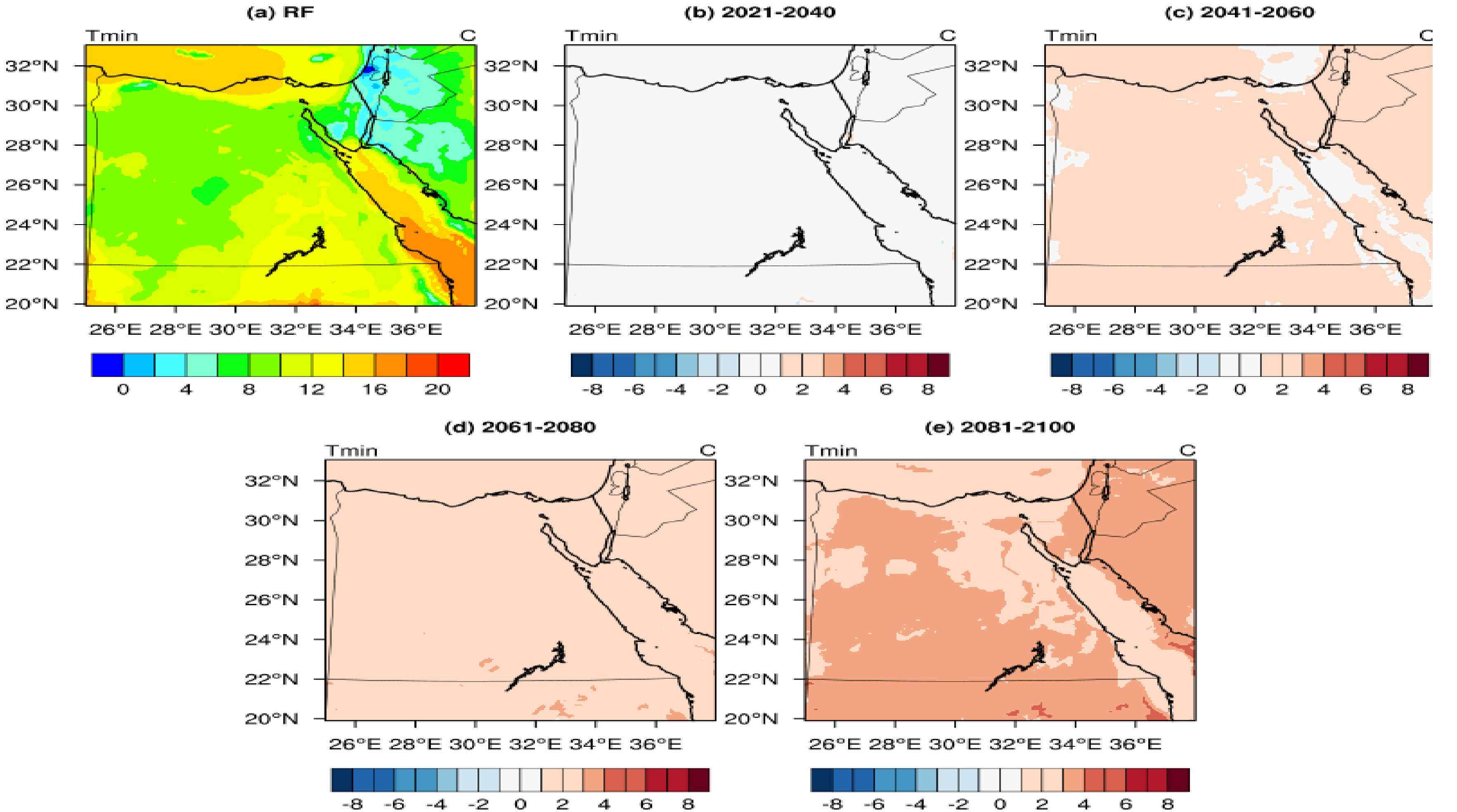


Figure 2 Minimum 2-m air temperature (hereafter T_{min}; in °C) over Egypt during 1985-2005 (RF) (a) and the potential change during the period 2021-2040 (b), the period 2041-2060 (c), the period 2061-2080 (d), the period 2081-2100 (e) according to the RCP85 scenario

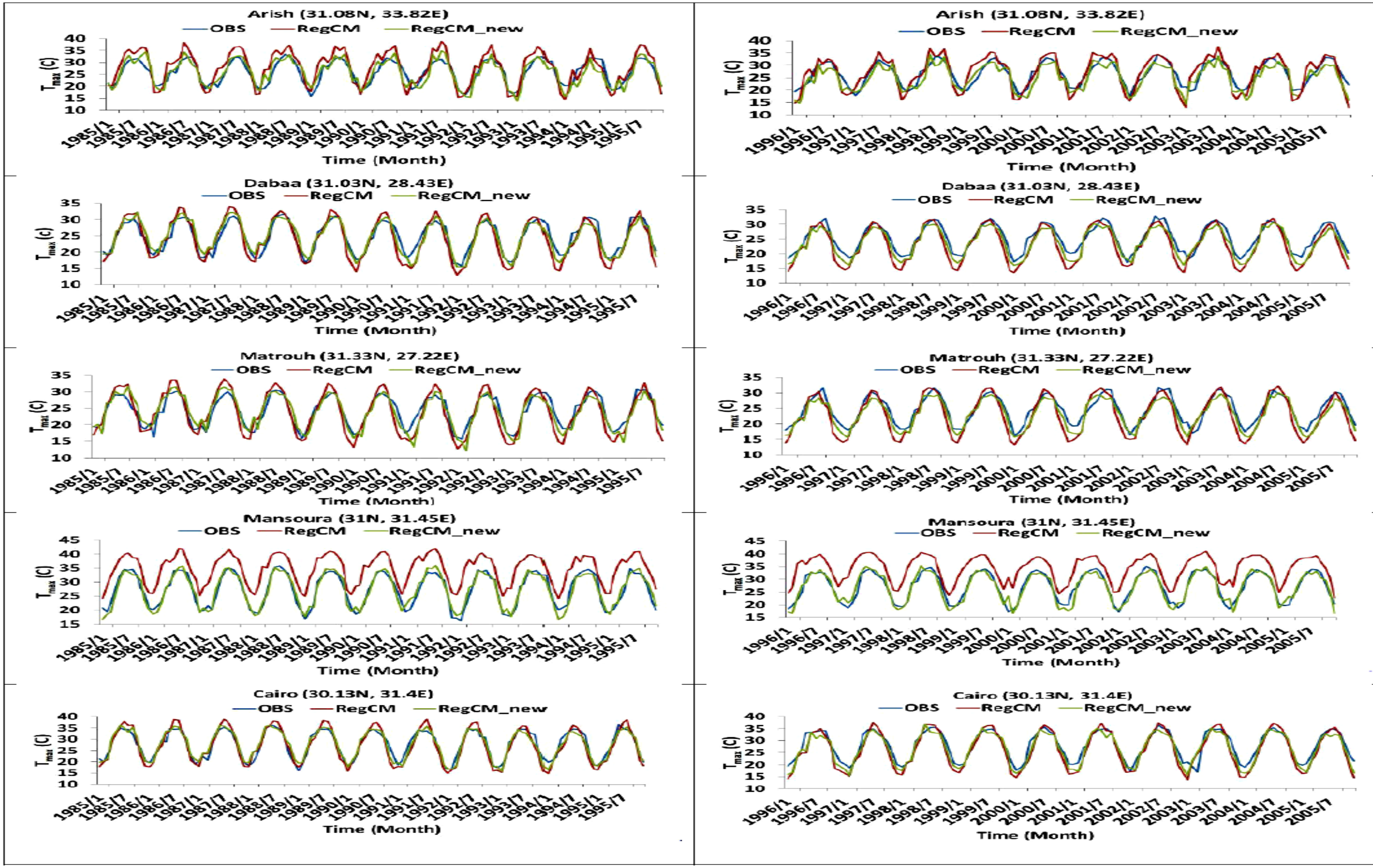


Figure 3 Monthly mean 2-m maximum air temperature (T_{max}; °C) for the station observation (in blue), RegCM before applying LS (in red) and RegCM_new after applying LS (in green) for the locations: Arish (first raw), Dabaa (second raw), Matrouh (third raw), Mansoura (fourth raw) and Cairo (fifth raw).

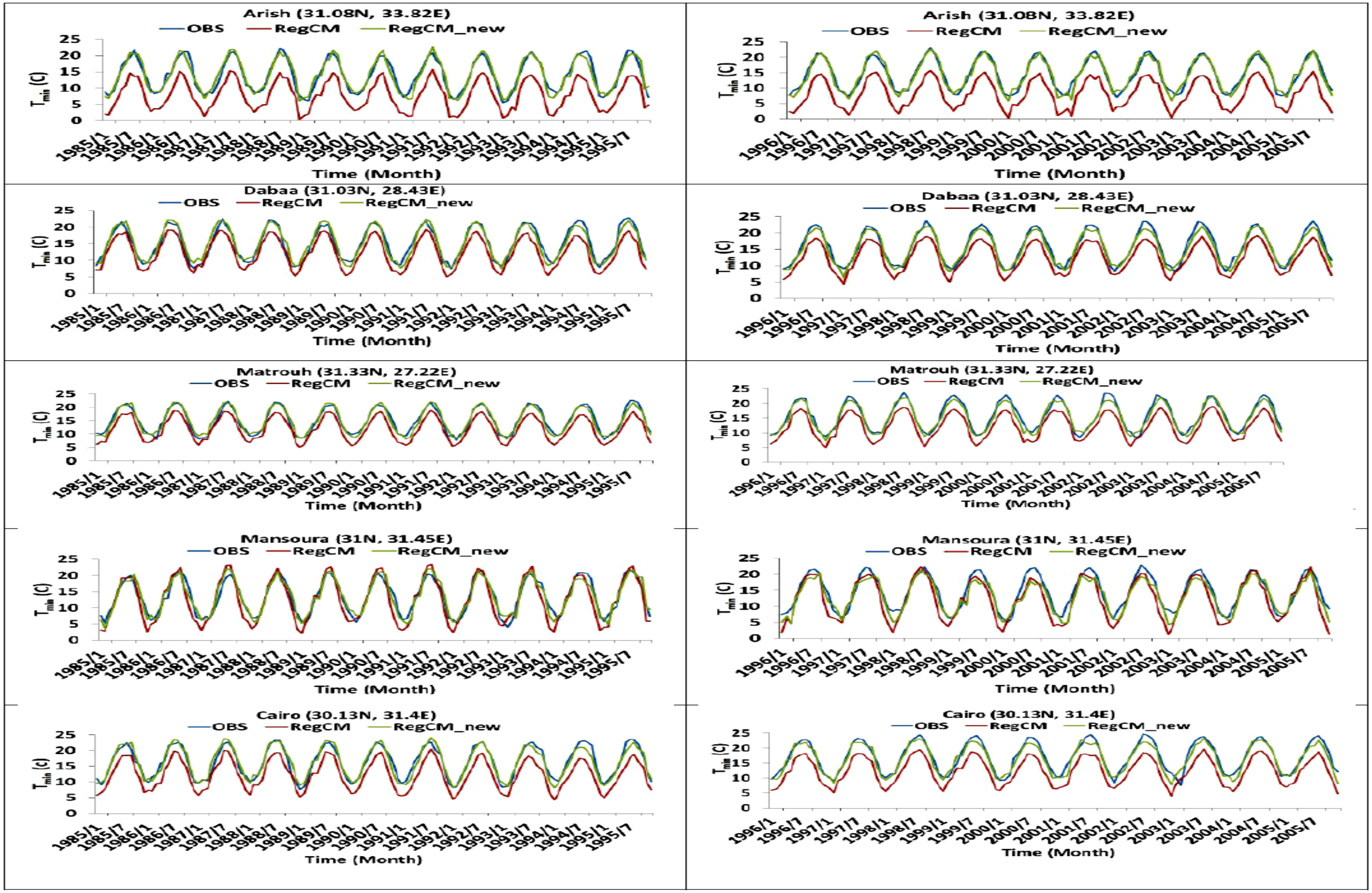


Figure 4 Monthly mean 2-m minimum air temperature (T_{min}; °C) for the station observation (in blue), RegCM before applying LS (in red) and RegCM_new after applying LS (in green) for the locations: Arish (first raw), Dabaa (second raw), Matrouh (third raw), Mansoura (fourth raw) and Cairo (fifth raw).

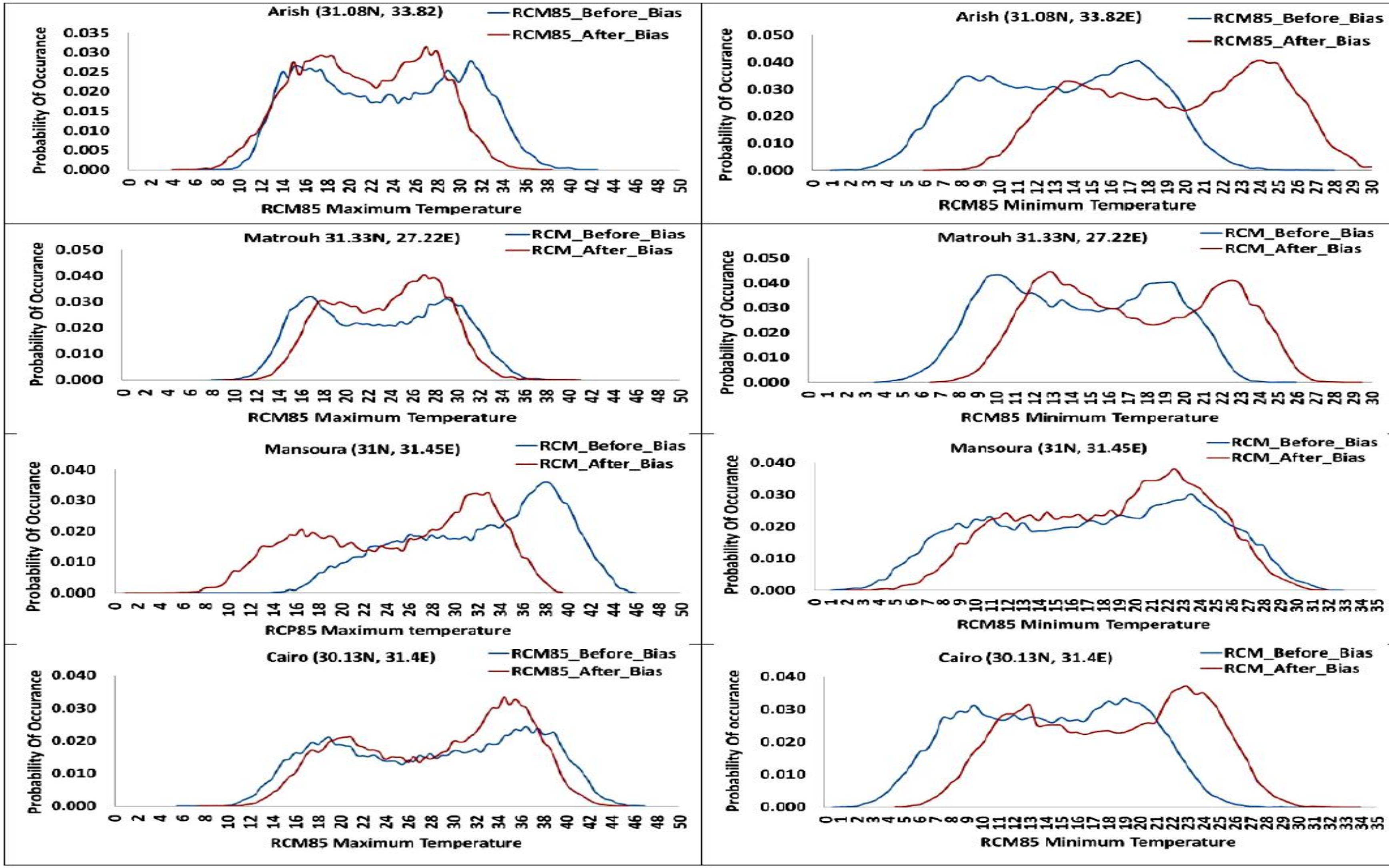


Figure 5 Probability of Occurrence for T_{max} (left side) and Tmin (right side) before applying LS (in blue) and after applying LS (in red) for the period 2021-2100 under the RCP85 future scenario for the stations: Arish (first raw), Matrouh (second raw), Mansoura (third raw) and Cairo (fourth raw). RCM stands for the RegCM4 model output

Discussion and Conclusion

- The results show that the RegCM4 shows an increase in the simulated temperature extremes under the RCP85 scenario more than the RCP45.
- In the historical period, the RegCM4 noted bias (either for T_{max} or T_{min}) can be attributed to the following reasons: 1) mismatch of the geographic features between the RegCM4 and OBS, 2) RegCM4 physical parameterization particularly the short/long-wave radiation, 3) using a prescribed value of ground emissivity during the RegCM4 simulations (which is supposed to vary with each season) and 4) uncertainty propagation from the lateral boundary condition of the mother domain (MENA) to the nested domain (Egypt).
- The RegCM4 performance is improved when the LS method is used. Such performance is confirmed with a low MB in both: EP and VP. Also, the potential skills of the LS appear in T_{min} more than T_{max}.
- However, in some stations; the LS cannot induce an improvement because the RegCM4 is close to the observation or it cannot explicitly represent the local geographic feature of station under study. It is important to highlight that the static data (which represents the initial condition of the RegCM4) is an important source of uncertainty. Therefore, the uncertainty of the static data propagates to the RegCM4 physical parameterization and eventually the simulated temperature extremes particularly over the arid-to-hyper-arid region (as in this study). Despite of the aforementioned sources of uncertainty, the RegCM4 shows an improved performance using the LS method over majority of stations.
- To ensure a robust performance over all of stations considered in the present study, the static data needs to be updated to account for the local geography features. Also, the RegCM4 physical parameterization needs to be revised; and additional sensitivity studies need to be conducted. After that, the RegCM4 can be re-evaluated with respect to the OBS. A future study will consider using multiple GCMs (CMIP5/CMIP6) and their ensemble to further examine the impact of climate change on the simulated T_{max}/T_{min}.
- In addition, a comparison between direct downscaling (using multiple GCMs with different spatial resolutions) and one-way nesting (using one GCM) to see which approach is suitable for simulating the temperature extremes of Egypt.

Thank you, any questions???